Advances in Periodontal Surgery

A Clinical Guide to Techniques and Interdisciplinary Approaches

Salvador Nares
Editor

Springer

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Preface

Like many aspects of health care, technological innovations in materials science, as well as development of new tools and techniques, drive advances in periodontal therapy. In this volume, I have attempted to provide the reader with a compilation of advanced knowledge of surgical periodontal therapy. In some respects, significant advancements are evident, such as the development of novel tools and surgical techniques for treatment of periodontal and mucogingival defects or as noted by advances in the use of laser energy to treat periodontal and peri-implant diseases. Conversely, other techniques, such as periodontal resective surgery, have changed very little over time. Here, I have compiled works from gifted clinicians specifically geared toward surgical treatment for the periodontal patient.

This volume is divided into five parts, each of which addresses a specific topic. Part I, *Key Considerations of Periodontal Surgery*, discusses patient-driven factors and practical ways both clinicians and patients can incorporate qualitative and quantitative patient information to monitor and self-motivate patients to help improve periodontal outcomes. This is followed by a decision tree-style discussion of resective versus regenerative therapy. This serves as an introduction to Part II, *Resective Techniques of Periodontal Surgery*, and Part III, *Regenerative Techniques of Periodontal Surgery.* Here, the discussion focuses on the use of technology-driven approaches (stem cells, lasers, videoscopes, biomimetics) as well as traditional approaches (resective surgery) in periodontal surgery. Next, Part IV, *Mucogingival and Periodontal Plastic Surgery*, shifts the focus to treatment of periodontal surgery associated with management of soft tissues. Finally, Part V, *Interdisciplinary Management of Periodontal Surgery*, discusses team management of patients requiring orthodontic, endodontic, or restorative dental care. Here, the reader will find useful and practical information related to interdisciplinary care of the periodontal patient.

My sincerest thanks and appreciation to each author for making this volume a reality. Despite the substantial demands of time and talent these experts face on a daily basis, it is humbling to witness their dedication to their craft and willingness to share their knowledge and experience with others.

Chicago, IL, USA Salvador Nares

Dedication and Acknowledgment

To Celia, my loving wife. As my late grandfather, Samuel said to me "Son, you hit the jackpot." Thirty years later, I could not agree with him more. Her love, strength, patience, and understanding shine each and every day we spend together. I could not have asked for a better life companion. Here's to another 30 years! To my precious daughters Monica, Marissa, and Melinda, gifts from Heaven. How quickly time passes, you've each grown into beautiful young ladies! You bring joy and energy and have enriched our lives more than you will ever know. To my parents Carmen and Ruben, who selflessly gave of themselves year after year for my brothers Ruben Jr. and Albert and me. Their smiles, hugs, wisdom, and sage advice are always welcomed and appreciated.

To Drs. Hallmon, Rees, and Iacopino whose patience, guidance, and discipline were and remain greatly appreciated. I could never repay them enough for all they did for me during my years of clinical and scientific training. Thank you.

To my current and former students and residents through the years. To quote Winston S. Churchill "We make a living by what we get. We make a life by what we give." And although I thought I was the one "giving," I was truly the one "receiving." Thanks to these wonderful young women and men for the many smiles, trials, triumphs, and wonderful moments we have spent together. It has been my privilege to witness each of you blossom into talented clinicians and clinician-scientists. Our profession is in great hands going forward.

To all my friends and colleagues in the periodontal and scientific community, your dedication, passion, and ingenuity are truly inspirational.

Finally, I would like to thank the many gifted clinicians for their contributions in making this volume a reality.

Contents

Part I

Key Considerations of Periodontal Surgery

1 The Miller McEntire Periodontal Prognostic Index (i.e., "The Perio Report Card") Usage in Practice

Robert A. Levine and Preston Dallas (PD) Miller

1.1 Introduction

The Miller McEntire Periodontal Prognostic Index (MMPPI), which the authors like to term "the Perio Report Card," is a simple, powerful, evidenced-based, statistically validated, and accurate motivational tool [1] which can be used daily in clinical practice with all patients (Fig. 1.1). The current score sheet has undergone multiple modifications, and individual clinicians can make further modifications to suit their practice needs. Its usage is not limited to patients presenting with periodontitis but is routinely used with periodontally healthy patients which is reviewed below in Case #1. The *benefits to the patient* are that they better understand their long-term periodontal prognosis of 15 and 30 years. Accurate prognosis can be determined by scoring the most periodontally involved molar that you plan to keep. The strength of the MMPPI is that it translates clinical outcomes into patient value [2].

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Miller-McEntire Periodontal Prognosis Index

Tooth	#	#	#	#
Date				
Furcation				
Diabetes				
Mobility				
Probing Depth				
Molar Type				
Smoking				
Age				
TOTAL				
15 Year Prognosis				
30 Year Prognosis				

*Our goal is a score of < 5

Score	15 Year	30 Year	
1	98%	94%	Excellent
2	97%	93%	
3	96%	89%	
4	95%	85%	
5	93%	80%	Good
6	90%	74%	
7	86%	66%	
8	81%	56%	Guarded
9	75%	45%	
10	67%	33%	
11	53%	22%	

Statistically, a score under 4.3 means you should never lose a tooth to periodontal disease

Smoking increases your chance of losing teeth to periodontal disease by 246%

Furcation	A1C Levels	Mobility	Probing (mm)	Molar Type	Smoking	Age
None = 0	< 6 = 0	None = 0	< 5 = 0	Mand = 0	Non-smoker = 0	1 - 39 = 0
1 = 1	6.1 - 7.0 = 1	1 = 1	5 - 7 = 1	Max 1st = 1	Smoker = 4	> 40 = 1
2 = 2	7.1 - 8.0 = 2	2 = 2	8 - 10 = 2	Max 2nd = 2		
3 = 3	8.1 - 9.0 = 3	3 = 3	> 10 = 3			
T-T = 3 "through & through"	> 9.1 = 4					

Keys to Success:

- Brush, floss, clean your teeth and tongue daily
- Complete recommended treatment
- Adhere to the recommended maintenance schedule
- Control your blood sugar (if diabetic)
- Stop smoking or at least cut back to under 5/day

Fig. 1.1 MMPPI (Miller, Levine, Fava 2017)

1.2 Objectives and Application

The *objectives* of using this index include:

- Motivating the patient to accept treatment, complete treatment, and make the patient aware of the importance of complying with periodontal maintenance [3–5] defined as the "Keys to Success."
- To simplify scoring so that the score can not only be determined by the dentist but also by trained auxiliaries. If performed by auxiliaries, it takes no chair time from the dentist. *To help to train staff easily to score patients, it is recommended to review in a scheduled team meeting on the MMPPI (Parts 1 and 2)*[1].
- To encourage patients to make lifestyle changes to improve their overall health**.** This would include smoking cessation and blood sugar control [6, 7].
- To empower the whole "team" (dentists, dental assistants, dental hygienists, and case presenters) in its use in helping patients to attain better periodontal and systemic health as we are the "physicians of the mouth."
- To encourage the patients to refer family and friends.

For a better understanding of clinical scoring, the reader is referred to online videos and resources (see Footnote 1). Since smoking was the most significant factor, there is a video on smoking cessation on this site. Smokers should also be referred to support services for in-depth counseling and assistance.[2]

For patients with diabetes mellitus or who are suspected of having diabetes mellitus, HbA1c values need to be evaluated. An in-office HbA1c testing kit should be readily available. If the patient has not been diagnosed with diabetes mellitus and the in-office HbA1c score is elevated, the patient should be referred to a physician for the diagnosis, as this is a medical diagnosis and not a dental diagnosis. By following these objectives, we can become more of a physician of the mouth rather than just simply performing traditional dental procedures [8–10].

Based on the study by Miller et al. [1], seven patient factors are highlighted to be scored that include (Fig. 1.1):

1. **Furcation involvement of the molar to be scored**:
   - none = 0,
   - 1 total furcation = 1 (does not matter if it is a Class 1, 2, or 3)
   - 2 total furcations = 2
   - T-T (through and through) furcation = 3

   (*Note: Typically when furcations are charted, the severity is noted,* i.e.*, Class 1, Class 2, and Class 3. This index only scores the number of furcations present, not the class or severity).*
2. **HbA1c levels:**
   - <6% =0
   - 6.1–7.0% = 1

[1] See https://pdmillerswebtextbook.com/.

[2] For smoking cessation help: call 1-800-QUITNOW (784-8669).

- 7.1–8.0% = 2
- 8.1–9.0% = 3
- >9.1% = 4

(Important note on scoring HbA1c: If the patient does not know their recent score, score the patient as a "2" until the patient's blood work is received. Using the MMPPI thus motivates the patient to better understand their HbA1c score and control their diabetes by lowering their blood sugar.)

3. **Mobility of the molar to be scored:**
   - none = 0,
   - 1 = 1
   - 2 = 2
   - 3 = 3 (tooth is depressible)
4. **Deepest probing depth in millimeters (mm) of the molar to be scored:**
   - <5 mm = 0
   - 5–7 mm = 1
   - 8–10 mm = 2
   - >10 mm = 3
5. **Molar type: 0–2:**
   - Mandibular molar = 0 (either a mandibular first or second molar is not significant)
   - Maxillary first molar = 1
   - Maxillary second molar = 2
6. **Smoking: either you smoke or do not smoke:**
   - non-smoker = 0,
   - smoker = 4,

   (Note: Of all categories scored, smoking was by far the most significant negative factor in determining periodontal prognosis. Using the Cox Hazard Ratio, statistically a score of 4 was assigned for smoking. The overall objective is to keep the MMPPI score below a 5. When the score is 5 or less, statistically patients never lose teeth to periodontal disease [1]. *For example, if a smoker has a score of 9, they have a 75% chance of keeping their teeth for 15 years (Fig. 1.1). If the patient stops smoking, the score becomes a 5, and they will have a 93% chance of keeping their teeth for 15 years (Fig. 1.1). While immediate cessation is desired, many patients will only stop smoking over a period of time (see online video on smoking cessation))* (see Footnote 1).
7. ***Age has a minimal and limited factor on periodontal long-term prognosis:***
   - 1–39 years of age = 0
   - 40 or > years of age = 1

Scoring and prognosis: our clinical posttreatment "target" goal is an MMPPI score of < 5:

- Score of 1 to 4 has an "excellent" prognosis
- Score of 5 to 8 has a "good" prognosis
- Score of 9 to 11 or greater has a "guarded" prognosis.

1.2.1 **Keys to Success** (Bottom Right of Fig. 1.1)

It is important to realize that the keys to success are not a promise of success but a guideline that allows the patient to succeed. All of these keys are the responsibility of the patient and if followed will produce a long-term favorable outcome. Until recently, the importance of cleaning the tongue has not been emphasized. Ninety-five percent of the bacteria left after brushing and interdental cleaning are on the posterior third of the tongue. It is impossible to remove these bacteria with a toothbrush without causing the patient to gag. To achieve this, a metal tongue scraper is required. For proper technique, view the online video on the importance of cleaning your tongue (see Footnote 1). For more information on how to further disinfect the mouth, an online video is available on the most effective, least expensive mouthwash (see Footnote 1).

Emphasizing the keys to success is an integral part of the initial examination. The goal/objective of getting to an MMPPI score of <5 does not happen without complying with all 5 of the keys to success (Fig. 1.1). If at periodontal maintenance the MMPPI score is elevated, the keys to success need to be reviewed to see in what area the patient is not compliant. For example, has the patient started smoking again?

*Important Note on "Keys to Success": As indicated in the title, this index is a periodontal report card. To further motivate the patient at the initial exam, taking a moment to give the patient a posttreatment target score has been found to be particularly motivational. The mnemonic phrase "If you want to keep your teeth alive, keep your MMPPI score below a 5" summarizes in lay-terms the objective of the target score. The patient should be scored at each maintenance appointment. Scoring even healthy patients demonstrates to the patient your concern for their overall oral health and reinforces the importance of periodontal maintenance in keeping their MMPPI stable. Thus the patient is more likely to accept aesthetically enhancing procedures such as veneers or periodontal plastic surgery. Although periodontal disease is a major cause of tooth loss, caries remains a significant factor, especially with the rising incidence of root caries. Today patients are on many more medications than in the past. Many of these medications cause dry mouth (*i.e.*, medication-induced xerostomia, MIX), which is a major cause of root caries.*

1.3 Case Examples

1.3.1 **Clinical Case Example #1: Using the MMPPI in a Periodontally Healthy Patient (Amy: MMPPI Score at Initial Exam = 1):** See Figs. 1.2, 1.3, 1.4 and 1.5

Amy presents to our periodontal practice (RAL) as a healthy (HbA1c <6% = 0) non-smoking (non-smoker = 0) 32-year-old female (age < 39 = 0) and a history of good compliance to preventative periodontal care at every 6 months frequency with her

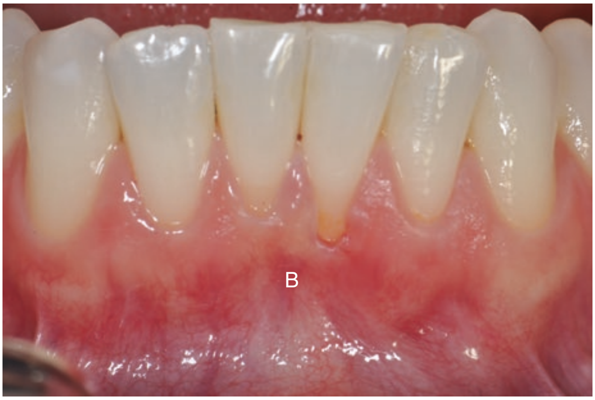

Fig. 1.2 Case #1: patient presents upon referral as a 32-year-old healthy, non-smoker for periodontal plastic surgery for root coverage #24 and 25. Surgical treatment performed by Dr. Robert Levine

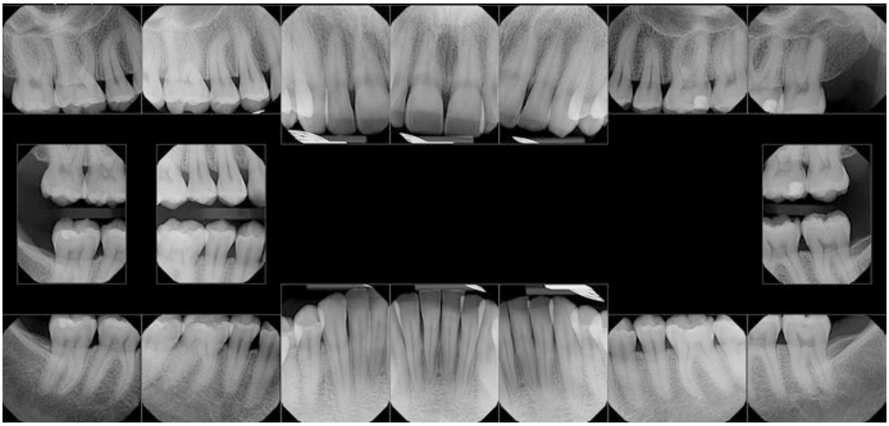

Fig. 1.3 Case #1: FMX

restorative dentist. She was referred for periodontal plastic surgery for root coverage #24 (Miller Class 2) and #25 (Miller Class 1) [11–16] (Figs. 1.2 and 1.3). A complete periodontal charting was completed as part of the initial periodontal examination including probing depths, mobility of teeth, gingival recession, and occlusion. The summary of this visit is noted in her MMPPI that was reviewed "knee-to-knee and eye-to-eye" with her (Fig. 1.4). Her deepest periodontal probing depth was 4 mm on the distal of #3 (see Fig. 1.1: probing mm <5 mm = 0) with light bleeding upon probing. The scored tooth #3 had no mobility (zero mobility = 0), and a total MMPPI score was recorded as 1 (15-year periodontal prognosis of 98% and 30-year periodontal prognosis of 94%). As noted prior, the 15- and 30-year periodontal prognosis advised the patient of an excellent long- term prognosis of not losing her teeth *due to periodontal disease*. However, there is still the possibility of losing these two teeth due to continued attachment loss, root caries, and its sequela. The use of the MMPPI in Amy's case is *highly motivational for four reasons*: she leaves the initial visit with our office with positive news on her overall case

Miller-McEntire Periodontal Prognosis Index

Tooth	# 3	#	#	#
Date	10/10/17			
Furcation	0			
Diabetes	0			
Mobility	0			
Probing Depth	0			
Molar Type	1			
Age	0			
Smoking	0			
TOTAL	1			
15 Year Prognosis	98%			
30 Year Prognosis	94%			

*Our goal is a score of less than 5

Score	15 Year	30 Year	
1	98%	94%	Excellent
2	97%	93%	
3	96%	89%	
4	95%	85%	
5	93%	80%	Good
6	90%	74%	
7	86%	66%	
8	81%	56%	Guarded
9	75%	45%	
10	67%	33%	
11	53%	22%	

Statistically, a score under 4.3 means you should never lose a tooth to periodontal disease

Smoking increases your chance of losing teeth to periodontal disease by 246%

Furcation	A1C Levels	Mobility	Probing (mm)	Molar Type	Age	Smoking
None = 0	< 6 = 0	None = 0	< 5 = 0	Mand = 0	1 - 39 = 0	Non-smoker = 0
1 = 1	6.1 - 7.0 = 1	1 = 1	5 - 7 = 1	Max 1st = 1	> 40 = 1	Smoker = 4
2 = 2	7.1 - 8.0 = 2	2 = 2	8 - 10 = 2	Max 2nd = 2		
3 = 3	8.1 - 9.0 = 3	3 = 3	> 10 = 3			
T-T = 3 "through & through"	> 9.1 = 4					

Keys to Success:

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- Complete recommended treatment
- Adhere to the recommended maintenance schedule
- Control your blood sugar (if diabetic)
- Stop smoking or at least cut back to under 5/day

Fig. 1.4 Case #1: MMPPI at initial periodontal consultation visit shared with the patient

Fig. 1.5 Seven month post-op of completed autogenous palatal subepithelial connective tissue graft for root coverage using a combination of the tunnel technique (#25) with lateral sliding pedicle flap (#24) and adjunctive patient's PRGF (plasma-rich growth factors) and Emdogain® (Straumann USA, Andover, MA). Near 100% root coverage was achieved with significant thickening of buccal soft tissues from #23 to 26. Surgical treatment performed by Dr. Robert Levine

prognosis from a periodontal perspective (MMPPI = 1); it reinforces her restorative dentist's referral for the recommended root coverage procedure; it motivates her to complete our combined recommendation of periodontal plastic surgical procedure for root coverage for teeth #24 and 25; and lastly it stresses the importance of continued periodontal maintenance visits with her dentist at his/her recommended frequency to keep her MMPPI below a 5. After discussing her MMPPI score of 1 and her excellent prognosis for 15 and 30 years, Amy shared with us that initially she thought that her "gum recession was the beginning of a cascading downhill course for herself from a dental standpoint." After presenting her an excellent case prognosis, we then gave her the solution to her site-specific periodontal problem with the benefits of thickening the gingival tissues, widening the zone of keratinized gingiva with attempts at partial to 100% root coverage, thus improving the long-term prognosis of #24 and #25 [11, 16]. The clinical goal of 100% root coverage in a Miller Class 1 or 2 is protecting these two teeth from future root caries and additional periodontal attachment loss while thickening the soft tissue which creates a more favorable barrier in preventing future gingival recession. Amy scheduled and completed the recommended treatment (Fig. 1.5). As part of discussion with Amy, we also shared the concerns that we see daily with medication-induced xerostomia (MIX) in our aging patient population. MIX relates to clinical concerns for recurrent caries or what we see frequently in the non-compliant patient of multiple areas of deep interproximal or buccal root caries. As our healthy patients age, many will be given medications for systemic diseases such as HTN, diabetes, anxiety, depression, asthma, etc. which will have significant detrimental effects on exposed root surfaces such as seen in Amy's case. Thus, this needs to be shared with a patient like Amy as their medical status may change as they grow older along with their systemic health and medications. These medications will significantly increase their susceptibility to MIX and subsequent root caries. This concern is illustrated in Case #2. Sadly, many in the medical profession are unaware of the harmful oral side effects caused by numerous medications they routinely prescribe. In all patients we recommend and stress the importance of the "Keys to Success" (bottom right of the MMPPI form) with good compliance to plaque control and their recommended periodontal maintenance frequency which in Amy's case is twice a year with her general dentist [17–20].

1.3.2 Clinical Case Example #2: Using the MMPPI in a Beginning to Moderate Periodontitis Patient (Michael: MMPPI Score at Initial Exam = 7): See Figs. 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13 and 1.14

Michael presents to our periodontal practice (RAL) referred by his wife, who had completed periodontal therapy under our care (for generalized moderate to localized advanced periodontitis). *Michael's wife, who had initially scored MMPPI of 5, had recently completed full-mouth LANAP* (laser-assisted new attachment procedure) *therapy in one visit under local anesthesia. This underlines one of the major benefits of routinely using the MMPPI and the power that the MMPPI has with referral of family and friends* to your practice for the treatment of periodontal diseases. This is a win-win outcome. Michael is a 58-year-old (>39 = 1), generally healthy: ASA II and a HbA1C <6% (<6% = 0), non-smoker (non-smoker = 0) with generalized bleeding upon probing, and probing depths up to 6 mm in the maxillary posteriors and up to 7 mm in the mandibular molars (Fig. 1.6). Michael reports

Fig. 1.6 Case #2: Michael, an RN, presents upon referral by his family member (wife) as 58-year-old generally healthy, non-smoker for initial periodontal therapy to treat generalized beginning to moderate periodontitis which was not under control per the patient as he was frustrated with his prior failing dental work and poor communication skills of his previous dentist and team members

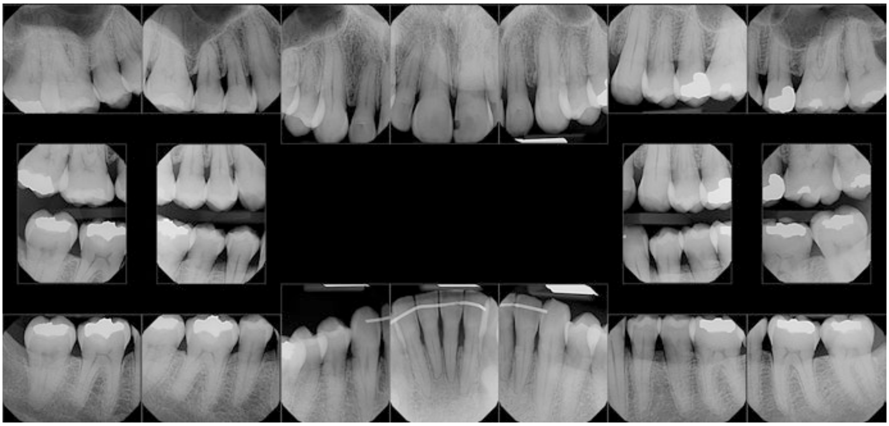

Fig. 1.7 Case #2: initial FMX

a history of good compliance to preventative periodontal care at every 4–6 months with his restorative dentist's office but was very frustrated that his "gums do not feel or appear healthy" to him. Medically he presents with HTN, anxiety, obsessive-compulsive disorder (OCD), arthritis, seasonal allergies, and high cholesterol and premedicates for a recent knee replacement. He is a practicing RN at a local VA Hospital and is very health conscious. Michael is presently on six different medications to treat his systemic diseases that are all associated with MIX/dry mouth which he admits to (Lisinopril, HCTZ, Norvasc, Lorazepam, Benadryl, and Claritin). The only significant mobility in his mouth was tooth #2 which recorded a 1 degree mobility (mobility 1 = 1). Several areas of facial mucogingival recession with lack of attached keratinized gingiva were noted (buccal of teeth #11,20,21,28). Even though there were deeper probing depths of 7 mm in the interproximal areas of his lower molars from the lingual, it was decided to use tooth #2 to be scored (maxillary second molar = 2) as this molar presented with two total furcation invasions (furcations: 2 = 2): buccal (Class 1) and mesial (Class 2) along with a Class 1 mobility (mobility: Class 1 = 1). The next worst MMPPI score would be tooth #31 (mandibular molars = 0) and presented only with a buccal Class 1 furcation (furcation = 1), no mobility (mobility = 0) probing depth of 7 mm (5–7 mm = 1), and age at 58 (age, >39 = 1) for a total MMPPI score of 7. *As all mandibular molars have a 0 score at the outset, it is best to use a maxillary molar if it is involved periodontally and has any mobility and possible furcation(s) to have an increased initial score,* and thus hopefully with the patient adhering to the "Keys to Success," a more dramatic MMPPI score reduction will be seen posttreatment. Michael's recommended treatment plan involved full-mouth nonsurgical therapy (scaling and root planning) with local anesthesia in one visit with a registered dental hygienist (RDH), occlusal adjustment of #2, in conjunction with 1 week of oral antibiotics (amoxicillin 500 mg with metronidazole 250 mg for 1 week TID) [21]. The patient is seen posttreatment with an emphasis on plaque control

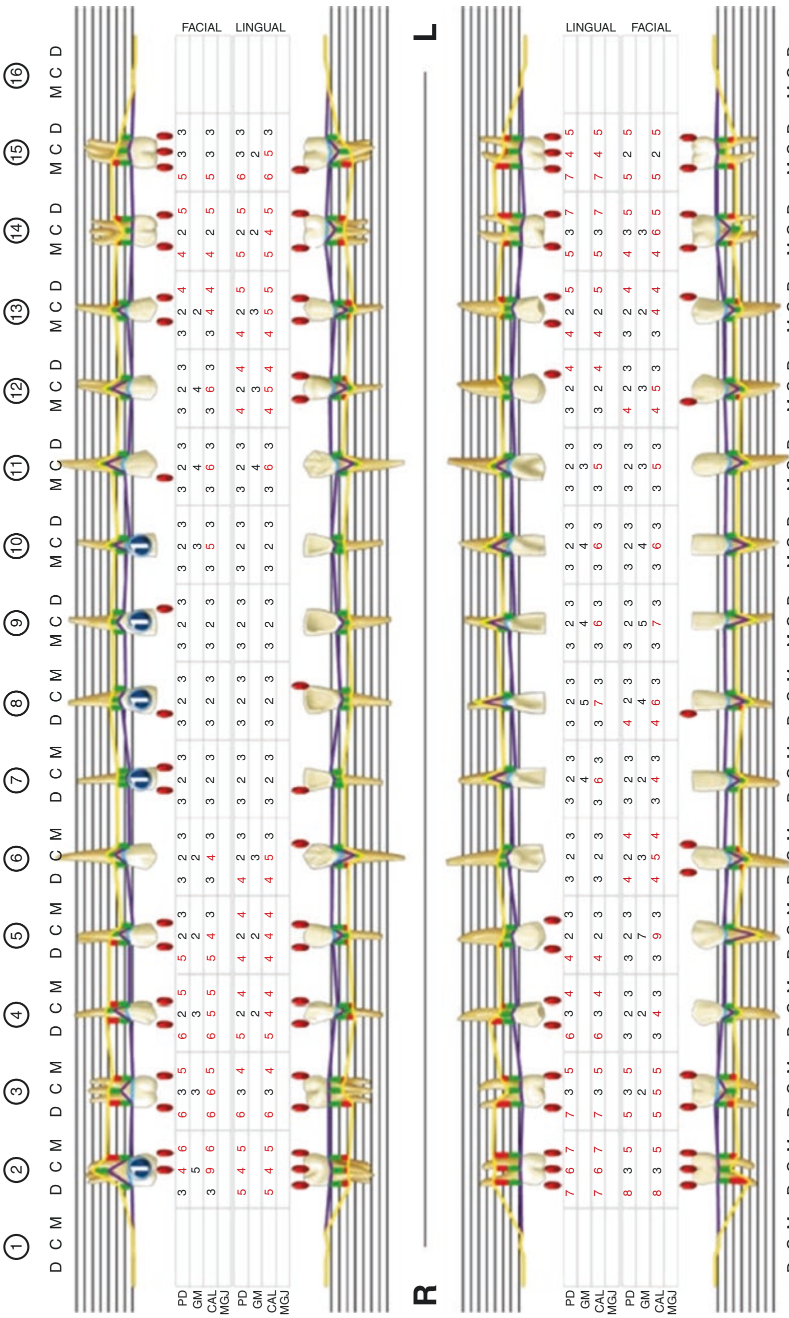

Fig. 1.8 Case #2: initial periodontal charting

Miller-McEntire Periodontal Prognosis Index

*Our goal is a score of less than 5

Tooth	# 2	#	#	#
Date	11/1/17			
Furcation	2			
Diabetes	0			
Mobility	1			
Probing Depth	1			
Molar Type	2			
Age	1			
Smoking	0			
TOTAL	7			
15 Year Prognosis	86%			
30 Year Prognosis	66%			

Score	15 Year	30 Year	
1	98%	94%	Excellent
2	97%	93%	
3	96%	89%	
4	95%	85%	
5	93%	80%	Good
6	90%	74%	
7	86%	66%	
8	81%	56%	Guarded
9	75%	45%	
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Furcation	A1C Levels	Mobility	Probing (mm)	Molar Type	Age	Smoking
None = 0	< 6 = 0	None = 0	< 5 = 0	Mand = 0	1 - 39 = 0	Non-smoker = 0
1 = 1	6.1 - 7.0 = 1	1 = 1	5 - 7 = 1	Max 1st = 1	> 40 = 1	Smoker = 4
2 = 2	7.1 - 8.0 = 2	2 = 2	8 - 10 = 2	Max 2nd = 2		
3 = 3	8.1 - 9.0 = 3	3 = 3	> 10 = 3			
T-T = 3 "through & through"	> 9.1 = 4					

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- Adhere to the recommended maintenance schedule
- Control your blood sugar (if diabetic)
- Stop smoking or at least cut back to under 5/day

Fig. 1.9 Case #2: MMPPI at initial periodontal consultation visit; scored tooth #2 with initial MMPPI of 7

Fig. 1.10 Case #2: posttreatment (ScRP w/ systemic antibiotics for 1 week) at 3 months

Fig. 1.11 Case #2: posttreatment buccal mirror views noting several mucogingival concerns (especially #28) that are discussed with the patient as he presents with MIX and potential for root caries as he is on six medications that will contribute to dry mouth

Fig. 1.12 Case #2: posttreatment buccal mirror views noting several mucogingival concerns (especially #28) that are discussed with the patient as he presents with MIX and potential for root caries as he is on six medications that will contribute to dry mouth

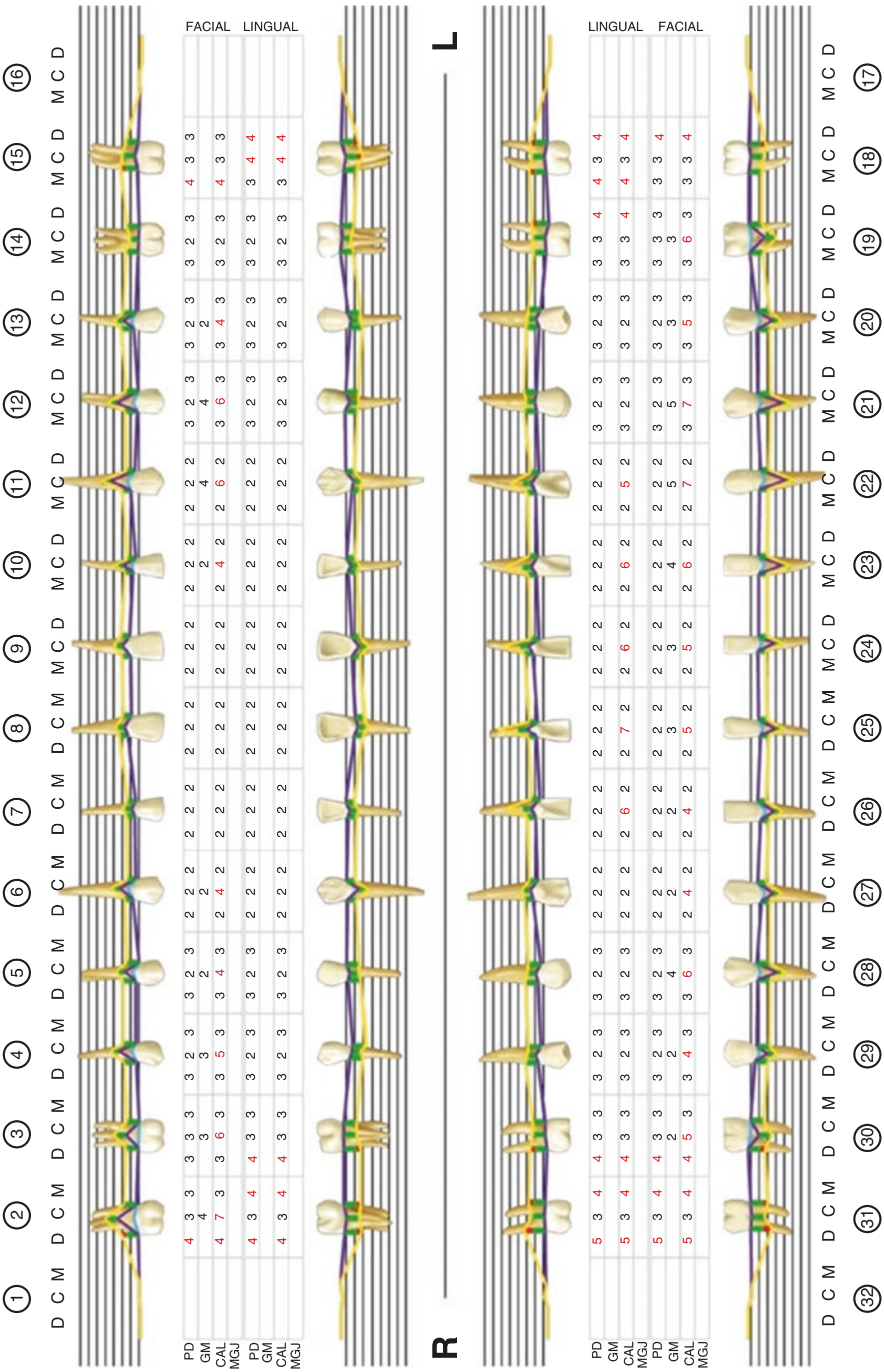

Fig. 1.13 Case #2: posttreatment periodontal charting

Miller-McEntire Periodontal Prognosis Index

Tooth	# 2	# 2	# 2	#
Date	11/1/17	2/7/17	7/11/18	
Furcation	2	-	-	
Diabetes	-	-	-	
Mobility	1	-	-	
Probing Depth	1	-	-	
Molar Type	2	2	2	
Age	1	1	1	
Smoking	-	-	-	
TOTAL	7	3	3	
15 Year Prognosis	86%	96%	96%	
30 Year Prognosis	66%	89%	89%	

*Our goal is a score of less than 5

Score	15 Year	30 Year	
1	98%	94%	Excellent
2	97%	93%	
3	96%	89%	
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- Adhere to the recommended maintenance schedule
- Control your blood sugar (if diabetic)
- Stop smoking or at least cut back to under 5/day

Fig. 1.14 Case #2: posttreatment MMPPI; scored tooth #2 with MMPPI now reduced to 3 reinforcement and follow-up deplaquing visits every 3 weeks for 3 months with a registered dental hygienist with full-mouth polish and prophylaxis. This is the same protocol we use for our LANAP patients. This protocol helps us in reinforcing the importance of all the "Keys to Success" in the patient's mind and gets them to participate as a "co-therapist" in their oral health outcomes [2]. Michael was seen 3 months' post-scaling and root planing for his first preventative periodontal maintenance visit when a new full-mouth periodontal charting was completed with tooth mobility being measured and an updated MMPPI (using tooth #2) reviewed with him. *His posttreatment MMPPI score was reduced from an initial score of 7 to a posttreatment score of 3* at 3 months (age > 39 = 1), scored tooth #2 (maxillary second molar = 2), probing depths was reduced to 4 mm associated with #2 (probing depths <5 mm = 0), #2 mobility was reduced to 0 (mobility 0 = 0), and the 2 furcations associated with #2 at presentation were now not probable (furcation 0 = 0). His updated MMPPI score of 3 puts him in the "excellent" periodontal prognosis category (<5 MMPPI score) with a 15- and 30-year prognosis of 96% and 89%, respectively (Fig. 1.13). In addition to the new MMPPI score of 3, we reviewed the importance of the "Keys to Success" for long-term success. His plaque control at the 3-month reevaluation was excellent. Discussions of our continued concerns with facial attachment loss and future dental caries susceptibility were addressed, and we decided together that we will reevaluate at each subsequent 3-month preventative periodontal maintenance visit for future periodontal plastic surgery. The goals of future periodontal plastic surgery would be partial to complete root coverage (starting with buccal sites #11, 20,21,28) that presented with Miller Classifications of Class 1 (#11), Class 2 (#20,21), to Class 3 (#28) [11]. Michael was very appreciative of the time we took to review his updated MMPPI and the benefits to him of knowing his periodontal prognosis along with the "Keys to Success" and concerns with his MIX which needs to be continually discussed and reinforced [19, 20].

The next two cases represent theoretical case reports for teaching purposes using Dr. Miller's original MMPPI score sheet and his present-day clinical recommendations for treatment.

1.3.3 Clinical Case Example #3 (Theoretical)

The MMPPI as noted prior provides supplemental health information that aids the physician in determining a medical diagnosis. This is especially true in diabetes mellitus. Linda, a 29-year-old overweight female, had a periodontal diagnosis of severe generalized gingivitis. Her chief complaints were bleeding gums and malodor (halitosis). The tissue was highly inflamed and enlarged, and there was spontaneous severe bleeding on probing. Although there was no attachment loss, probing depths were an average of 5 mm because of the swollen tissue. Although the patient denied being diabetic, her mother and three aunts had been diagnosed with diabetes mellitus. Because of the strong family history in clinical findings, an in-office HbA1c test was performed, and the HbA1c score was 8.7. Although the HbA1c score indicates that the patient has diabetes mellitus, diabetes is a medical diagnosis, and the patient should be referred to a physician to make the actual diagnosis. Additionally, the patient smoked two packs of cigarettes a day. Her MMPPI score was 11, which indicated that she had only a 53% chance of keeping her teeth for 15 years even though at this point she has no attachment loss. If the patient will follow the 5 "Keys to Success," she can lower her MMPPI score to a 3 and have a 96% chance of keeping her teeth for 15 years (Table 1.1).

1.3.4 Clinical Case Example #4 (Theoretical)

In an aging population, more senior citizens are seeking in-depth dental care including advanced periodontal therapy. George, a 78- year-old male, was diagnosed with severe generalized periodontitis with numerous probing depths more than 7 mm with multiple furcation involvements. The tissues were more fibrotic than hemorrhagic and bleeding on probing was moderate. *He indicated that he was diagnosed with diabetes mellitus 25 years prior and declined an in-office HbA1c test; therefore a score of 2 was used for diabetes in accordance with the MMPPI protocol.* Even though there was slight mobility of #14 (mobility 1), clinically it was felt that this was not remarkable. In this modern era, many patients with this perceived poor prognosis will elect to have their teeth removed in favor of an implant-supported prosthesis. Surprisingly, the MMPPI pre-op score was an 8, indicating that with treatment the patient has an 81% chance of keeping his teeth for 15 years.

Although periodontal health can be improved with nonsurgical treatment, because the tissue response was fibrotic rather than hemorrhagic, only minimal pocket reduction would result, and there will be residual calculus. This patient

Table 1.1 Theoretical Case #3: MMPPI for a 29-year-old female (Linda) who is a 2-pack/day smoker with severe generalized gingivitis and generalized 5 mm probing depths with heavy bleeding upon probing

Tooth	#14 (pretreatment)	#14 (pretreatment)
Age	–	–
Smoking	4	–
Diabetes	3	1
Molar type	1	1
Probing depth1	1	–
Furcation	–	–
Mobility	2	1
Total	11	3

There is a strong history of diabetes in her family and an in-office HgA1c test revealed it to be 8.7%. The pretreatment MMPPI = 11. Theoretically, the patient went through periodontal and occlusal therapy, quit smoking, lowered her HgA1c which resulted in a posttreatment MMPPI = 3. *This shows the power that the MMPPI has increasing patient periodontal case acceptance while helping them to improve their periodontal, social (quit smoking), and medical (lowering HgA1c) status of our patients*

Table 1.2 Theoretical Case #4: MMPPI for a 78-year-old male (George) who is non-smoker with severe generalized periodontitis and generalized >7 mm probing depths with heavy bleeding upon probing

Tooth	#14 (pretreatment)	#14 (pretreatment)
Age	1	1
Smoking	–	–
Diabetes	2	1
Molar type	1	1
Probing depth	2	1
Furcation	1	1
Mobility	1	–
Total	8	5

He has a history of diabetes and is not aware of his HgA1c score. The pretreatment MMPPI = 8. Theoretically, the patient went through periodontal and occlusal therapy, lowered her HgA1c which resulted in a posttreatment MMPPI = 5. *This case again shows the power that the MMPPI has in increasing patient periodontal case acceptance while helping them to improve their periodontal and medical (lowering HgA1c) status of our patients*

would respond favorably to one-visit (LANAP) therapy or conventional periodontal surgery for pocket reduction reducing the MMPPI score to a 5 (Table 1.2).

As stated earlier, by making the patient aware of the possible post-therapy prognosis, the authors have found that patients are both pleased and surprised by what can be accomplished with periodontal therapy. This has proven very motivational in getting patients to accept and complete treatment, as well as becoming a compliant maintenance patient. Since smoking has the most negative impact on periodontal prognosis out of all the factors scored, some level of smoking cessation counseling should be provided to the patient (see Footnote 2).

1.4 Conclusions

For far too long, dentists have presented a treatment plan to the patient based on their personal opinion, procedures that they prefer to perform, or those that are economically rewarding. Patients deserve treatment options based on evidence-based research which is statistically validated. The MMPPI fulfills those requirements. When using this index, the patient can then properly evaluate treatment options. Patients with gingival defects including recession and any periodontal disease from a slight gingivitis to advanced periodontitis deserve the opportunity to accurately determine how periodontal therapy can impact them. Scoring allows the patient to select the best treatment options and decide if they want to keep their natural teeth. The MMPPI provides that information as the patient becomes a "co-therapist" in the decision process. With this better understanding, a higher percentage of patients will accept treatment; the patients become more compliant in all phases of treatment and see the rationale for lifestyle changes that improve their oral health and their overall systemic health. This forthright and honest approach has proven very motivational in convincing patients to accept and comply with treatment. When shared with family and friends, for the first time, we have a successful way of getting patient referrals. Using the MMPPI we can become more of a physician of the mouth rather than just simply doing the mechanics of dentistry. In short, every new patient should be scored (see Footnote 1).

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2 Decision Trees in Periodontal Surgery: Resective Versus Regenerative Periodontal Surgery

Aniruddh Narvekar, Kevin Wanxin Luan, and Fatemeh Gholami

2.1 Introduction

For decades, clinicians and researchers have aimed to develop therapies to predictably regenerate periodontal structures and regain attachment lost due to periodontal disease. The advent of new surgical procedures, growth factors, and other biomimetic agents to complement existing bone replacement grafts has fundamentally changed the field of regenerative dentistry by increasing the long-term survival rate of teeth often categorized as having a poor prognosis. In the last decade, several new techniques have been demonstrated both preclinically and clinically, to further improve the success rate of periodontal regeneration.

2.2 Clinical Decision Considerations

Guided tissue regeneration (GTR) was formally introduced by Isidor et al. [1] where an occlusive membrane was utilized to allow only cells from the periodontal ligament to repopulate the root surface. The concept of cell occlusion and space provision prevented the gingival epithelium and connective tissue from entering the defect. Since then, the need for an occlusive membrane for defect isolation has been questioned by several authors, and the focus has shifted to the role of the undisturbed fibrin clot and wound stabilization between the tooth and gingival flap to prevent the downgrowth of epithelium [2, 3].

Based on current evidence, the predictability of GTR procedures has been shown to be influenced by several factors related to the defect site such as intrabony defect

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depth, angle, and configuration. According to Reynolds et al. [4], narrow defects less than 3 mm in width show a higher gain in attachment level, and bone fill suggesting defects which were shallow and wide would benefit more from osseous resective surgery. Indeed, several authors have consistently shown deep intrabony defects greater than 3 mm to have improved clinical outcomes using GTR compared to shallow defects [5, 6].

As our understanding of wound healing and periodontal regeneration has improved, a shift in treatment strategy from primarily one of cell occlusion to blood clot stability has occurred. Several minimally invasive surgical procedures have been introduced with the primary objectives of minimal flap reflection, wound stabilization, and establishing primary closure of the surgical flap(s). These approaches have demonstrated similar clinical outcomes irrespective of the defect configuration. The use of microsurgical instruments and microscopes has allowed for smaller surgical flaps with more predictable flap positioning, thereby stabilizing the blood clot and maintaining the integrity of the blood supply. With the help of these techniques and tools, a prognostic change has been reported whereby periodontally involved teeth with a hopeless prognosis show significant improvement and increased survivability after treatment.

Although there are many advantages to minimally invasive techniques such as improved patient comfort, reduced surgical trauma, improved wound stability, and primary closure of the flap, the main disadvantages lie in the added cost of the equipment and additional training required by the surgeon. Further, strict patent compliance and proper case selection are necessary with the application of these techniques primarily limited to localized and smaller interproximal defects with an intrabony component. The rationale of treatment utilizing these techniques is thus focused on regenerative approaches and less on resection of osseous tissues.

2.3 Systemic and Behavioral Factors

Patient-centered factors can have a significant impact on the success of regenerative therapy. Therefore, it is imperative that systemic and behavioral factors are carefully reviewed prior to initiating regenerative therapy as these factors can often relate to poor outcomes. It is well established that hyperglycemia, as occurs in poorly controlled diabetics, is associated with increased occurrence of infection and inflammation owing to impaired cellular immune responses and microcirculation during the wound healing process [7]. The combination of compromised wound healing and reduced bone turnover in the presence of hyperglycemia needs to be taken into consideration during treatment planning. Environmental factors such as smoking have also shown to have a negative impact on regeneration of new bone. Stavropoulos et al. [8] reported that smokers had a reduced gain in clinical attachment level following GTR as compared to non-smokers after 1 year. This finding is supported in a study by Tonetti et al. [9], who also showed the deleterious effects of smoking on the outcome of GTR. Matuliene [10] et al. in their study showed that teeth with probing depths of over 5 mm were at risk for loss and progression of periodontal disease. Therefore, supportive periodontal therapy such as routine maintenance care and good oral hygiene practices and behavior management are crucial to the long-term success of regenerative therapy.

In general, clinical advances in periodontics can be grouped into three main categories: tools, techniques, and materials. In this section we will describe advances in these categories.

2.4 Tools

2.4.1 Imaging

Dental radiography has been widely accepted and utilized in the field of periodontology. Recent advancements have made this diagnostic technology increasingly relevant, especially with regard to cone beam computed tomography (CBCT). Currently, two-dimensional imaging is performed regularly but with well-documented limitations [11–13]. CBCT has given clinicians the ability to better visualize and ascertain more information about the dentition and adjacent or surrounding bone with three-dimensional imaging resulting in better prognosis evaluation, treatment planning, and surgical management of a variety of periodontal diseases and conditions [14, 15]. Currently, the majority of literature supports the usage of CBCT for the management of surgical implant patients as well as conditions related to implant site preparations such as sinus grafting and location of anatomic structures [16]. The use of CBCTs to assess dentoalveolar bone change for dehiscences or fenestrations as a result of orthodontics has been recommended [17]. For patients with periodontitis, CBCT has significant improved visualization of furcations, root fractures, periodontal-endodontic lesions, and location of alveolar bone changes [18]. Although CBCT is currently not recommended as a replacement of the traditional 2D imaging for diagnosis, it is important to recognize advancements in CBCT technology that offer distinct advantages. Prakash and colleagues demonstrated the ability of CBCT to provide images of lamina dura and the periodontal space with higher quality and greater accuracy than 2D imaging [19]. With regard to bone levels, CBCT offers the advantage of analyzing buccal and lingual/palatal surfaces [20]. In a clinical study by Raichur et al. it was reported that CBCT imaging can significantly and more accurately detect infrabony periodontal defects (Fig. 2.1) [21]. Root morphologies and furcations of maxillary molars were visualized with higher accuracy using CBCT [22]. In addition, CBCT images were shown to more accurately detect furcation involvement compared to clinical measurement [23–25]. As CBCT technology advances, companies are manufacturing CBCTs that utilize less radiation and produce higher resolution images with a variety of field of views (FOV) [26]. With these advances, there may soon come a time where CBCT may replace the traditional 2D radiograph images currently used in periodontology.

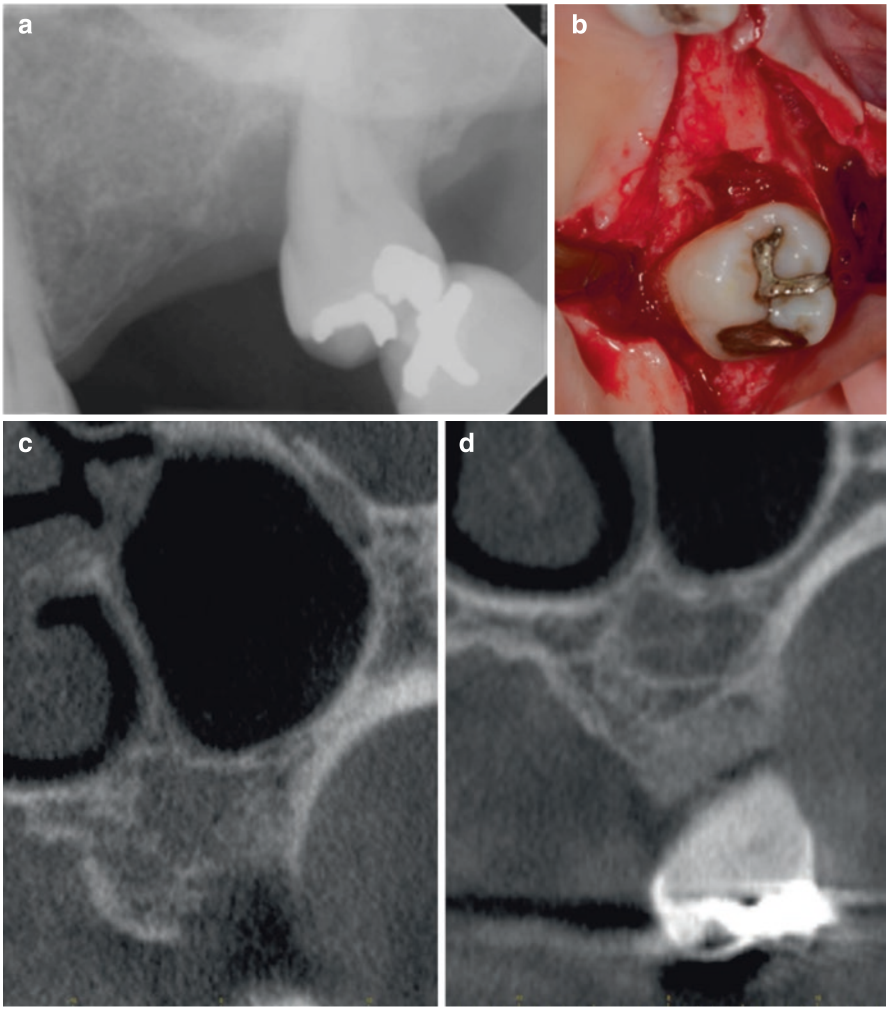

Fig. 2.1 (**a**) Radiographic image of infrabony defect on the mesial of the maxillary left second molar. (**b**) Clinical photograph showing infrabony three-wall defect. (**c**) Presurgical CBCT image of defect. (**d**) Postsurgical CBCT image showing bone fill within the infrabony defect

2.4.2 Magnification

Microscopes have been widely used in the field of endodontics and restorative dentistry. In recent years, these microscopes have been utilized in periodontal therapy with more literature supporting this technology to aid with positive outcomes from periodontal therapy, both nonsurgical and surgical. Belcher highlighted three key principles that support the usage of microscopes in periodontics: refined surgical skills, magnification, and illumination [27]. Outside of adequate

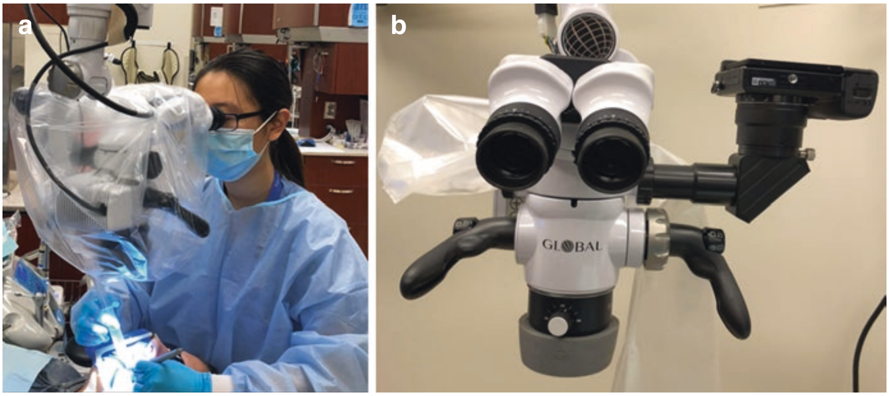

Fig. 2.2 (**a**) Clinician using a microscope with ergonomic posture. (**b**) HD video camera mount attached to microscope (Global Surgical Corporation, St. Louis, MO, USA)

surgical training to successfully perform periodontal surgical procedures, magnification and illumination have aided surgical outcomes with respect to postoperative scarring and pain and reduced healing time [28]. Fiber-optic technology in illumination has been utilized to help focus light to provide a clear visual of specific areas [29]. Operatively, it has been suggested that there is a distinct advantage of the utilization of the microscope in extending the longevity of practice and health of the clinician. Indeed, studies have documented the ergonomic benefit of posture while using microscopes which results in a reduction of soreness and pain in areas of the body including the back, shoulder, and neck [30], while the elevated position of the head reduces eye fatigue and improved vision [31]. Recent advances in microscope usage in the field include HDTV integration in a single camera three-dimensional system to project a surgery onto a high-definition display [32]. This technology aids visual acuity for microsurgery and provides specific advantages for clinicians who become proficient in microsurgical knowledge and procedures (Fig. 2.2).

2.4.3 Instruments

As minimally invasive periodontal surgery procedures gain more popularity, the tools clinicians use have adapted accordingly. In addition to magnification using microscopes and loupes, microsurgical instruments are becoming increasingly more important to manage tissue trauma and minimize bleeding during surgery. Microsurgical instruments are shorter than standard surgical instruments to allow for adequate tactile grip between the thumb and index fingers. Instruments are circular in cross section than the traditional rectangular or oval shape, allowing a more flexible rotational movement. Additionally, the use of titanium metal for tissue forceps and needle holders is increasing compared to the heavier alternative of surgical

Fig. 2.3 Relative size of a No. 15 scalpel blade (top) and Mini 69 blade (middle) and Mini 63 blade (bottom) (Salvin Dental Specialties, Charlotte, NC, USA). The microblades are bendable up to 45° and have a full radius edge

stainless-steel instruments. A thorough knowledge of microsurgical principles in addition to the appropriate usage of these instruments will help the clinician achieve the benefit of using these microsurgical instruments (Fig. 2.3).

2.5 Techniques

Significant advances in the treatment of periodontal disease, specifically in periodontal regenerative, have come in the way of development and refinement of microsurgical techniques. These techniques capitalize on progress in our understanding of wound healing, and the role of space maintenance, clot stabilization, and primary closure on tissue regeneration.

2.5.1 Minimally Invasive Techniques

Harrel and Rees were the first to propose the minimally invasive surgical (MIS) technique [33]. In this technique, thorough granulation tissue removal and root debridement were accomplished using minimal flap reflection and gentle manipulation of soft tissues. This technique was subsequently modified by the incorporation of microscopes and microsurgical instruments to improve surgical precision. In 2007, Cortellini and Tonetti [34] introduced the MIST (minimally invasive surgical technique) in combination with enamel matrix derivative (EMD) to treat isolated intrabony defects. In this approach, the intrabony defect was accessed using either a simplified papilla preservation flap in narrow interdental spaces or the modified papilla preservation flap in wide interdental spaces. The authors owed the success of this technique to clot stability and primary wound closure. In 2009, the same group proposed M-MIST, consisting of reflection of only the buccal papilla using buccal sulcular incisions connected by a horizontal incision close to the papilla tip to gain access to the interproximal defect in what they described as the "buccal window." The authors described the same principles used for the previous technique, emphasizing the importance of space provision on success rates [35]. However, a major drawback to this technique is the lack of application to interproximal defects that extend buccally and/or lingually.

A recent retrospective study by Nibali et al. [4] showed significant improvements in intrabony defects by means of clinical attachment gains and radiographic bone fill using minimally invasive *nonsurgical* therapy (MINST). Following, supra- and subgingival debridement using thin piezoelectric devices and Gracey mini curettes under a magnification lens, an attempt was made to stimulate and stabilize a blood clot within the defect. One-year results from baseline showed a probing depth reduction of 3.5 mm and 2.8 mm for the buccal and lingual interproximal sites, respectively, with average attachment gains of 3.1 mm and 2.4 mm on the buccal and lingual interproximal aspects. In addition, a significant improvement in radiographic vertical defect depth from 6.74 mm to 3.8 mm and defect angle from 28.4 to 44.3° was noted. According to the author, the significant widening of the defect angle could be attributed to bone remodeling which occurs in addition to the formation of a long junctional epithelium following MINST. This minimally invasive, nonsurgical technique using microsurgical instruments reduced the risk of soft tissue trauma and may have a significant positive impact in the treatment of medically compromised patients or patients that are not good surgical candidates.

The major limitations to the microsurgical techniques mentioned above are the lack of visualization and accessibility to intrabony defects. To address these limitations, Harrel [36] recently introduced the V-MIS technique which permits either buccal or lingual access. After flap reflection, the site is visually debrided with the aid of a videoscope; the root surface is treated with EDTA, followed by grafting with a mix of demineralized freeze-dried bone allograft (DFDBA) and EMD. A single suture at the base of the papilla followed by finger pressure with a soaked gauze is used to stabilize the clot and achieve primary closure of the wound. The results showed a significant improvement in clinical parameters as compared to traditional periodontal regenerative techniques at 36 months. However, the most significant finding was a similar gain in attachment irrespective of the defect configuration (one-, two-, three-walled defects). The author attributes the success of this technique to the removal of "micro-islands" of calculus on the root surface and has been shown to be associated with an increase in subgingival inflammation which was not previously visible with high magnification surgical telescopes but easily visualized using the videoscope. This technique is described in the chapter by Harrel in this volume (Figs. 2.4 and 2.5).

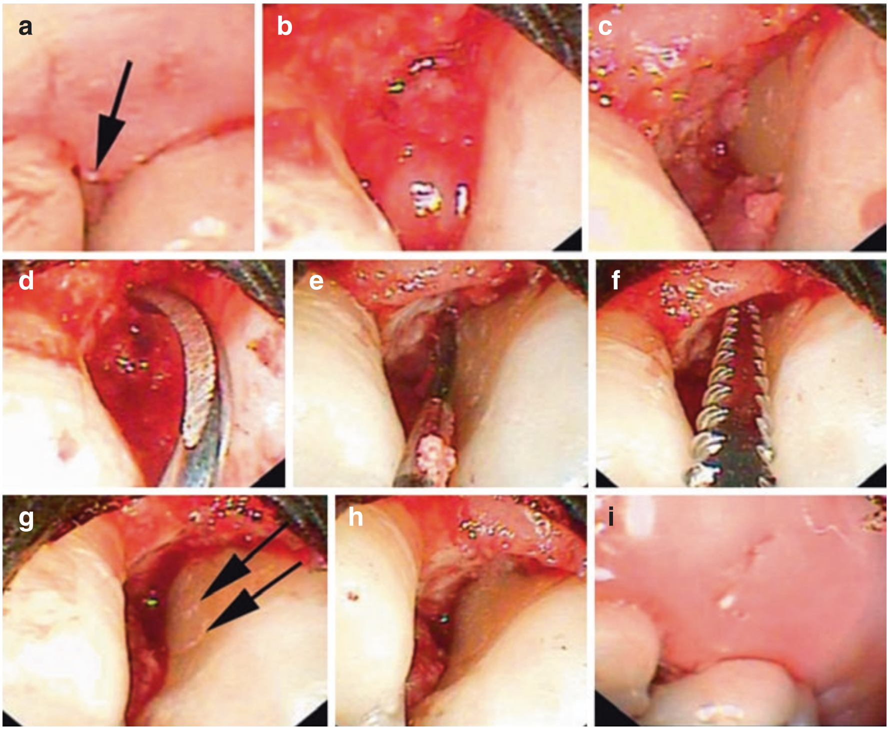

Fig. 2.4 V-MIS procedure. (**a**) Arrow pointing to initial incision design. (**b**, **c**) Flap reflection showing granulation tissue within the infrabony defect visualized by the videoscope prior to instrumentation and following partial instrumentation. (**d**-**f**) Instrumentation within the defect using curettes and files to remove granulation tissue and calculus. (**g**) Arrow pointing to micro-islands of calculus present on the root surface. (**h**, **i**) Removal of the micro-islands of calculus using EDTA followed by flap closure using vertical mattress sutures

2.5.2 Soft Tissue Wall Technique

In a case series, Rasperini [37] described a technique for use in non-contained intrabony defects with a radiographic intrabony vertical component ≥4 mm. A horizontal incision was made at the level of the base of the interproximal papilla and extended one tooth on both sides of the defect leaving the facial portion of the papilla intact. Following the reflection of a full thickness flap, the facial interproximal papilla was degranulated creating a connective tissue bed for the future flap to be sutured. The defect-associated papilla was dissected and elevated at its base, providing access to the defect which is then degranulated followed by scaling and root planing. The flap was mobilized using periosteal releasing incisions to ensure passive placement of its marginal portion coronal to the CEJ. EDTA (24%) was applied to the root surface to remove the smear layer. Finally, EMD was placed in

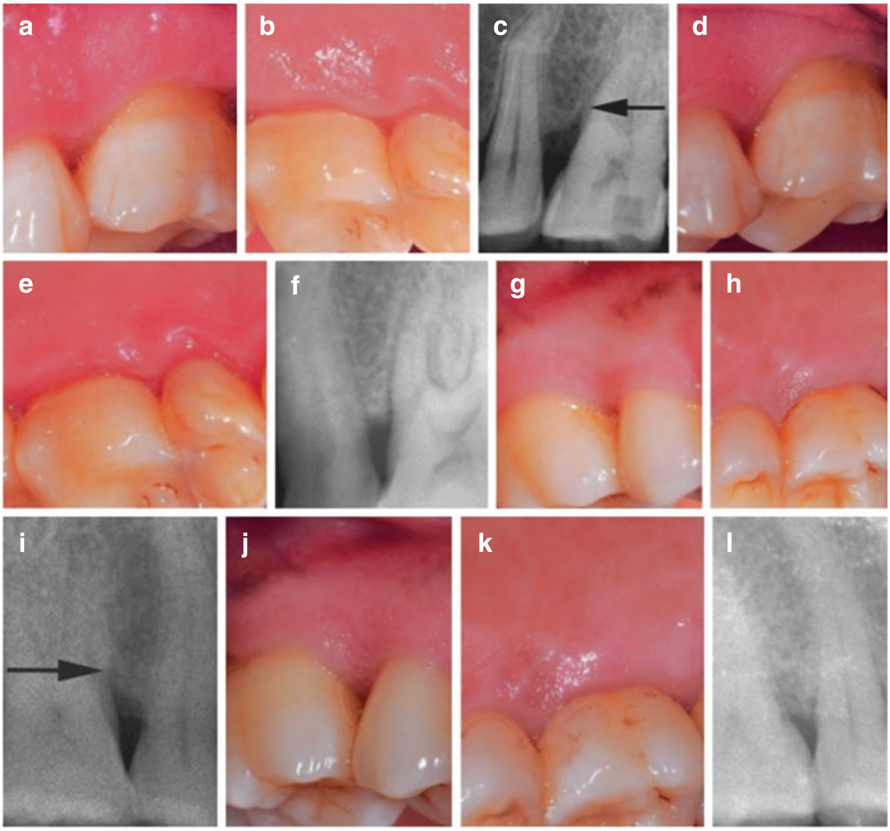

Fig. 2.5 V-MIS procedure. (**a**-**c**) Presurgical clinical and radiographic images of infrabony defect on the maxillary left first molar. (**d**-**f**) Postsurgical clinical and radiographic images of infrabony defect showing bone fill. (**g**-**i**) Presurgical clinical and radiographic images of infrabony defect on the maxillary right first molar. (**j**-**l**) Postsurgical clinical and radiographic images of infrabony defect showing bone fill

the defect and site closed using horizontal mattress sutures. One-year results showed significant potential for the regeneration of one-wall defects with a probing depth reduction of approximately 6 mm and a clinical attachment gain of approximately 7 mm. The author described the importance of clot stability [9] and space provision [10] during the early healing phase to allow for the migration and proliferation of cells from the periodontal ligament and alveolar bone along the root surface. In addition, this technique followed two basic principles, a papilla preservation flap, preservation of the supra crestal soft tissue aiding in wound closure and prevention of soft tissue collapse providing space provision for the blood clot, and the predictable coronally advanced flap.

2.5.3 Non-incised Papillae Surgical Approach

In 2017, Rodriguez et al. [38] described the non-incised papillae surgical approach (NIPSA). This technique allows for treatment of deep intrabony defects with non-containing topography affecting the buccal, lingual, mesial, and distal aspects. This technique consists of a horizontal or oblique incision made apical to the defect and the marginal tissues and wide enough to visualize the boundaries of the defect. A full thickness flap was raised coronally providing access to the defect corono-apically leaving the marginal tissues untouched acting as a “dome” for clot stability. The author described the use of this incision in the treatment of defects with minimal keratinized tissue predisposed to collapse into the defect and to prevent postoperative tissue shrinkage due to flap reflection. After gaining access to the defect, granulation tissue removal and root debridement, EDTA is applied to the root surface followed by the placement of EMD. Primary wound closure is achieved using the combination of horizontal mattress and interrupted sutures two millimeters away from the incision line. This technique follows the two main principles commonly used in other minimally invasive techniques: space provision for the blood clot by maintaining the marginal gingiva and placement of the incision at a significant distance from the defect allowing for primary wound closure. Although introduced very recently, the results are promising, showing a reduction in probing depth and gain in clinical attachment of approximately 8 mm with limited postsurgical shrinkage and reduced morbidity in teeth initially diagnosed with a hopeless prognosis (Fig. 2.6).

2.5.4 Entire Papilla Preservation Technique

The entire papilla preservation technique (EPPT) [39] was described by Aslan to regenerate bone in deep and wide intrabony defects. A tunnellike approach, consisting of a buccal intrasulcular incision around the defect associated with the tooth, was followed by a single beveled vertical incision on the buccal gingiva of the neighboring interdental space past the mucogingival junction. A microsurgical periosteal elevator was used to raise a full thickness flap from the vertical incision to the defect-associated interdental papilla. Tunneling was performed in the defect-associated interdental papilla providing adequate access for mechanical therapy to the intrabony defect. Mini curettes were used for debridement followed by application of EDTA. EMD was placed on the root surface of the tooth followed by application of xenograft bone material within the defect. According to the author, by shifting the vertical incision to the adjacent interproximal papilla, the biomaterial was protected from exposure thereby stabilizing the blood clot. In addition, tunneling under the defect-associated interproximal papilla maintains the vascular integrity, thereby decreasing the chances of wound failure. The drawback of this procedure is its inapplicability to defects associated with lingual aspect of the tooth. Outcomes at 8 months showed a probing depth reduction from 6 to 15 mm and significant gain in clinical attachment level ranging from 6 to 14 mm (Figs. 2.7 and 2.8).

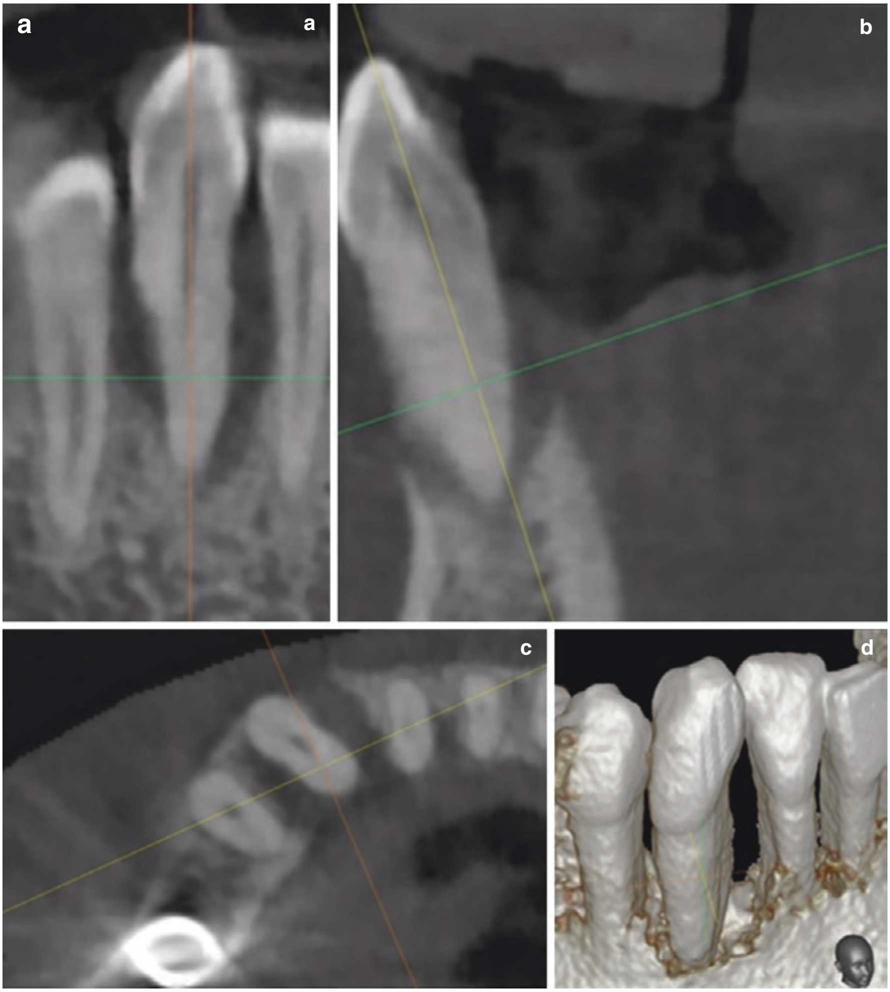

Fig. 2.6 Non-incised papillae surgical approach. (**a**) Presurgical CT scan showing deep and wide infrabony defects surrounding the mandibular right canine. (**b**) Incision design followed by the application of EMD. (**c**) Postsurgical CT scan showing new bone formation within the infrabony defect

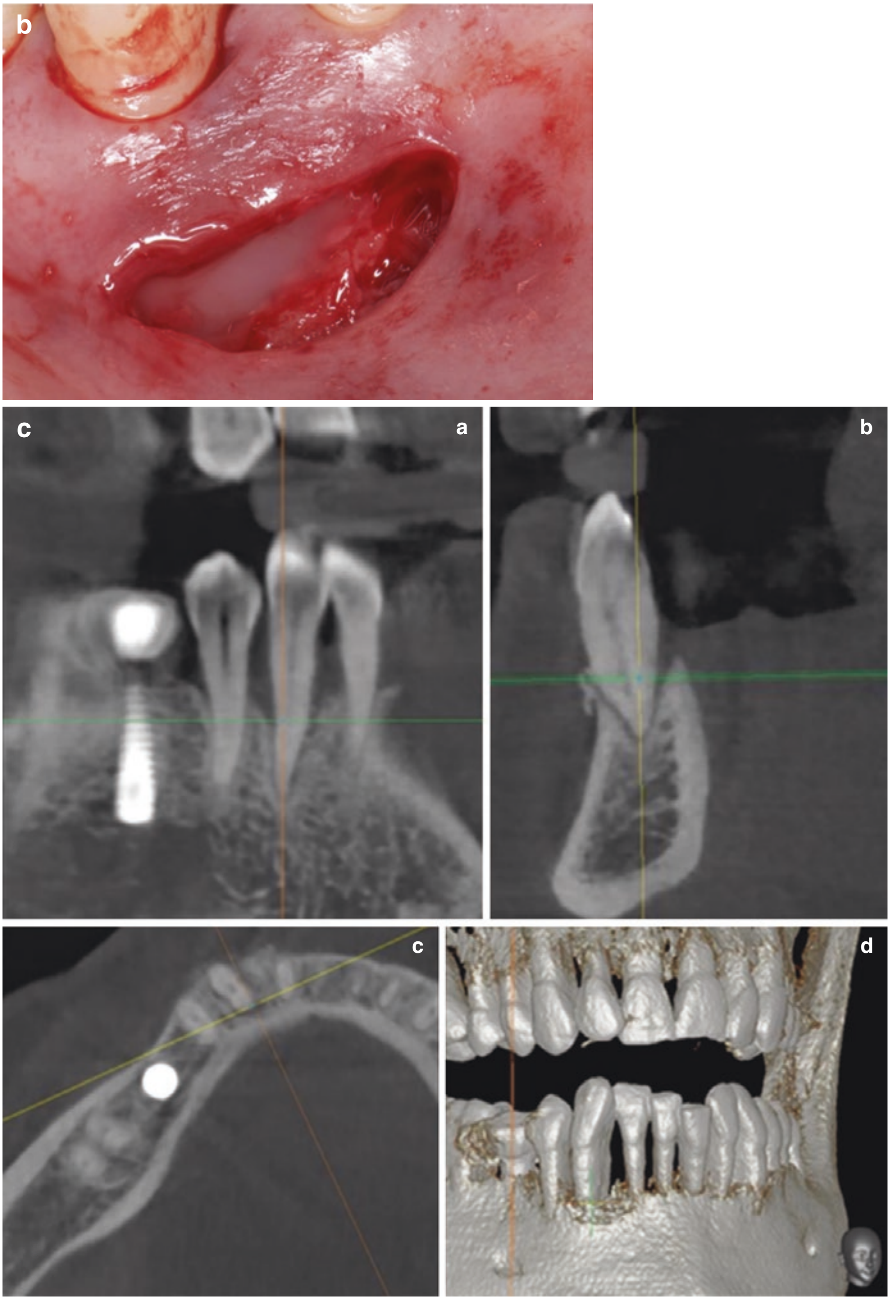

Fig. 2.6 (continued)

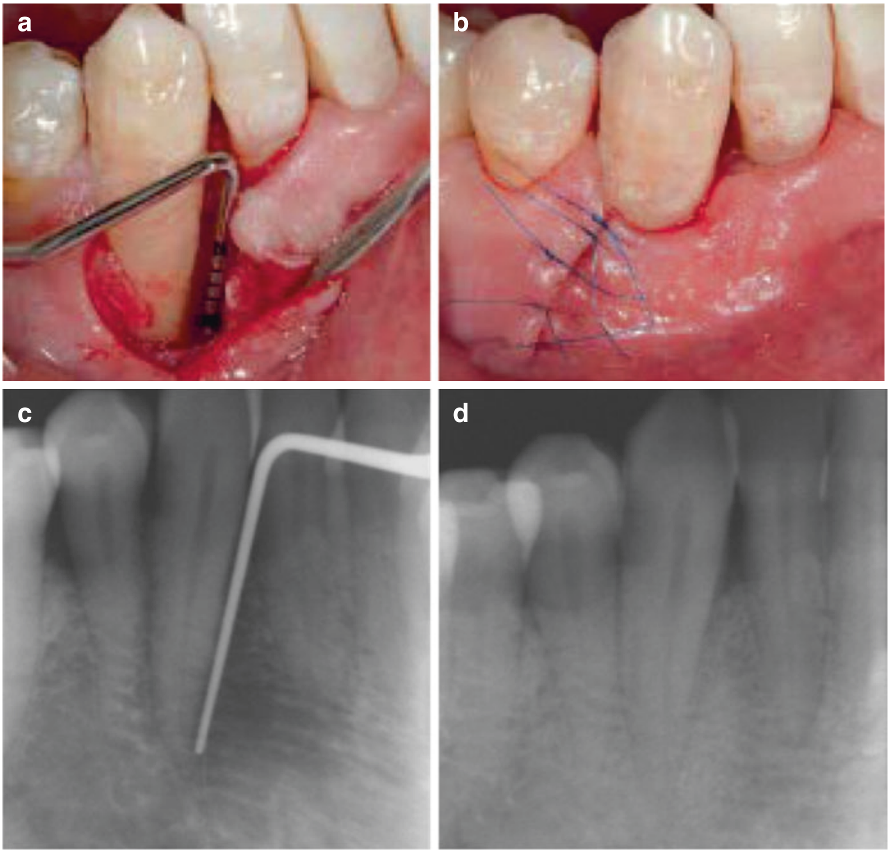

Fig. 2.7 Entire papilla preservation technique. (**a**) Incision design gaining access to the infrabony defect on the mesial of the mandibular right canine. (**b**) Site closure following the application of EMD and bone substitutes within the infrabony defect. (**c**) Presurgical and postsurgical radiograph of infrabony defect on the mesial of the mandibular right canine. (**d**) Postsurgical radiograph of bone fill within the infrabony defect

2.6 Biomaterials

The techniques described above incorporate microsurgical principles and the use of biomimetic agents and graft materials to regenerate lost periodontal tissues. This section will focus on highlighting the evidence regarding the use of biomimetic agents in periodontal regeneration therapy. Numerous studies have been published that evaluate the efficacy of different biomaterials [40–45]. Tables 2.1, 2.2, and 2.3 summarize key points of the most studied biomimetic agents, rhPDGF-BB, EMD, rhFGF-2, and PRP.

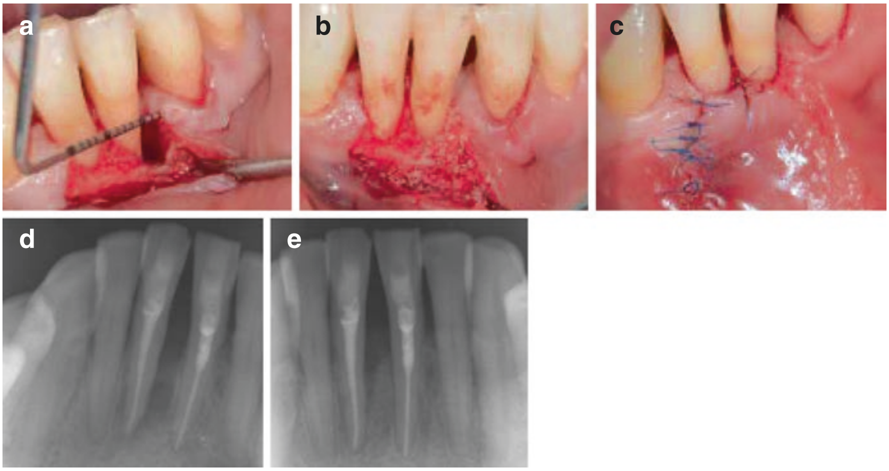

Fig. 2.8 Case 2: entire papilla preservation technique. (**a**) Incision design gaining access to the infrabony defect on the mesial of the mandibular right central incisor. (**b**) Application of EMD and bone substitute into the infrabony defect. (**c**) Primary wound closure of the surgical site. (**d**) Presurgical radiograph of infrabony defect on the mesial of the mandibular right central incisor. (**e**) Postsurgical radiograph of bone fill within the infrabony defect

Table 2.1 Recent systematic reviews on the effect of rhPDGF-BB in regeneration of the periodontium

Author	Materials and methods	Results
Kao [40]	Systematic review on 45 controlled studies in the use of biologics for treatment of intrabony defects	rhPDGF is comparable with DFBA and GTR, and it is superior to OFD procedures in treatment of intrabony defects
Lin [41]	Systematic review on well-designed studies with evidence of regeneration with the use of rhPDGF-BB	rhPDGF-BB plus bone allograft showed regeneration (new bone, cementum, and functionally oriented PDL fibers)
Khoshkam [47]	Systematic review of RCT studies in the use of PDGF for periodontal regeneration	rhPDGF-BB demonstrated significantly better CAL gain and higher percentage of LDF
Reynolds [42]	Systematic review- consensus report from AAP regeneration workshop	rhPDGF-BB with b-tricalcium phosphate were shown to be efficacious in regeneration of intrabony defect
Feifei Li [45]	Systematic review on effect of PDGF on regeneration of intrabony defects. Effective concentration of this growth factor was evaluated	5 RCT studies were included for meta-analysis. Results indicate that 0.3 mg/ml rhPDGF-BB has 22.71% greater bone fill than other concentrations and superiority to control groups

rhPDGF recombinant human platelet-derived growth factor, *DFDBA* demineralized freeze-dried bone allograft, *GTR* guided tissue regeneration, *OFD* open flap debridement, *CAL* clinical attachment level, *LDF* linear defect fill, *RCT* randomized controlled trials.

Table 2.2 Recent systematic reviews on effect of EMD in regeneration of the periodontium

Author	Materials and methods	Results
Kao [40]	Systematic review on controlled studies in the use of biologics	When compared with OFD, EMD application resulted in substantial improvements in clinical measurements and bone fill. EMD vs GTR: no significant difference with GTR
Lin [41]	Systematic review of well-designed studies with evidence of regeneration	Significant results in CAL gain (1.30 mm), PD reduction (0.92 mm), and radiographic bone level improvement (1.04 mm)
Graziani [48]	Systematic review on the effect of EMD vs. OFD on treatment of suprabony defects	EMD group has shown better CAL gain vs. OFD in treatment of suprabony defects
Esposito [49]	Cochrane-based systematic review study on EMD	EMD showed similar clinical results to GTR but is easier to be used and creates less complications
Koop [50]	Systematic review on the use of EMD	PD and CAL gains using EMD showed no difference compared to GTR
Reynolds [42]	Systematic review-consensus report from AAP regeneration workshop	EMD was shown to be effective in regeneration of intrabony defects
Sculean [44]	Systematic review of 58 human histologic studies	Eight studies all utilizing EMD were included. All studies except one reported a healing by regeneration and/or connective tissue attachment

EMD enamel matrix derivative, *OFD* open flap debridement, *GTR* guided tissue regeneration, *CAL* clinical attachment level, *PD* probing depth.

Table 2.3 Recent systematic reviews on the effect of rhFGF-2 and PRP in regeneration of the periodontium

Author	Materials and methods	Results
Lin [41]	Systematic review of well-designed studies with evidence of regeneration	Significant results in CAL gain (1.30 mm), PD reduction (0.92 mm), and radiographic bone level improvement (1.04 mm)
Fiefie Li [45]	A systematic review and meta-analysis on the effect of FGF-2 on regeneration of intrabony defects	Results indicated that 0.3% rhFGF-2 has a greater capacity for periodontal regeneration than other concentrations and superiority to control groups
Rosello-Camps [46]	Systematic review on the effect of PRP on regeneration of intrabony defects. 18 studies were included for meta-analysis	There was heterogeneity between studies in this systematic review, and there was no definite conclusion on the effect of PRP in treatment of intrabony defects

rhFGF-2 recombinant human fibroblast growth factor-2, *GTR* guided tissue regeneration, *CAL* clinical attachment level, *PD* probing depth, *PRP* platelet-rich plasma.

Other growth factors which were examined in studies to evaluate their effect on periodontal regeneration are human growth differentiation factor-5 (rhGDF-5) and recombinant human insulin growth factor-1 (rhIGF-1) and P15 (polypeptide of 15 amino acids) and parathyroid hormone PTH. There are limited numbers of clinical studies for these growth factors at this time to make a conclusion regarding their efficacy.

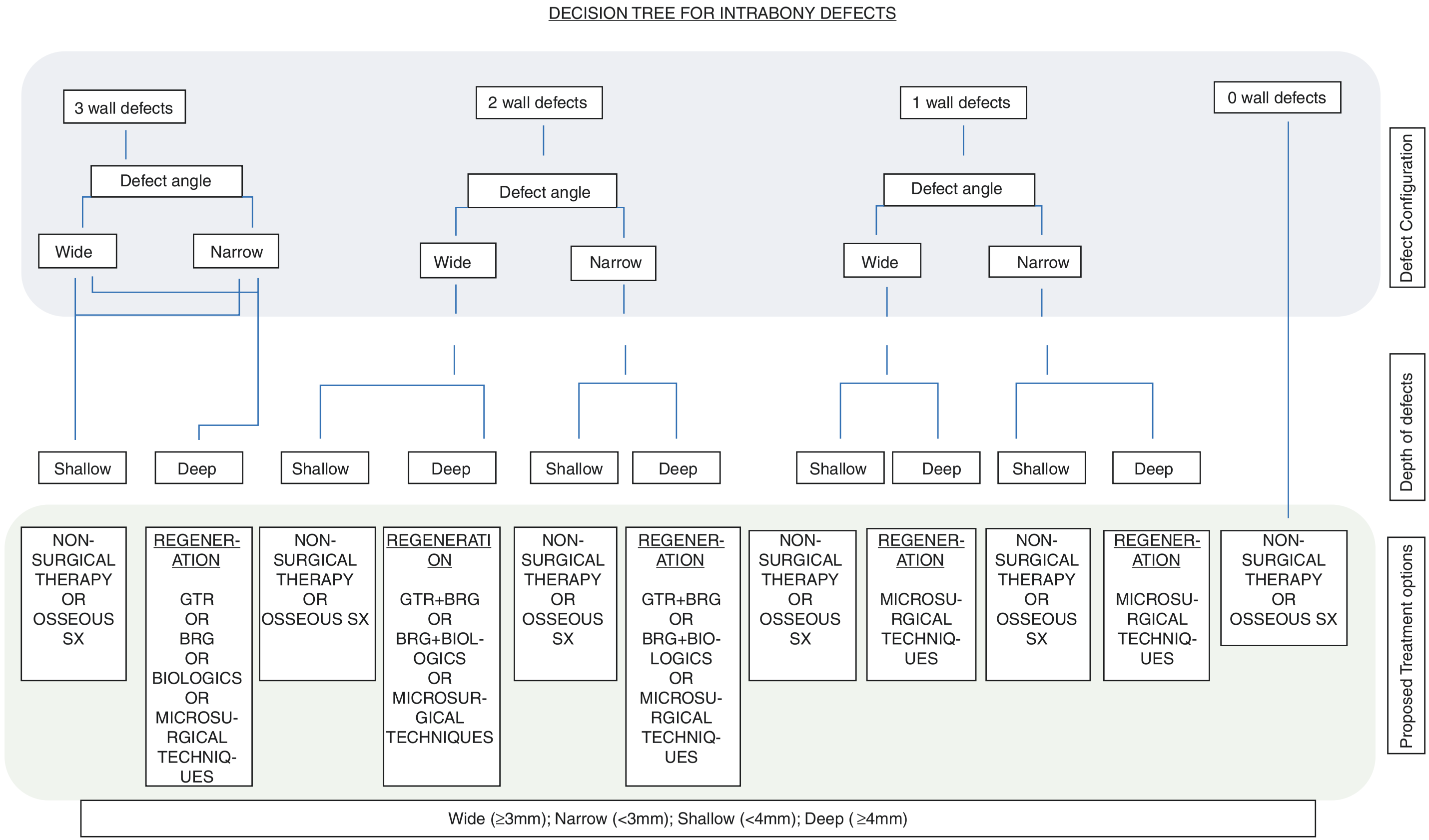

Fig. 2.9 Clinical decision tree based on current evidence and available techniques for treatment of infrabony defects using defect configuration, defect angle, and defect depth as guides

2.7 Conclusions

Recent advances in our understanding of periodontal wound healing and tissue regeneration have created a shift in the management and treatment of periodontal disease. This new knowledge has driven innovation and the creation of a variety of new tools, techniques, and materials useful in clinical practice. This is particularly evident with advances in minimally invasive approaches and the use of biomimetic agents where the focus is on regenerative as opposed to resective techniques. A thorough review of protocols and relevant literature is recommended as the usage of the variety of tools is customarily case dependent. As is shown in the decision tree (Fig. 2.9), clinicians can apply this new knowledge to determine the best course of treatment for their patients.

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Part II

Resective Techniques of Periodontal Surgery

3 Periodontal Flap Designs for Access and Osseous Surgery

Antonio Moretti and Karin Schey

3.1 Introduction

Upon completion of initial periodontal therapy, when inflammation of the gingiva has been reduced and the patient has shown improved compliance with oral hygiene, surgical intervention might be necessary. Periodontal surgery may become important to facilitate the access to the root surfaces for proper debridement as well as access to the alveolar bone to reestablish a more desirable bony architecture.

Historically, the rationale for performing periodontal surgeries, according to Barrington [1], is as follows:

1. Eliminate pockets by removing soft tissue, recontouring it, or by using a combination of the two procedures.
2. Eliminate pockets by removing osseous tissue, recontouring it, or by using a combination of the two procedures.
3. Remove diseased periodontal tissue in order to create conditions favorable for new attachment or readaptation of the soft and/or osseous tissue to the tooth.
4. Correct mucogingival deficiencies and deformities.
5. Establish acceptable gingival contours to aide in effective hygiene.
6. Improve the esthetic appearance of soft tissue in areas of tissue enlargement.
7. Create a favorable environment for necessary restorative dentistry.
8. Establish drainage for gingival or periodontal abscess to turn an acute periodontal problem into a more treatable state.

To date, the rationale for surgery includes access for scaling and root planing and access for restorative procedures, soft tissue biopsy, and periodontal regeneration

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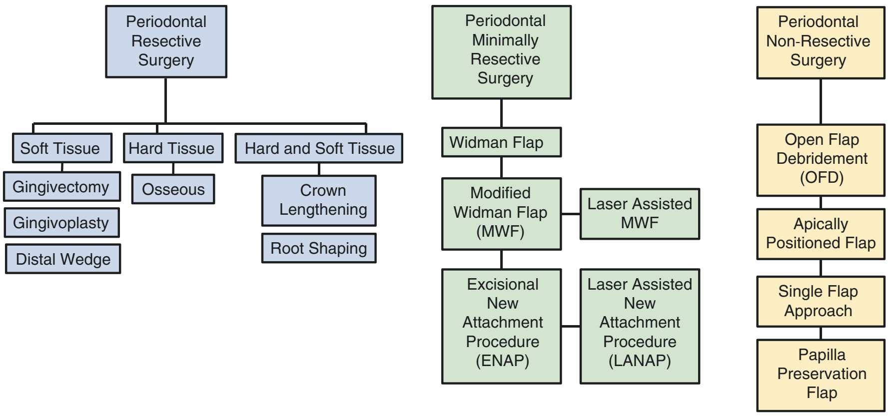

Fig. 3.1 Categories of periodontal surgery

procedures. The goal for this chapter is to exclusively discuss the periodontal flap designs for access and osseous surgery. The objectives described here have been established for several decades, but the techniques have evolved to reflect new knowledge and preferences.

Broadly speaking, periodontal surgery can be divided into resective and non-resective techniques as depicted in Fig. 3.1.

3.1.1 Periodontal Resective Surgery

Soft Tissue

Periodontal resective surgery can be categorized into soft tissue or hard tissue procedures. Soft tissue focused surgeries include gingivectomy, gingivoplasty, and distal wedge procedures.

Gingivectomy

Gingivectomy is among the oldest surgical periodontal procedure documented in the literature. In [2], Kronfeld revitalized and reimagined the original surgical technique described by Robicsek in 1884 in a more conservative manner. For review, Orban [3] described the surgical technique aimed at treating a *pyorrhea pocket* that did not resolve after nonsurgical therapy. By surgically removing the free gingival margin of tissue to the bottom of the gingival pocket, the clinician would physically eliminate the pocket and thus “cure” periodontal disease.

Gingivoplasty

Goldman [4] described gingivoplasty with the intention to reestablish a physiological gingival contour. By creating a bevel margin and festooning into the interdental spaces, the gingivoplasty procedure created a more esthetic and physiologic contour to the soft tissue after these soft tissue resective surgeries. Figure 3.2 shows a case

Fig. 3.2 Patient with amlodipine-induced gingival overgrowth treated with full mouth gingivectomy. Preoperative images of right (**a**), front (**b**), and left (**c**) gingival overgrowth. Notable improvement in gingival contours can be noted 7 months after full mouth gingivectomy (**d**-**f**). Courtesy Dr. Alex Gillone

of gingivectomy and gingivoplasty before treatment and 7 months after completion of surgeries.

Distal Wedge

In [5], Robinson devised a technique to eliminate the periodontal pocket on the distal of maxillary or mandibular second or third molars. The technique was introduced with three options for incision design described as triangular, square, and linear. The anatomy of this area typically presents with an excessive soft tissue volume, which makes plaque control more challenging. Pocket elimination in this area of the mouth will likely result in more favorable long-term periodontal outcomes.

Hard Tissue

Osseous Surgery

The rationale for osseous surgery, alveolar bone recontouring, arose from the need to further assist cases of gingivectomy that did not have satisfactory outcomes [6]. A flap technique that involved access to and reshaping of alveolar bone leading to a more favorable topography (physiologic architecture) would result in shallower pockets that were easier to maintain after surgery. Historically, these resective procedures required significant removal of supporting alveolar bone. When reviewing the longitudinal studies comparing different periodontal therapies, Kaldahl et al. [7] concluded that osseous surgery often resulted in greater short-term reduction of probing depths than surgery without osseous resection. In regard to attachment levels, osseous resection showed no additional gain compared to non-resective flap surgeries. In fact, flap surgeries without osseous resection showed greater short- and

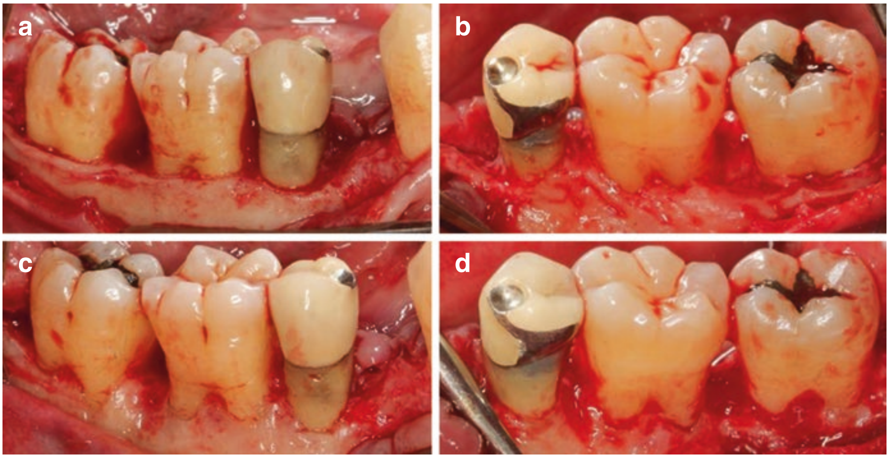

Fig. 3.3 Periodontal patient treated with osseous surgery. (**a**) Facial and (**b**) lingual view after flap reflection. (**c**, **d**) Facial and lingual view after ostectomy and osteoplasty. Courtesy Dr. Acela Martinez

Fig. 3.4 (**a**) Image of right central incisor prior to crown lengthening procedure. (**b**) Immediately after procedure and 14 days postoperatively (**c**), an increase in the clinical crown is noted

long-term gains in attachment. Figure 3.3 documents intra-surgical views of a case before and immediately after ostectomy and osteoplasty.

Soft and Hard Tissue

Crown Lengthening

The intersection of soft and hard tissue resective surgeries is seen in crown lengthening procedures. Utilizing any combination of the surgical techniques described above, crown lengthening surgery aims to gain access to the tooth surface for restorative purposes [8]. This topic is discussed with details in the chapter by Karateew et al., in this volume. Figure 3.4 gives a depiction of a crown lengthening procedure before and after surgery.

Biologic Shaping

One of the main challenges of the profession is to have full access to the furcation area for proper debridement. Biologic shaping, as part of periodontal surgery, has been proposed by Melker and Richardson [9] as a means of addressing furcation-involved teeth (decreasing or eliminating class I and II furcation lesions), root grooves, concavities, and projections of the cemento-enamel junction. The authors proposed that by establishing smooth root surfaces, a more biocompatible anatomy would be present for soft tissue attachment and long-term care. Biologic shaping is discussed in the chapter 4 in this volume.

3.1.2 Periodontal Minimally Resective Surgery

The aim of minimally resective periodontal surgeries is to gain access for thorough debridement while being conservative in the amount of soft or hard tissue removal.

Widman Flap

One of the first techniques described, the Widman Flap, was introduced in 1918. This type of flap included a scalloped gingival incision 1 mm apical to the free gingival margin, a full-thickness flap elevation past the mucogingival junction, curette of the collar of tissue surrounding teeth, planing of root surfaces, minimal resection of bone, and re-approximation of the flaps with interrupted sutures [10, 11]. By attempting to obtain primary closure with an intimate contact between the flap and tooth, the desired outcome of the Widman Flap was to obtain reattachment.

Modified Widman Flap (MWF)

As a modification to the Widman Flap, Ramfjord and Nissle described a new flap design in 1974. The Modified Widman Flap became a more precise surgical technique to eliminate some of the unpredictability of the Widman Flap. As a series of incisions and a minimal flap elevation, the Modified Widman Flap includes an initial incision parallel to the long access of the tooth. The location of this initial incision is dictated by either the buccal or the lingual pocket probing depth. If a pocket is present, deeper than 2 mm, this initial incision is made 0.5–1 mm apical to gingival margin in a scalloped pattern. If the pocket is minimal, a sulcular incision is made. Additionally, the scalloping is exaggerated on the palatal aspect to thin the palatal flap for improved adaptation of the re-approximated tissue. The second incision is made in the sulcus until alveolar bone is contacted with the blade. The last incision is made supracrestal with a narrow interproximal knife perpendicular to the long access of the tooth. Again, the collar of tissue is removed with curettes; the flap is minimally (2–3 mm) reflected to gain access to the tooth surface for scaling and root planing. Finger pressure is applied to the flaps and interrupted sutures are placed.

Laser-Assisted MWF

Current alterations to the Modified Widman Flap include the use of diode laser to aid in the removal of the epithelial lining of pockets and improve clinical outcomes of flap surgery. Treatment protocols include the abovementioned steps of incision and reflection of the Modified Widman Flap. In addition, the application of an 810-nm diode laser to all surfaces of the flap, the exposed bone, and the tooth surface takes place [12]. While this study included only a small sample size over a relatively short follow-up period, they show promising results in decreasing postoperative pain while improving clinical measurements of probing depth and attachment level [13].

Excisional New Attachment Procedure (ENAP)

Approximately, at the same time as the Modified Widman Flap, the excisional new attachment procedure (ENAP) was introduced in 1976 as a “definitive subgingival curettage performed with a knife” [14]. Pockets are marked with an explorer, an internally beveled incision is made from the free gingival margin to the base of the pocket to remove the pocket epithelium, and this tissue is removed with a curette. The fresh connective tissue of the pocket lining is repositioned against the tooth, and digital pressure is applied. Interrupted sutures maintain the flap in place. In order to gain access and improve healing after flap surgery, the ENAP showed improved clinical attachment during long-term follow-up (5 years) [15].

Laser-Assisted New Attachment Procedure (LANAP)

More recent modifications to the ENAP include the application of laser therapy in the laser-assisted new attachment procedure (LANAP). It became popular among periodontists and general dentists over the last two decades as a minimally invasive procedure with favorable outcomes. In a case series, Martin and David [16] demonstrated that a majority of treated sites had clinical improvement after LANAP therapy. To date, there is still limited evidence that laser therapy is a superior technique to other modalities of periodontal treatment [17]. LANAP is discussed in depth in the chapter by Honigman and Sulewski, in this volume.

3.1.3 Periodontal Non-resective Surgery

When treating periodontitis, one of the most conservative ways to access root surfaces, for debridement, is through a simple flap that preserves periodontal structures. For moderate to severe pockets, these procedures facilitate full access and promote superior calculus removal versus nonsurgical (closed) scaling and root planing [18].

Open Flap Debridement (OFD)

In [19], Kirkland published the technique to treat periodontal pockets. Prior to surgery, nonsurgical scaling and root planing and occlusal adjustment were performed as part of the protocol. Procedure-specific curettes were introduced in this publication for use during this flap procedure. After mechanically cleaning the root surface, a chlorinated soda was applied for further debridement. Flaps were then re-approximated and sutured by primary closure and covered with a wax dressing.

The author claimed that this procedure was minimally traumatic resulting in no swelling and no postoperative pain, when compared to minimally resective procedures.

Intrabony Defects

Becker et al. [20] studied the value of open flap debridement. A small group of patients with moderate to severe three-walled intrabony defects were monitored after surgery with a reentry procedure. The authors noticed a 61% bone defect fill and approximately 10% crestal resorption after open flap debridement. This underlines the value of flap access per se, without adding grafting materials (membrane, bone, or biologic agents) for regeneration.

In addition to vertical bony defects, OFD for access to furcation-involved teeth is valuable. In a systematic review and meta-analysis of randomized clinical trials, Graziani et al. [21] concluded that teeth with mandibular class II furcation involvement treated with OFD had significant clinical improvements 6 months after surgery.

Apically Positioned Flap

Building on the surgical techniques described for an open flap debridement, the apically positioned flap was introduced by Friedman in [22] to further reduce pocketing. The author aimed to reposition the attached gingiva more apically after thorough debridement of the root surfaces. By performing vertical incisions and suturing to precisely place the free gingival margin at the level of the alveolar crest, pocket elimination was achieved.

Single-Flap Approach

Trombelli and collaborators published a case series, in [23], where they described a conservative approach called the single-flap approach. This procedure involved the reflection of a buccal flap while preserving the lingual flap. The original technique was aimed at gaining access to the root surface, and over time this procedure was also adopted for use in regeneration procedures.

Papilla Preservation

The papilla preservation technique, introduced by Takei and collaborators in [24], described a very conservative approach of flap design and elevation for primary closure of the wound. The original application of this technique was in regeneration procedures. However, this technique can be utilized for access for debridement without a reconstructive goal. More recent evolutions of this flap design include the simplified papilla preservation, minimally invasive techniques, etc. From an operator point of view, the simplified procedures require limited equipment, fast learning curve, and potentially improved healing. In addition, for the patient these procedures appear to reduce pain, discomfort, and faster resumption of daily activities. For both patient and provider, these procedures minimize chair time and office visits [25]. For in-depth review of flap design for regeneration purposes, please refer to the chapter by Narvekar in this volume.

Regardless of which flap design variation is chosen for non-resective surgery, the benefits of conservative surgery have been notable. In a systematic review by Graziani et al. [26], it was determined that the clinical performance of conservative surgery for the treatment of intrabony defects resulted in high tooth retention and improvement in periodontal clinical parameters.

3.1.4 Smoking and Healing After Periodontal Surgery

As a modifying risk factor for periodontitis, tobacco smoking has major adverse effects on periodontal tissues. Pathologic mechanisms involved with cigarette smoking and impaired healing include reduced neutrophil function, decreased production of IgA and IgG in both saliva and serum, increased presence of select periodontal pathogens, and impaired fibroblast function and proliferation [27].

When treating a periodontitis patient who smokes, clinical outcomes of both nonsurgical and surgical therapy may be hindered compared to non-smokers. It is important for both clinicians and patients to discuss expectations and understand long-term benefits to surgical intervention. While smoking is not a contraindication to surgery, the benefits of periodontal surgery may be reduced.

In a prospective controlled human clinical trial, Bunæs et al. [28] compared treatment outcomes after nonsurgical and surgical periodontal therapy in smokers and non-smokers. Overall, smokers and sites positive for bacterial biofilm showed less improvement from therapy. In particular, probing depths associated with deeper pockets (≥7 mm) and posterior maxillary sites showed the least favorable outcomes, with likely need for additional therapy. In a review by Kotsakis et al. [27], reductions in probing depth and gain in clinical attachment were diminished by 0.4 mm and 0.3 mm, respectively, in smokers.

3.1.5 Oral Hygiene, Periodontal Maintenance, and Compliance

It is well established that bacterial biofilm is a main etiologic factor for periodontal diseases. Control of bacterial biofilm, after periodontal surgery, is critical for the long-term success of these interventions. In fact, longitudinal studies have shown that when comparing different surgical modalities, regardless of the type of surgery, periodontal maintenance was the most important variable for the long-term retention of the dentition. A classical study by Nyman et al., in [29], demonstrated that patients receiving professional plaque control once every 2 weeks exhibited less inflammation, reduced probing depth, and improved gain of attachment, when compared to a control group who was recalled every 6 months only. In a subsequent study by [30], patients treated with periodontal surgery, who did not receive periodontal maintenance, for an average of 5.25 years, demonstrated higher average tooth loss when compared to treated and maintained patients.

When determining the appropriate frequency for periodontal maintenance, after surgery, there is a paucity of randomized, controlled clinical trials to support a predetermined interval. To date, a preestablished 3-month periodontal recall has no robust data to support its implementation. Risk assessment algorithms may provide a more tailored and patient-specific protocol [31].

3.2 Conclusion

Surgical techniques utilized for improved access to scaling and root planing and osseous surgery have evolved and solidified their place as very reliable and predictable for specific clinical situations. These techniques are invaluable for the care of periodontal patients and for the goal to arrest disease progression, achieving long-term periodontal stability.

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4 Biologic Shaping in Periodontal Therapy

Danny Melker, Alan Rosenfeld, and Salvador Nares

4.1 Introduction

Periodontal surgery involves modification of hard and/or soft tissues to achieve a therapeutic goal. These goals include treatment of periodontal defects, including furcation involvement of molars, and crown lengthening procedures to facilitate restoration of a tooth or teeth. Traditionally, resective and regenerative techniques focus on osseous structures with little attention given to modification of tooth surface. Unfortunately, this could lead to excessive removal of the bone and/or creation of an environment that is not cleansable and biologically incompatible. Further, regenerative techniques can yield unpredictable results in furcation lesions thus predisposing molars to further attachment loss. Biologic shaping is intended to create a cleansable, biologically compatible root surface that is manageable by both patients and dentists/hygienists. Here modification of tooth surface is the primary focus with removal of the bone performed only when absolutely necessary to create a biocompatible environment. This chapter will focus on biologic shaping during the course of periodontal therapy.

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4.2 Indications and Rationale for Biologic Shaping

Biologic shaping was first reported by Melker and Richardson in 2001 and described for esthetic dentistry in 2003 [1, 2]. It combines periodontic and restorative phases of dentistry and aims to facilitate home care by patients using simple hygiene aids such as floss and a toothbrush, as well as facilitate professional maintenance by hygienists to remove plaque and calculus. It also creates biologically compatible dimensions necessary for the restoration of a tooth without infringement on biologic width. Further, biologic shaping removes tooth-derived risk factors such as developmental grooves, enamel projections, and concavities. This is particularly important if a developmental groove, concavity, or enamel projection is in close proximity to an existing crown margin resulting in a void or retainment of cement in the groove (Fig. 4.1). This can create an unmanageable situation and increases risk of further attachment loss. Therefore, the ideal therapy will involve modification of tooth structure to eliminate these anatomical discrepancies and create a new restorative margin that is supragingival to the previous margin. The point being that biologic shaping limits the unnecessary removal of bone and creates a biocompatible environment.

Biologic shaping is an alternative to conventional crown lengthening surgery [3–5]. Crown lengthening utilizes the margins of an existing restoration or the cementoenamel junction (CEJ) of a non-restored tooth to gauge the amount of ostectomy necessary to reestablish the biologic width (see Chap. 12 by Karateew et al. in this volume). Creating proper space ensures that a new margin will not impinge upon the attachment apparatus. This creates challenges in the furcation as removal of the bone in this region further compromises the tooth by creating an environment that is not cleansable for both the patient and the hygienist (Fig. 4.2). Thus, it is critical to preserve as much bone in the furcation area as possible. Therefore, rather than removing the bone away from the planned restorative margin, biologic shaping moves the restorative margin away from the bone, minimizing the amount by

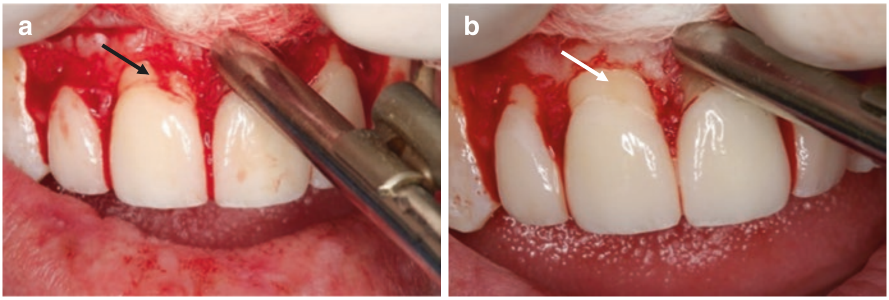

Fig. 4.1 Removal of developmental groove. (**a**) Developmental groove present on the right central incisor illustrating the problem when a margin finishes in a developmental groove (black arrow). There is a lack of adequate seal, and bonding material is located in the groove causing severe inflammation. (**b**) Removal of the developmental groove to allow for maintenance of the area (white arrow)

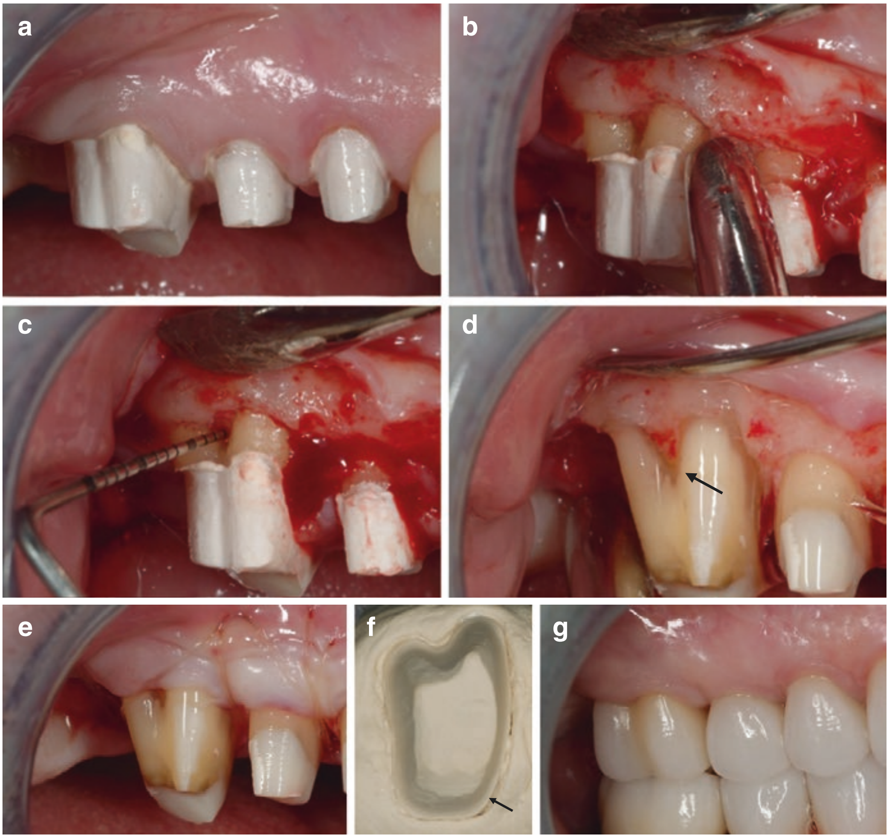

Fig. 4.2 This patient was referred for correction of biologic width invasion. Prior treatment involved removal of existing restorations and decay and placement of cores and provisionals. (**a**) Provisionals removed. Note Durelon cement still present on the teeth. Antimicrobial effects of this cement are protective. (**b**) Reflection of a full thickness flap followed by a partial thickness dissection apical to the mucogingival junction. (**c**) Of critical importance is the location of the existing margin approximating the furcation. In essence there is no space for the biologic width. (**d**) After biologic shaping 100% of the tooth structure is perfectly smooth from the bone to the occlusal surfaces. Note that there is absolutely no margin present after biologic shaping. Critical is the actual location of the bone in the furcation. Removal of furcation results in coronal movement of the bone (arrow). No matter how much bone is removed, space for the biologic width cannot be achieved. By removing the previous margin and allowing a new biologic width to establish, the new margin can be placed coronal to the gingival collar. (**e**) The flap is sutured with 5–0 chromic gut just coronal to the bone. Primary closure helps to decrease postoperative discomfort. (**f**) The day of impressions. A chamfer margin is placed with a 0.3 mm thickness and placed just coronal to the gingival collar (arrow). Note the large amount of tooth structure remaining. (**g**) Final restorations cemented. All margins are supragingival. The furcation on #3 is perfectly contoured to follow the shape of the underlying tooth structure. The barreling in of the furcation is extended to the occlusal surface. The material for these restorations is Feldspathic porcelain. This case has now passed the 15-year period of stability and function. Restorations by Dr. William Strupp Jr

which the crown must be lengthened to establish biologic width. Table 4.1 lists the rationale for biologic shaping.

When treating combined periodontal and restorative cases, the periodontist must facilitate creation of a final margin (supragingival or just into the sulcus), improve tissue health to facilitate an accurate impression, and provide an abundance of dense connective tissue for augmentation of keratinized gingiva to protect the underlying periodontal support (Fig. 4.3). The dense connective tissue is essential for taking accurate impressions and cementing final restorations as there is greater probability

Table 4.1 Rationale for biologic shaping [5]

1.	Replacing or supplementing the current indications for clinical crown lengthening
2.	Minimizing osteotomy
3.	Facilitating supragingival or just slightly intrasulcular margins (when there is a dark substructure) to preserve the biologic width
4.	Eliminating developmental margins
5.	Eliminating previous subgingival restorative margins
6.	Reducing or eliminating furcation anatomy, thus facilitating margin placement
7.	Allowing supragingival or intrasulcular impression techniques
8.	Removing all CEJs

Fig. 4.3 (**a**) Case with three teeth requiring new restorations with chronic inflammation present on the first premolar (white arrow). (**b**) Restorations removed and decay excavated. (**c**) Core buildup (DenMat (Lompoc, CA, USA) enamel shade core paste) adds restorative volume to the teeth and helps determine placement of the final restorative margins. Connective tissue graft in place on the first premolar (black arrow). (**d**) Final restorations fabricated with Feldspathic porcelain with margins placed supragingival. Healing of the connective tissue graft provides a thick band of keratinized tissue an elimination of the chronic inflammation (arrow). Note that the new crown margin on the first premolar is now supragingival to the previous crown margin. The case is now in function for 11 years. Restorations by Dr. William Strupp Jr

of chronic inflammation if the restorative margin approximates mucosa [4]. This is discussed in greater detail in the Chaps. 9 and 10 and by Zadeh et al. and Chambrone et al., in this volume. For esthetic surgical procedures, the periodontist must provide ideal clinical anterior crown length to aid the restorative dentist in providing the highest level of esthetic treatment. The periodontist also must make every attempt to avoid black triangles as a result of periodontal surgery and support the restorative dentist by motivating patients to accept the comprehensive treatment plan.

4.3 Clinical Prerequisites and Steps

Successful treatment requires a team approach and a thorough understanding of macro- and microanatomy, biology, and restorative materials. Incumbent upon the laboratory technician is to fabricate a restoration that follows the newly created tooth contours, otherwise a plaque and food trap will be created increasing the risks of further periodontal breakdown. When executed correctly, biologic shaping can provide patients with successful long-term outcomes. Clinical prerequisites and steps for success have been previously published and are summarized below [3, 5]:

1. All previous restorative materials and decay should be removed.
2. A core buildup of composite-bonded resin should be placed where necessary to add volume to the teeth. The core helps determine the placement of the final restorative margin.
3. Acrylic provisionals should be placed with Durelon (3M™, ESPE™; St. Paul, Minnesota, USA) as the temporary cement. This cement is recommended for its antimicrobial properties and ability to help decrease sensitivity.
4. Removal of provisional restorations at time of surgery to allow for better access.
5. Inverse bevel incisions and removal of a collar of gingival tissue. Otherwise, sulcular incisions without the removal of gingival collar if <2 mm of attached keratinized tissue is present. Split-thickness flap reflection permits visualization of the core/tooth relationship to the bone.
6. Shape root and remove old margins as well as 360° of CEJs. Reduce or eliminate cervical enamel projections, concavities, developmental grooves, flutes, etc. facilitate ideal restorative emergence profile (flat is better than fat contours). Diamond burs are recommended for this process.
7. Correction of any reverse architecture and removal of the bone where violation of the biologic width will be anticipated.
8. If insufficient keratinized attached connective tissue is present at the surgical site, perform soft tissue augmentation to create a thicker gingival biotype and increase the zone of keratinized tissue to resist restorative procedures and minimize the probability of chronic inflammation that can result when a restorative margin resides on mucosa [4].
9. Once the flaps are adapted, potassium oxalate should be used to help decrease postsurgical sensitivity. The liquid is applied to the root surface for 45–60 s and then lightly air-dried. Repeat 2–3 times.
10. Cement provisional prosthesis with a polycarboxylate cement such as Tylok (Dentsply International: York, Pennsylvania, USA) or Durelon.

11. Home care instructions include rinsing with chlorhexidine twice daily (morning and evening) and brushing with Prevident toothpaste (Colgate-Palmolive, New York, New York, USA) at bedtime. After meals the patient rinses with water or Listerine (Johnson and Johnson, New Brunswick, New Jersey, USA) to remove food particles.
12. At 4 weeks, the provisionals are either remade or relined leaving 1 mm of space between the provisional margin and tissue for continued biologic width growth in a coronal direction. No margination of the tooth surface is undertaken at this time.
13. At 14 weeks, chamfer margins are placed just coronal to the gingival collar and impressions taken. When a dark substructure is present in the anterior, margin placement may be necessary in the sulcus to avoid cosmetic issues. The new crown contours must follow the prepared tooth surface in the final impression. It is imperative that the lab fully understand furcation removal and the need for the new restoration(s) to follow such contours.
14. The patient is instructed on measures to facilitate hygiene and maintenance procedures initiated.

4.4 Case Examples

This protocol is applicable to any tooth slated for treatment. The cases below will provide examples of biologic shaping of teeth.

4.4.1 Case 1

Figure 4.4. (a) Preoperative image of the maxillary left quadrant. Due to occlusal issues and temporomandibular disease, the treatment plan included provisionalization of all maxillary teeth to correct occlusal concerns. (b) Provisionals and residual cement removed. (c) Incisions were made using a #15 scalpel blade and full thickness flap elevated to avoid flap perforation due to an underlying exostosis. Once the flap was reflected beyond the exostosis, a split-thickness flap was initiated to allow suturing of the flap to the periosteum upon closure. An internal bevel incision was used to elevate the lingual flap. It is critical that the buccal and lingual flap incisions preserve as much of the papillary tissue as possible to allow for primary closure of the flaps. All granulation tissue or remaining tissue from reflection of the flap was removed with a #4 Goldman-Fox curette. Note the presence of a mesial concavity and residual calculus on the first premolar (arrow). (d) A coarse diamond bur (c847–016, Axis Dental Co., Coppell, TX, USA) is used to remove all irregularities on the root surface including CEJs, concavities, developmental grooves, and the lip of furcations. (e) This is followed by preparation using a superfine bur (f847–016, Axis Dental Co., Coppell, TX, USA) to smooth the root surfaces to a polished finish. (f, g) To complete the procedure, a diamond round bur #4 is used to contour the bone to create a parabolic architecture. If there are any areas where biologic

Fig. 4.4 Biologic shaping of multiple teeth in quadrant eliminates mesial concavity of first premolar and creates a biocompatible environment and fabrication of full-coverage restorations that do not violate biologic width. Occlusion was a factor and therefore all teeth are needed to be restored. Final restorations by Dr. Howard Chasolen. The case is over 5 years old. See text for details

width space is still needed, minor ostectomy is performed to create such a space. Complete furcation removal is confirmed when a periodontal probe is placed at the level of the bone in the furcation and moves freely without catching any undercuts coronal to the furcation. (h, i) A Castro-Viejo is used to suture 5–0 chromic gut material through the flap into the periosteum starting from the distal aspect of the second molar from buccal to lingual. A knot can be used to begin the continuous suture technique. Because the suture passes through the periosteum when the suture is pulled to tie the knot, the flap lays just coronal to the bone creating primary coverage. The suture is continually passed from buccal to lingual interproximally from the distal to the mesial of the canine, and the suture is tied. The entire flap should lay tight against the bone and just coronal to the bone to create primary closure. There is no need for any pak as the flap will not move. See Supplementary Figures for suturing technique. (j, k) E-Max restorations with full-coverage gold on the second molar. This case is over 5 years old. Final restorations by Dr. Howard Chasolen

4.4.2 Case 2

Figure 4.5. (a, b) Upon removal of provisional restorations, a mesial concavity and calculus can be observed on the first premolar. For the patient and hygienist, this creates a non-cleanable environment that is at risk for continued periodontal breakdown. (c, d) Removal of the provisional restoration provides unimpeded vertical and visual access for the periodontist. Elimination of the concavity facilitates plaque removal for the patient and hygienist. Because the concavity is interproximal, it is critical that it not be accentuated as with buccal or lingual furcations. Rather, removal or blending of the line angles approximating the furcation should take place. The objective is to remove or flatten the concavity so floss and a hygienist's curette will achieve removal of plaque and calculus. (e) Minor ostectomy with a round diamond bur to create a parabolic bony anatomy. (f) Continuous suture provides primary closure (see supplementary figures for suturing technique). (g) At 14 weeks, a new restoration can be fabricated resulting in a biocompatible environment. Thereafter, the patient is placed on alternating 3-month recall with the restorative dentist.

Fig. 4.5 Mesial concavity and calculus present on the first premolar. Biologic shaping eliminates the concavity and facilitates hygiene measures. Restorations by Dr. William Strupp Jr. See text for details (Reprinted with permission from General Dentistry, July/August 2012. © Academy of General Dentistry. All rights reserved. On the Web at www.agd.org. License # 54836)

4.4.3 Case 3

Figure 4.6. (a, b) The provisionals and any remaining cement were removed. Note the minimal tooth structure remaining on the first molar and location of cord in the furcation area (white arrows). (c) Incisions were made using a #15 scalpel blade and split-thickness flap elevated past the mucogingival junction. On the lingual an internal bevel incision was used to elevate the lingual flap. As stated above, it is critical

Fig. 4.6 Example of multiple teeth requiring crown lengthening and long-term follow-up of the case using biologic shaping. Conventional crown lengthening surgery will further open the furcation area creating a non-cleanable area for patient and hygienist. Porcelain fused to metal restorations fabricated by Dr. Howard Chasolen. See text for details

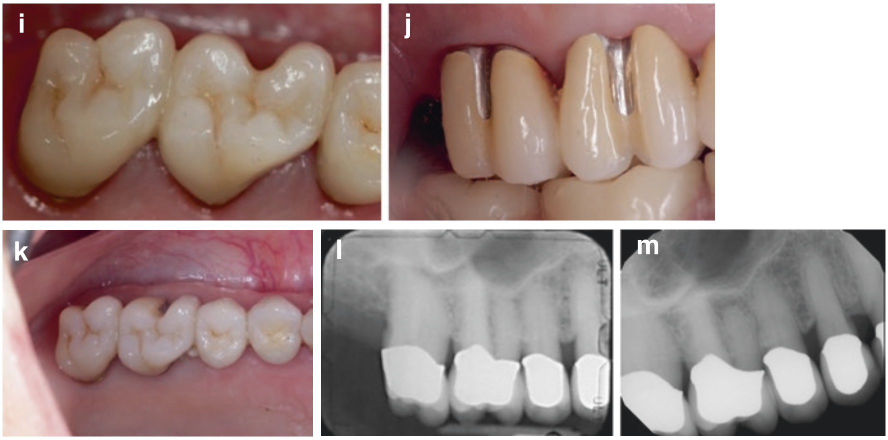

Fig. 4.6 (continued)

for both the buccal and lingual flap incisions that as much of the papillas be kept to allow for primary closure to occur when the flaps are sutured after all necessary surgical procedures. Note the presence of existing margin in furcation space (black arrow). Restoration of this tooth would require placement of a new margin in the furcation area. (d) Biologic shaping procedures performed as per Case 1. (e, f) Final preps with thin chamfer margins finished at the tissue level 4 months postsurgery. Tissue retraction with only one cord: #7 Sil Trax Epi (Pascal International Inc., Bellevue, WA, USA) soaked in Hemodent (Premier Dental, Plymouth Meeting, PA, USA) immediately rinsed after gentle placement so as not to damage connective tissue fibers in the biologic width. (g–i) Restorations cemented in place. (j, k) Clinical images taken at a 10-year follow-up. (l, m) Radiographs demonstrating conservative nature of biologic shaping. Over a 10-year period, it is noted that endodontic therapy was not needed on any tooth. Unless endodontic treatment is needed prior to biologic shaping, very rarely was endodontics needed after treatment. (l) First radiograph October 2005. (m) Second radiograph January 2018. Patient is now 84 years old. Restorative work by Dr. Howard Chasolen.

4.5 Biologic Shaping of Molars

As stated above, furcation lesions present unique challenges for both the periodontist and restorative dentist. When treating molars with periodontal-restorative needs, alternative approaches to conventional crown lengthening procedures should be considered when furcation involvement is present due to the potential for biologic width/supracrestal fiber invasion and further opening of the furcation. This is due to the fact that the bone in the furcation usually moves coronally as one tries to crown lengthen in the furcation area. This makes it virtually impossible to create

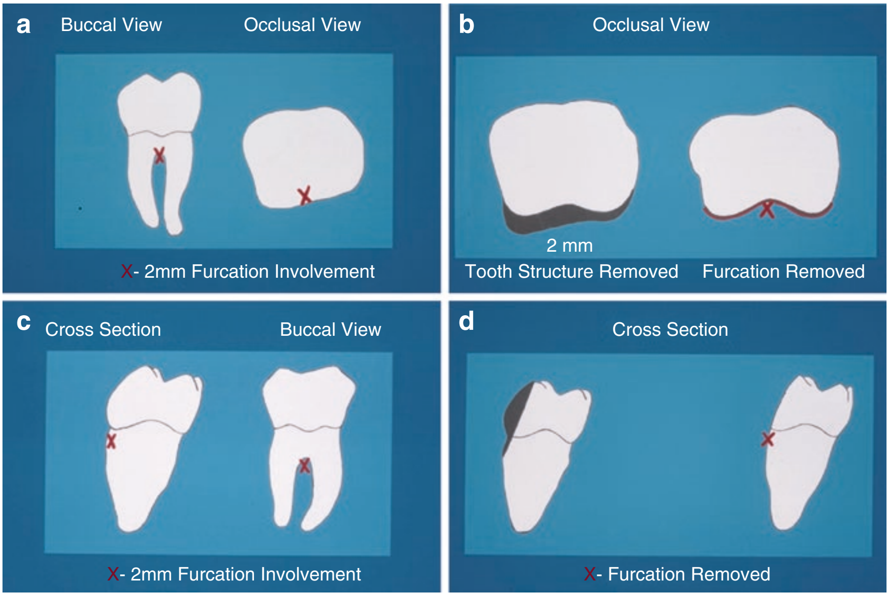

Fig. 4.7 (**a**) When looking at the images, the letter x is used to indicate the location of the furcation from the buccal and occlusal view. (**b**) The shaded areas indicate exactly where tooth structure should be removed. It is always important to remove tooth structure adjacent to the furcation to avoid creating a deep groove that cannot be cleaned. The x on the second photograph indicates that the furcation is no longer present as is located outside of the tooth structure. (**c**) Images indicate the location of the furcation from a cross-sectional view. (**d**) The shaded area indicates where the necessary tooth structure needs to be removed so that the furcation will be in fact eliminated. One should notice that no height of contour is now present and should be kept that way in the final restoration. Again notice in the photograph on the right the x location is now on the outside of the tooth surface and is thus eliminated. The barreled-in furcation must be continued to the occlusal surface to avoid creating a not cleanable area

a space for the biologic width without destroying the furcation bone and considerably compromising the tooth. Therefore, rather than removing the bone, begin by removing the restorative margin or CEJ, and shape the tooth structures surrounding the furcation (Fig. 4.7). Once this is accomplished, it will be easier to determine if ostectomy is required. Importantly, this approach is applicable to teeth with either shallow or deep furcations and is particularly advantageous in teeth that require full-coverage restoration. When properly performed, the furcation defect will be eliminated. As stated above, this is confirmed when a periodontal probe is placed at the level of the bone in the furcation and moves freely without catching any undercuts coronally for the furcation (Fig. 4.2). Once restored, hygiene measures will be facilitated for the patient and hygienist. The following cases are presented below to illustrate the benefits of biologic shaping of molars. Additional discussion on treatment options for furcations is discussed in the Chap. 8 by Martinez and Gholami in this volume.

4.5.1 Case 4

Figure 4.8. (a) Example case of multiple teeth requiring crown lengthening. Exiting restorative margins approximating the crest of the bone on the premolars and furcation entrance on the first molar (black arrows). There are concerns with trying to perform crown lengthening in the furcation to create a space for the biologic width. As one tries to remove the bone in the furcation, the bone actually moves coronally as the surgeon tries to crown lengthen making it virtually impossible to create a space for the biologic width. By simply removing the old margin, there is no mechanical location from which the bone has to be removed, thus creating a space for the biologic width. (b) Example of this phenomenon after the lip of the margin is removed in the furcation area. The bone of the furcation is located coronally to adjacent bone (white arrow). (c) Biologic shaping of both teeth creates necessary space for the biologic width and facilitates fabrication of restorations that are cleansable for both patient and hygienist. The material is porcelain fused to gold and the margins are supragingival. Restorative work by Dr. Ira Berger

4.5.2 Case 5

Figure 4.9. (a) Upon flap reflection, the margin on the mesial aspect of the first molar can be noted approximating the bone (white arrow) indicating that crown

Fig. 4.8 Biologic shaping of premolars and molars in quadrant. Biologic shaping of molar and fabrication of full-coverage restoration mimicking the new tooth contours removes the furcation lesion and facilitates long-term maintenance of periodontal health. Restorations by Dr. Ira Berger. See text for details

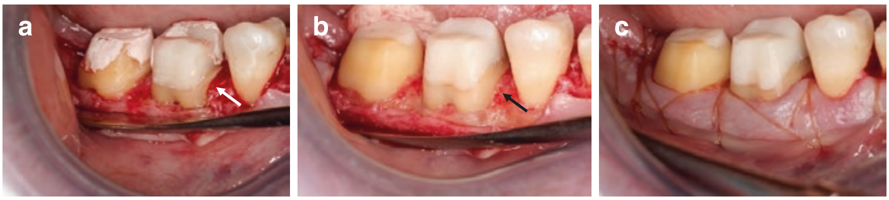

Fig. 4.9 Minor osseous recontouring combined with biologic shaping creates a cleansable environment and restorative margins that do not impinge upon the biologic width or furcation. See text for details. Core and provisional placed by Dr. William Strupp Jr. See text for details

lengthening is required to establish the biologic width. Conventional crown lengthening surgery guided by the existing restorative margin will result in excessive removal of interproximal bone as well as the bone along the buccal and lingual roots to create a parabolic architecture necessary to avoid future periodontal breakdown. (b) Biologic shaping removes the existing margin negating the need to aggressively recontour the bone. Once accomplished, minor osseous contouring when required creates space for the biologic width and creates a parabolic architecture for bone and soft tissue continuity (black arrow). (c) Careful incision design and continuous suturing technique provide complete flap closure. Note supragingival location of core buildup/tooth interface. Core and provisional placed by Dr. William Strupp Jr.

4.5.3 Case 6

Figure 4.10. (a) Old crowns with severe microleakage resulting in caries. Endodontics was required due to pulpal necrosis on the first molar. (b) Caries removed, as much as

Fig. 4.10 Comprehensive team approach demonstrates how hopeless teeth can be treated and retained long term. Case is over 10 years old. Restorations by Dr. William Strupp Jr. See text for details

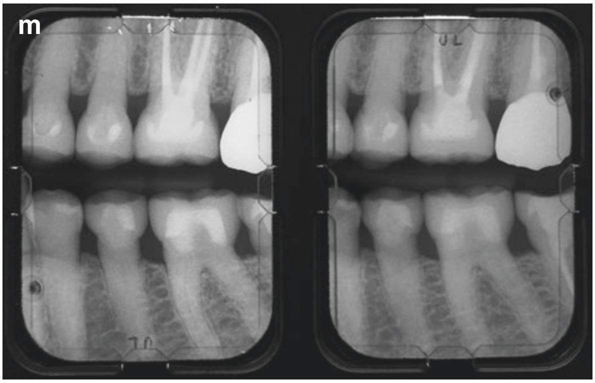

Fig. 4.10 (continued)

possible. Non-antimicrobial coronal endodontic seal placed by the endodontist. (c) Minimal tooth structure left with significant demineralized chalky dentin left after removing as much caries as possible without pulp exposure. (d, e) Core buildups with feather edge preps carrying margins to sound tooth structure. (f) Due to a thick buccal plate, a full thickness flap was elevated to avoid perforation of the flap. Once the flap was elevated past the mucogingival junction, a split-thickness flap was initiated. (g) Biologic shaping has been performed, and at this point, there is absolutely no margins remaining on any teeth. All concavities, furcations, or surface irregularities have been removed. Osseous contouring has taken place to create a parabolic architecture. It can be noted that the periosteum is still intact on the bone which will be used to suture the flap. (h) Continuous suturing to the periosteum allowing flap positioning just coronal to the bone. (i) Occlusal view showing primary closure of the flap. The occlusal view also demonstrates how biologic shaping has created smooth root surfaces to the flap position. From previous photos the smoothness ends at the level of the bone. It can also be noted that the furcations have been removed to the occlusal surfaces. (j, k) Final preps with thin chamfer margins finished at the tissue level 4 months postsurgery. Tissue retraction with only one cord as described in Case 3. Restorations fabricated using Feldspathic porcelain with gold on the second molar. (l, m) Ten-year follow-up clinical image and radiographs. It should be noted that all endodontics was completed prior to periodontal treatment because of pulpal involvement and lack of tooth structure above the tissue. After 10 years no further endodontics was undertaken. Restorations by Dr. William Strupp Jr.

4.6 Considerations When Performing Biologic Shaping

It is imperative that the patient understand and accept the need for full-coverage restoration of teeth due to the modification of existing tooth structure to facilitate hygiene. Further, when treating a concavity on any tooth interproximally, it is important not to accentuate the concavity but to blend the line angles so that the concavity is removed. Blend the line angles adjacent to the furcation to remove the concavity and as best as possible create a convexity to allow for maintenance

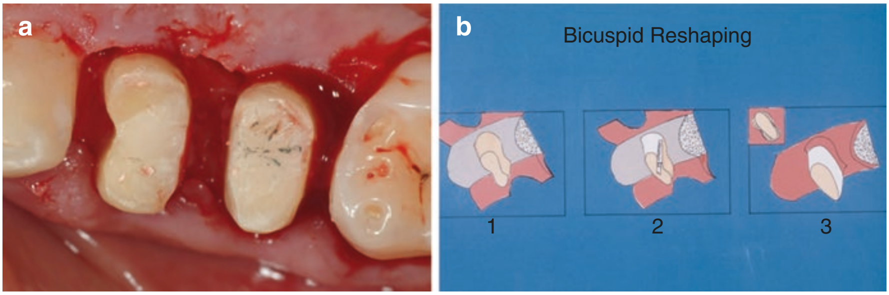

Fig. 4.11 Example of incorrect biologic shaping of a mesial concavity on a premolar. (**a**) Instead of removing the line angles to blend away the concavity, the concavity was accentuated. The situation results in a virtually impossible area for floss or a hygienist's curette to effectively remove plaque or calculus. (**b**) To prevent accentuating the concavity interproximally, do not barrel into the concavity or furcation. Rather, blend the line angles, and as best as possible create a convexity to allow for maintenance

(Fig. 4.11). By removing the line angles, the patient will be able to use dental floss, and the hygienist's curette will be effective in removing plaque and calculus. If root sensitivity is present after biologic shaping, it should be managed by topical application of agents to seal dentinal tubules. It should also be realized that biologic shaping is not indicated for Class III furcation involvement. Finally, molars with Class I and II furcations are at minimal risk of pulpal exposure when biologic shaping is properly performed.

4.7 Conclusion

Biologic shaping conserves the bone while establishing biologic width necessary for restoration of teeth. It facilitates hygiene measures by both patient and dentist/hygienist and creates a biocompatible environment required for long-term success. However, incorporating biologic shaping into practice requires a team approach with a thorough understanding of the rationale, anatomy, surgical and restorative procedures, materials, and final restorative contours to be achieved. When properly done, biologic shaping can improve the short- and long-term prognosis of teeth.

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Lasers in Periodontal Surgery

5

Allen S. Honigman and John Sulewski

5.1 Introduction

The term laser, which stands for **l**ight **a**mplification by **s**timulation of **e**mitted **r**adiation, refers to the production of a coherent form of light, usually of a single wavelength. In dentistry, clinical lasers emit either visible or infrared light energy (nonionizing forms of radiation) for surgical, photobiomodulatory, and diagnostic purposes.

Investigations into the possible intraoral uses of lasers began in the 1960s, not long after the first laser was developed by American physicist Theodore H. Maiman in 1960 [1]. Reports of clinical applications in periodontology and oral surgery became evident in the 1980s and 1990s. Since then, the use of lasers in dental practice has become increasingly widespread.

5.2 Laser-Tissue Interactions

The primary laser-tissue interaction in soft tissue surgery is thermal, whereby the laser light energy is converted to heat. This occurs either when the target tissue itself directly absorbs the laser energy or when heat is conducted to the tissue from contact with a hot fiber tip that has been heated by laser energy. Laser photothermal reactions in soft tissue include incision, excision, vaporization, ablation, hemostasis, and coagulation. Table 5.1 summarizes the effects of temperature on soft tissue.

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Table 5.1 Effects of temperature on soft tissue [2, 3]

Temperature	Visual change	Biological change
37–60 °C	No visual change	Warming
60–65 °C	Blanching	Coagulation, hemostasis
65–90 °C	White/gray	Protein denaturation
90–100 °C	Puckering	Drying, tissue desiccation
100 °C	Smoke plume	Vaporization

Another type of laser-tissue interaction relevant to the use of lasers in periodontal surgery is nonthermal, whereby visible or infrared laser energy is used at lower power (subablative) levels to elicit photophysical and photochemical events that produce beneficial therapeutic outcomes. Such photobiomodulation outcomes may include alleviation of pain or inflammation and promotion of wound healing and tissue regeneration [4].

Laser energy may be absorbed, reflected, or scattered. However, it is only when the laser is absorbed by the substrate that useful interactions occur. Absorption of the laser energy by the target tissue is dependent on the laser wavelength, tissue composition, pigmentation, and water content.

5.3 Types of Lasers

The commonly used surgical lasers in the dental profession range from 445 to 10,600 nm in wavelength and can be classified based on the types of tissue with which they interact:

5.3.1 Hard Tissue Lasers

Erbium lasers (2780-nm Er,Cr:YSGG and 2940-nm Er:YAG) are well absorbed by water and hydroxyapatite and are mainly used for cutting tooth structure and bone. They can also be used for soft tissue procedures. However, due to their absorption characteristics, they have shallow penetration into soft tissue and provide limited hemostasis.

5.3.2 Soft Tissue Lasers

9250-nm and 10,600-nm carbon dioxide (CO_2) lasers are well absorbed by hydroxyapatite and water. They are used mostly for soft tissue surgery. Like the erbium lasers, they have relatively shallow penetration and provide reasonable hemostasis. The 10,600-nm laser is contraindicated for use on teeth and bone, whereas the 9250-nm laser can be used for cavity preparation and bone modification.

Diode lasers (445, 450, 457, 808, 810, 940, 970, 980, 1064 nm) are absorbed by melanin and hemoglobin and are most commonly used in the general dental office for soft tissue surgery via the aforementioned hot tip methodology. These wavelengths penetrate soft tissue more deeply than the erbium and CO_2 lasers and provide excellent hemostasis. Diode lasers are contraindicated for use on bone.

The Nd:YAG laser (1064 nm) is absorbed by melanin and hemoglobin and, like the diode lasers, has a deeper penetration into soft tissue and provides excellent hemostasis. The use on osseous tissue is contraindicated. The tissue absorption and pulsing characteristics of the Nd:YAG laser make it an effective instrument for treatment of moderate-to-severe periodontal disease.

5.4 Lasers in Periodontal Surgery

Collectively, the erbium, CO_2, diode, and Nd:YAG lasers enable a variety of soft tissue surgical procedures, including gingivectomy [5–7], reduction of gingival hyperplasia [8–11], frenectomy [12–16], operculectomy [17], vestibuloplasty [18, 19], free gingival graft [20–22], second-stage recovery of implants [23–25], incisional and excisional biopsy [26, 27], and fibroma removal [28, 29].

Photobiomodulation studies using various laser wavelengths have demonstrated their ability to promote conditions conducive to wound healing in gingivectomy and gingival graft sites and in the management of periodontal disease [30–37].

Compared to conventional treatment modalities, some of the advantages of the use of lasers in periodontal surgery include control of surgical and postsurgical bleeding, reduced bacteria in the surgical field, reduced need for anesthesia in some cases, reduced need for sutures, reduced or eliminated wound contraction and scarring, decreased postoperative edema and discomfort, and high patient acceptance and preference [26, 38, 39].

Limitations of laser use in dentistry include the relatively high cost of the instruments, the requirement of specialized training, and the strict adherence to safety precautions such as the need to protect nontarget tissues from laser exposure and the need for patients and operatory personnel to wear protective laser-specific eyewear. Optimum clinical results are achieved when proper technique and laser parameters are used, in accordance with manufacturer's directions and specified treatment protocols.

5.5 Lasers in Periodontal Treatment

The use of lasers for the treatment of periodontal disease has a lengthy history, with some reports dating from the early 1990s.

Reports of the use of erbium lasers to treat periodontal pockets began to appear in 2001, some 4 years after commercial availability in clinical dentistry. Manufacturers of erbium lasers have tried to develop protocols to treat periodontal disease but have only anecdotal reports and no human histological evidence to back up claims of regeneration. Some practitioners use erbium lasers to remove or contour osseous tissues after a flap is made. These devices can also remove calculus, but because they cannot differentiate calculus from dentin and cementum, or determine where the calculus ends and the tooth surface begins, their use in calculus removal can lead to undesirable ditching of the root surface [40, 41].

Carbon dioxide lasers are not amenable to treating periodontal disease as they have no selectivity in removing diseased tissue and can heat the bone and teeth which is not desired in the treatment of periodontal disease. Anecdotal reports of their use within the periodontal pocket exist, but their rigid delivery system tips do not readily lend themselves to accessing the full depth of the pocket without first laying a flap. In 1995, Israel et al. investigated whether de-epithelialization with a CO_2 laser at the time of flap surgery would enhance the formation of connective tissue attachment. Indeed, a 90-day postoperative assessment showed positive results in one of the two patients treated [42].

A popular use of diode lasers is sulcular debridement and bacterial reduction within the periodontal pocket, performed either by dentists or dental hygienists. The first reports of such procedures were published in 1997, 1 year after diode lasers were introduced in dentistry. Effectiveness of treatment varies, and some studies have shown that scaling and root planing (SRP) with diode laser use shows no greater benefit than SRP alone [43–47]. Human histological studies of new attachment or regeneration have not yet appeared in the literature.

The Nd:YAG laser has the longest history in periodontal pocket therapy and treating periodontitis, dating from 1991, 1 year after introduction of this laser device in clinical dentistry [5, 48, 49]. Its flexible fiber-optic delivery system facilitates minimally invasive access within periodontal pockets (Fig. 5.1). In 1994, Gold and Vilardi showed that the use of a pulsed Nd:YAG laser inside a periodontal pocket will specifically remove the diseased tissue and leave intact rete ridges to facilitate new attachment of the gingiva to the root surface [50].

Subsequent human histological investigations using one particular Nd:YAG laser (PerioLase MVP-7, Millennium Dental Technologies, Cerritos, Calif., USA) in a well-defined clinical protocol established the ability of this protocol to achieve

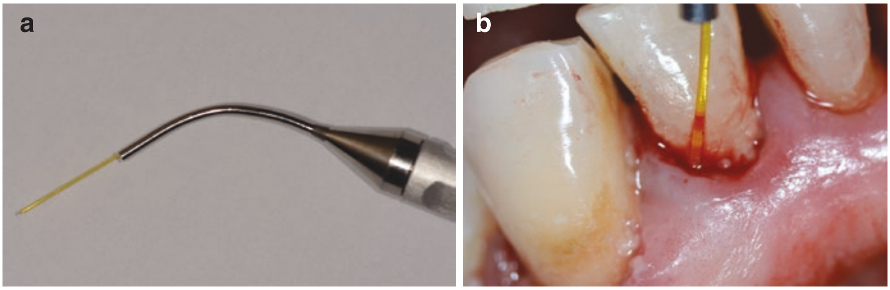

Fig. 5.1 Flexible optical fiber can be extended several millimeters past the end of the bendable cannula tip, which allows for delivery of pulsed Nd:YAG laser energy to difficult-to-access areas, such as the distal of second molars (**a**). Example of the optical fiber placed within a periodontal pocket during the LANAP protocol, removing the diseased, inflamed epithelium without removing outer gingival epithelium (**b**)

periodontal regeneration in patients presenting with moderate-to-severe periodontal disease. Based on independent studies conducted by Yukna et al. [51] and Nevins et al. [52], in March 2016, the US Food and Drug Administration granted marketing clearance to the PerioLase Nd:YAG laser for true regeneration of the attachment apparatus (new cementum, new periodontal ligament, and new alveolar bone) on a previously diseased root surface when used specifically in the LANAP® protocol.

The full-mouth LANAP procedure (Figs. 5.2 and 5.3) involves using a digitally pulsed Nd:YAG laser to remove diseased epithelium from the periodontal pocket, leaving the rete ridges intact, and reduce pathogens within the periodontal pocket. Scaling and root planing (SRP) is then performed with a piezo scaler. Osseous modification/decortication is performed to induce bleeding and release stem cells and

Fig. 5.2 Clinical application of a digitally pulsed Nd:YAG laser for periodontitis treatment. The patient was 79-year-old female who was seen for treatment of localized advanced periodontitis. Probings on the maxillary right central incisor showed severe pocketing with bleeding on probing (BOP) and suppuration (**a**). The X-ray showed vertical bone loss (**b**). Localized laser-assisted periodontal treatment (LAPT) was performed on both maxillary central incisors along with a maxillary anterior frenectomy. The frenectomy was performed due to the tension from the frenum on the interproximal tissue, which may have interfered with proper healing. After treatment she was put on 3-month periodontal maintenance. A 12.75-month post-LAPT treatment view showed decrease in pocket depths to maintainable levels, no BOP, and with minimal impact on esthetics (**c**). A follow-up X-ray showed regeneration in the vertical defect and a functional lamina dura (**d**)

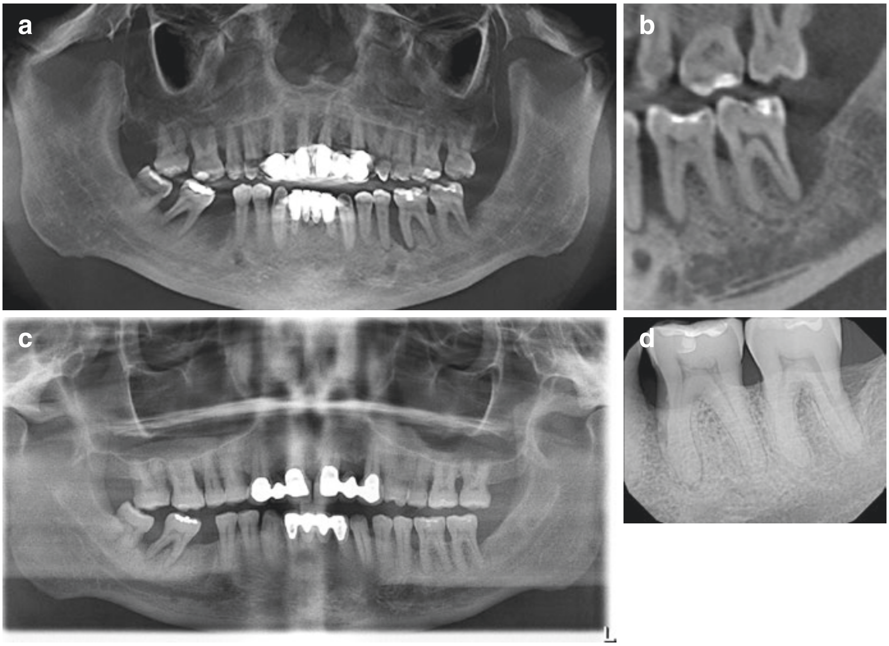

Fig. 5.3 Clinical application of digitally pulsed Nd:YAG laser for periodontitis treatment. The patient was 41-year-old male who was seen for treatment of advanced periodontitis (**a** and **b**). Probing showed generalized non-maintainable pockets. The pretreatment radiograph showed vertical bone loss and horizontal bone loss. The LANAP procedure was performed. After treatment he was put on a 3-month periodontal maintenance schedule. The 70-month post-LANAP treatment view showed no loss of any dentition. The 8.4-year follow-up showed long-term bone regeneration stability (**c** and **d**)

growth factors. The Nd:YAG is then used for hemostasis, to establish a stable fibrin clot, activate growth factors, and upregulate gene expression. The Nd:YAG laser-induced hemostasis allows patients on anticoagulants to be treated without taking them off their medications. Occlusal adjustment, essential in any regenerative procedures, is performed at the time of surgery (Fig. 5.4) and throughout periodontal maintenance during the first year post-LANAP treatment.

A study by McCawley et al., which compared periodontal bacteria reduction before and immediately after LANAP treatment and ultrasonic debridement, demonstrated that 85% of the LANAP-treated sites showed 100% reduction in the periodontal bacteria. Meanwhile, 83.3% of patients treated with ultrasonic root debridement alone remained culture-positive for most of the periodontal bacteria. Decreasing the putative periodontal bacteria is essential in the treatment of periodontitis [53].

The advantages of the LANAP protocol over conventional treatment include:

- Decrease in recession, so esthetic areas can be treated.
- Decrease in patient postoperative discomfort and sensitivity.

Fig. 5.4 Example of fibrin/thermogenic clot produced during the hemostasis part of the LANAP protocol. White powder (porcelain crown particles) shown is from the occlusal adjustment portion to decrease occlusal trauma to aid in healing and regeneration. Occlusal adjustment is performed with diamond football bur on a high-speed handpiece with no water

- Ability to treat the periodontal disease not only mechanically but at the bacterial level.
- Bone regeneration is possible without additional materials or cost to the patient or practitioner.
- Patients on blood thinners can still be treated.
- Higher patient acceptance.

5.6 Lasers in the Treatment of Periimplantitis

The prevalence of periimplantitis is recognized as a serious concern, with some estimates as high as 47% among patients with implants. Surgical treatment can entail the use of full/split thickness flaps, bone grafting with xenografts and/or allografts, resorbable/nonresorbable membranes, bone morphogenetic proteins, biomimetics, or combination of all or some of the above [54–61].

These surgical procedures require surgical skills that the practitioner may or may not have. Also, the cost to the patient may be prohibitive, and the practitioner may have to find a more cost-effective or compromised way to treat the periimplantitis. Decontamination of the implant surface seems to be essential to the treatment, but the method of decontamination is not settled [55, 62]. Even removal of the implant surface itself with drills has been advocated [63].

But there is no consensus as to which treatment gives the most consistent or predictable results. Recently, the use of lasers has also been put forward as a method of decontaminating the implant surfaces.

The two laser wavelengths that are mainly used for periimplantitis treatment are the erbium and Nd:YAG lasers.

The main use of the erbium laser is for the decontamination of the implant surface prior to bone grafting. This involves the reflection of a flap to gain access to the contaminated surfaces, degranulation either with or without the laser, and lasing the implant surface directly with simultaneous coaxial water spray to minimize heating of the implant. After decontamination, bone grafting materials with or without membranes are placed, based on the practitioner's preference, and then the suture is closed [64].

In the REPAIR implant protocol (Biolase, Irvine, Calif., USA), a closed flap procedure, the area around the implant is de-epithelialized, a collar of tissue around the implant is removed (which may cause esthetic concerns in the anterior region), and then a radial-firing tip is used to decontaminate the implant surface with Er,Cr:YSGG laser energy. Decortication of the bone follows to allow blood to fill the site; the laser is used to assist with hemostasis, followed by compression of the surgical site for 3–5 min. As mentioned previously, the Er,Cr:YSGG laser does not provide the same level of coagulation as the Nd:YAG laser to achieve a stable fibrin clot. In the REPAIR implant protocol, removal of the restoration would seem to be essential, given the non-flexibility of the laser's glass tips, as implant restorations with multiple attachments or with large convexities may not be amenable to flapless procedures. This would mean that a flapped approach with bone grafts and other regenerative materials would be indicated. The advantage of the erbium laser is that it utilizes a water spray to help cool the implant during irradiation.

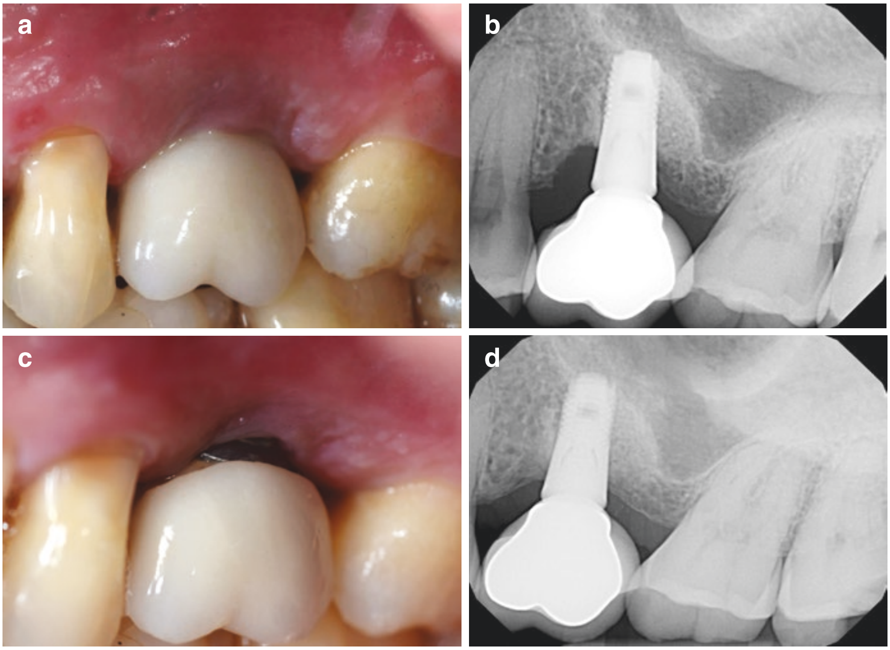

Fig. 5.5 Clinical application of digitally pulsed Nd:YAG laser in periimplantitis treatment in posterior. The patient was 47-year-old male who was seen for discomfort and suppuration on the upper left first molar (**a**). Probing showed non-maintainable pockets. The X-ray showed vertical bone loss on upper left first molar (**b**). LAPIP treatment was performed on the same day as Fig. 5.4a, b. No removal of restoration was necessary, and he was kept on a 3-month periodontal maintenance. Once inflammation and swelling of the gingiva resolved, a buccal overhang of the restoration was noted, which probably contributed to the periimplantitis (**c**). The 44-month follow-up showed decrease in pockets to maintainable levels with no suppuration or BOP. The X-ray showed stable regeneration of bone (**d**)

The Nd:YAG laser is utilized in the LAPIP protocol (Millennium Dental Technologies) for the treatment of periimplantitis. This minimally invasive surgical protocol is a modified LANAP procedure that does not require a fully reflected flap or regenerative materials. Due to the flexibility and various diameters of fibers available, removal of the implant restoration is not always necessary (Fig. 5.5). This can be particularly useful in anterior regions and in situations where there are multiple joined restorations (Fig. 5.6). Through careful fiber angulation and measuring exactly how much energy (Joules) is being produced by the Nd:YAG laser, overheating of the implant can be avoided. Aiming the laser fiber tip at the implant is not necessary to achieve disinfection of the tissues and implant surfaces. The fiber is used parallel to the implant surface, and the laser energy interacts with the implant surface via scattering from tissue. Further disruption of biofilm on the implant surface is achieved using a piezo scaler with chlorhexidine and water irrigation. As with all regenerative procedures, occlusal adjustment of the implant restoration (if not already removed) is essential to allow for nondisruption of the fibrin clot and healing of the area in the least traumatic way. In a study by Nicholson et al. on the use of the Periolase Nd:YAG laser for the LAPIP treatment of periimplantitis, the investigators reported control of the infection, reversal of bone loss, and rescue of the incumbent implant. One cited case showed a rate of bone healing of 2.097 mm^2/month [65].

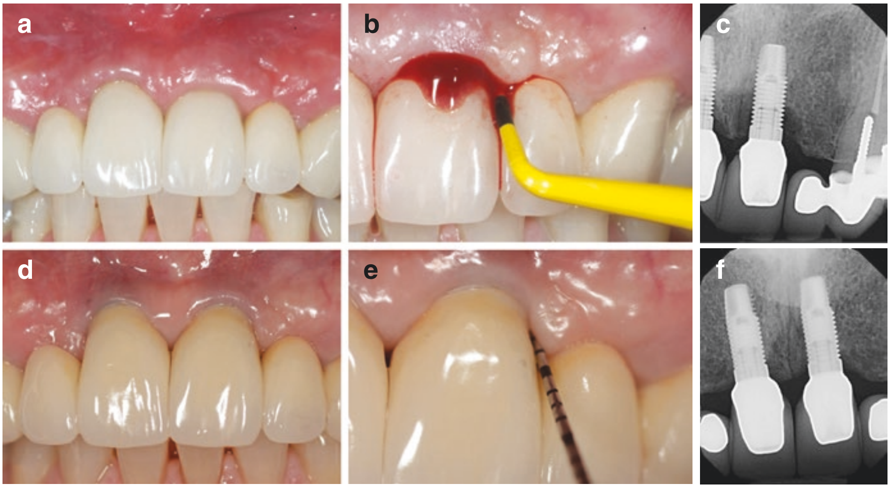

Fig. 5.6 Clinical application of digitally pulsed Nd:YAG laser in periimplantitis treatment in anterior maxilla. The patient was a 52-year-old woman who was seen for periodontal maintenance. Swelling with BOP was noted (**a**). Probings showed non-maintainable pockets on the maxillary central incisors with BOP and suppuration (**b**). The X-ray showed vertical bone loss on the distal aspect of both incisors (**c**). LAPIP treatment was performed. No removal of restoration was necessary, and she was put on a 3-month periodontal maintenance. The 49-month follow-up showed decrease in pockets to maintainable levels with no suppuration or BOP (**d** and **e**). The radiograph showed stable regeneration of the bone in defects on both teeth (**f**)

5.7 Conclusion

Overall, lasers have become essential tools in the dental practice, either as standalone or as an adjunctive instrument. It is important for the practitioner to be cognizant of the pros and cons of the different wavelengths and how those different wavelengths fit into the dental professional's practice philosophy. Completing device-specific laser training programs, studying the research available, and speaking with peers are essential to find the laser with the right fit for one's practice.

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Part III

Regenerative Techniques of Periodontal Surgery

Videoscope-Assisted Minimally Invasive Surgery (VMIS) for Bone Regeneration

6

Stephen Harrel

Minimally invasive surgery was first defined in a 1990 editorial in the *British Journal of Surgery* as the ability to perform a standard surgical procedure through a much smaller opening than had been used previously [1]. The need for this definition was based on the growing popularity of medical surgical procedures that were being introduced at the time that used various forms of improved lighting and magnification. These visualization improvements included surgical loops with headlights, surgical microscopes, and hard (non-flexible) endoscopes. Prior to the introduction of the term "minimally invasive surgery," the instrument used for magnification often defined many of these procedures. Examples would be microsurgery when a surgical microscope was used or endoscope surgery when an endoscope was used. In the process of introducing the concept of minimally invasive surgery to medicine in 1993, Hunter and Sackier made the point that the procedure had to accomplish the same beneficial end point that was obtained with larger surgical openings [2]. This was to counter the fact that in some cases surgeons were performing a surgical procedure using smaller incisions and using new technology but were not obtaining the positive results that were obtained with traditional larger incisions. Periodontal procedures have faced a somewhat similar dilemma with the words "minimally invasive" being applied to many procedures that are not significantly smaller or as effective as more traditional procedures using a larger access approach.

In the periodontal literature, the first description of a minimally invasive procedure was in 1995 by Harrel and Rees [3]. Following the original description, a detailed minimally invasive procedure for periodontal bone regeneration (MIS) was described by Harrel in 1999–2001 [4–6]. This procedure used much smaller incisions than are traditionally used for bone grafting. At that time either surgical

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magnification loops or a surgical microscope was utilized for visualization. Several case series using this technique were published showing results that were similar or improved when compared to traditional bone regeneration procedures.

In 2005, Harrel and Wilson published a case series that described the use of enamel matrix derivative (EMD) used in conjunction with the then current minimally invasive bone grafting procedure. Improved results from MIS were reported at 1 year postoperatively [7]. In 2009, a 6-year long-term report of this same group of patients showed that the favorable results originally reported were stable or improved over time [8]. This was felt to establish the fact that a minimally invasive surgical approach yielded long-term results that were equal to or improved when compared to more traditional large incision surgery. Harrel and Wilson used high magnification surgical loops for their technique. In 2007, Cortellini and Tonetti modified the original Harrel MIS procedure to include the papilla preservation incision and suturing techniques. They termed their procedure the minimally invasive surgery technique (MIST). They published several studies that showed various modifications of the MIST approach yielded results similar to those reported by Harrel and Wilson [9]. Cortellini and Tonetti utilized a surgical microscope for their technique.

Within this historical context, it became obvious that a new means of visualization was necessary to allow a move to smaller incisions than those being used at that time. The surgical access incisions reported by Harrel and Wilson as well as those used by Cortellini and Tonetti while much smaller than traditional incisions remained larger than ideal. The size and types of incisions were dictated by the use of the visualization method used, either magnification loops or a surgical microscope. Additionally, these forms of magnification were more applicable to the use of a buccal approach, which influenced the placement of entry flaps for all types of minimally invasive periodontal surgery. A surgical microscope or surgical loops can be used with a mirror for lingual access flaps, but this tends to limit the field of vision, and it is difficult to obtain visual angles that allow complete visualization of the bony defect. Because a buccal approach necessitates a flap in an esthetically sensitive area, a visualization method that allows for the effective use of a lingual approach is preferable.

Based on the desire to utilize both smaller surgical openings and the need to perform surgical procedures from the lingual, research was initiated to develop a videoscope that would allow for these improvements. A videoscope is a very small camera that can be placed in the surgical site. This is different from an endoscope that places an optical lens in the surgical site and has an external camera. A videoscope is capable of much improved true color optics and also can be made smaller than most traditional endoscopes. A videoscope for use in periodontal minimally invasive surgery has to be small enough to allow visualization of the defect and allow for easy access to the defect using a lingual approach and needs to incorporate technology that prevents the fouling of the lens with moisture, blood, or surgical debris. Past attempts to use a videoscope for periodontal surgery had failed to achieve these results due to both size constraints and the fact that the lens could not be kept clean and would rapidly be obscured by blood. With grants from the National

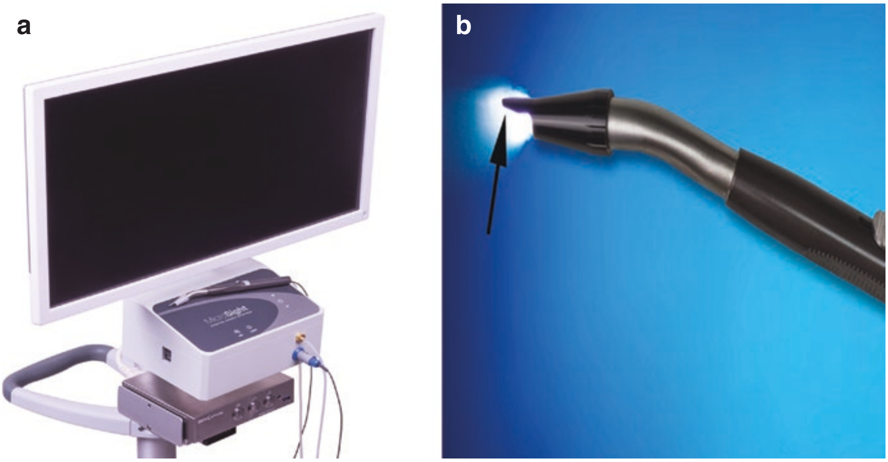

Fig. 6.1 (**a**) The MicroSight™ videoscope used for VMIS (**b**). The handpiece of the videoscope. The rotatable tip of the handpiece has an integral tissue retractor (arrow) to allow gentle displacement of the tissue for visualization

Institutes of Health (Bethesda, MD, USA), a videoscope prototype was developed that overcame these problems and was first described in 2013 [10]. The currently used videoscope is shown in Fig. 6.1. This videoscope is small enough to fit into minimally invasive incisions and uses a constant stream of air to keep the optics clear.

6.1 Videoscope-Assisted Minimally Invasive Surgery (VMIS) for Periodontal Defects

A surgical procedure that utilized the advantages of the newly developed videoscope was designed and tested, again with the assistance of National Institutes of Health funding. The procedure has been described as videoscope-assisted minimally invasive surgery or VMIS. The essential elements of VMIS are (1) the use of only a single small, usually lingual, flap, (2) the use of split thickness incisions to preserve as much of the blood supply as possible, (3) avoiding the use of a periosteal elevator so that most of the blood supply from the periosteum to the bone and soft tissue remains intact, (4) leaving the buccal papilla and esthetic facial gingiva intact and unreflected whenever possible, and (5) the use of simple suturing techniques that do not pass sutures through the thin marginal tissue of the incision. Each of these steps is outlined in detail in the following paragraphs.

The guiding principle for the design of the soft tissue access flaps used in VMIS is aimed at preserving as much of the blood supply to the surgical area as possible. This is based on the experience in medicine that the less damage to the blood supply, the more rapid the healing of the tissue and the more rapid the healing, the less discomfort and morbidity the patient will experience. It is also theorized that better preservation of the blood supply will be beneficial in the regeneration of bone and periodontal attachment. Another factor in the design of VMIS flaps is, if at all possible, avoidance of any flaps or incisions on the facial aspect in order to preserve esthetic soft tissue contours.

The VMIS procedure may be used in multiple situations but is most frequently used to treat the isolated interproximal deep lesions with bone loss that have not fully responded to nonsurgical periodontal treatment. The flap design described here assumes an area of bone loss confined to the interproximal area with minimal extension to the facial and lingual of the teeth. In most cases, the flap can be limited to the lingual of the lesion. The videoscope allows for visualization of the interproximal bone structure from the lingual without the elevation of the papilla. Unlike the surgical microscope, visualization of the lesion utilizing a lingual access incision is straightforward and relatively simple. The obvious exception to the use of a lingual flap is when the bony defect is isolated to only the buccal aspect.

The incisions are shown in Fig. 6.2. A sulcular incision is made in the interproximal aspect of the teeth in the area of bone loss. Care is taken in making this sulcular incision to not remove any of the gingival tissue. In other words, unlike many traditional types of periodontal surgical procedures, removing the sulcular lining or removing a small "collar" of soft tissue is avoided. The purpose of the sulcular incision is merely to sever any attachment to granulation tissue that has formed in the bony defect. The sulcular incision is not for the purpose of introducing a periosteal

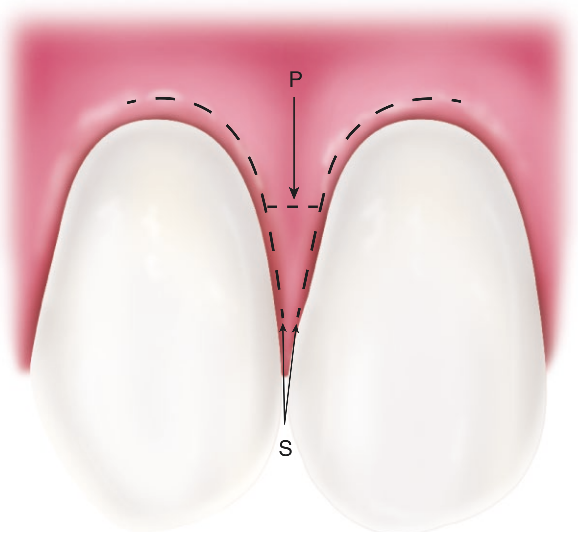

Fig. 6.2 Initial incisions. *S* sulcular incisions are placed on the lingual aspect of the teeth adjacent to the defect. In this case, two maxillary bicuspids are shown. The incisions are sulcular only and no tissue is removed. *P* a split thickness connecting incision is made at the base of papilla. This incision should be made well away from the tip of the papilla

elevator to elevate a "flap." A periosteal elevator is designed to remove the periosteum from the underlying bone. The periosteum is the major blood supply to the gingival tissue, and with VMIS, every effort is made to retain the periosteum undisturbed. Any further tissue reflection uses a split thickness incision made by sharp dissection on the lingual at the base of the interproximal papilla. An Orban Knife that has been reduced in size is usually used for this procedure. The incision should be made to the crest of the remaining bone. This procedure is shown in Fig. 6.3. If at all possible, this split thickness incision is not extended beyond the margin of the remaining bone and in no instance is a periosteal elevator used to make the flap larger. The purpose of this incision and flap is to gain enough access for the placement of the soft tissue retractor that is integral to the videoscope. The videoscope in place and the integral adjustable retractor used for tissue control is shown in Fig. 6.4. Depending on the anatomy of the teeth and the bony lesion, the mesiodistal length of this incision is usually no more than 5–6 mm, and the depth of the incision is dictated by the remaining height of the bone on the lingual aspect of the defect.

Once the above incisions have been made and adequate access for the placement of the videoscope has been verified, the granulation tissue is removed. This is usually performed with standard periodontal curettes that have been reduced in size. The curette most frequently used is a Younger-Good 7/8 that has been reduced by approximately 1/3 from its original width used in a motion similar to that used to "spoon out" caries during preparation for a restoration. The small incision makes this motion preferable to the more traditional method used with surgical curettes

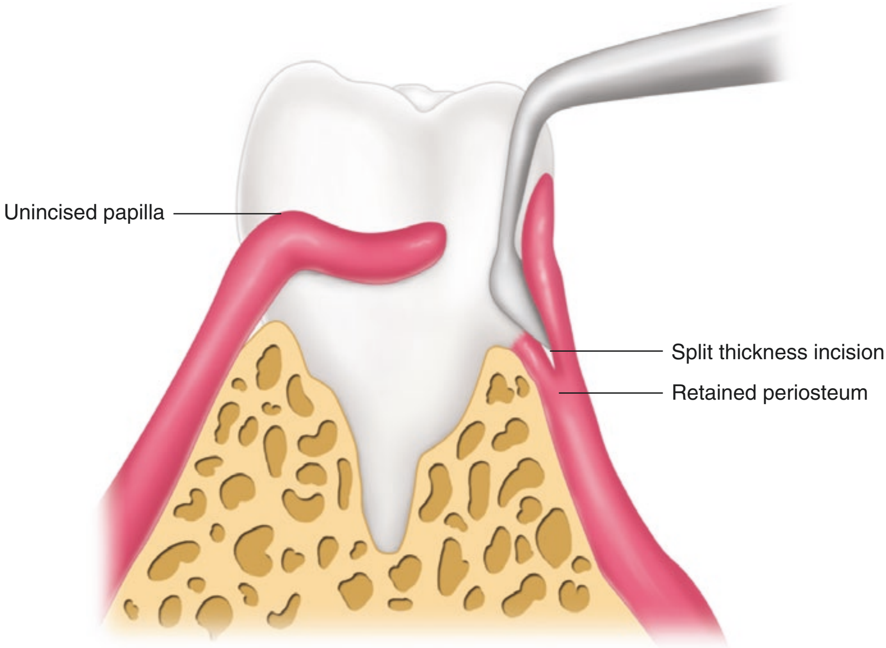

Fig. 6.3 The split thickness flap on the lingual aspect is shown. This approach is used to maintain the periosteal blood supply to the soft tissue and bone. A periosteal elevator should not be used

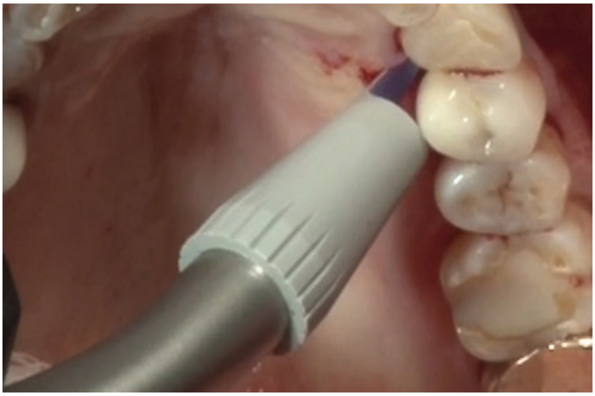

Fig. 6.4 The videoscope retractor tip is inserted into the incision, and the tissue is gently retracted allowing the lesion to be seen on the videoscope monitor

that is similar to the motion used for root planing calculus. This portion of the surgical procedure can be performed in a stepwise fashion where the granulation tissue is removed and the videoscope is then used to evaluate the progress of tissue removal. The experienced operator will often perform this step holding the videoscope in one hand and the curette in the other. Another option with an experienced surgical team is for the assistant to hold the videoscope in place leaving both of the surgeon's hands free for tissue manipulation. The granulation tissue is removed from the periodontal lesion to the point that the osseous defect can be evaluated and the root surfaces examined. The 20–40× magnification of the videoscope allows for visualization of very small tags of granulation tissue that would not be visible with other types of available magnification/visualization. It appears unnecessary to remove the tissue to the point that none can be visualized at this high magnification.

The high magnification of the videoscope also allows for the visualization of calculus and imperfections on the root surface that are virtually invisible with other forms of visualization. The ability to visualize and remove these very small areas of calculus is unique to VMIS and the use of the videoscope. When the large areas of calculus have been removed, the videoscope will often reveal multiple small areas of calculus that are referred to as "microislands" of calculus. These microislands of calculus can be very difficult to remove mechanically with hand or ultrasonic scalers but can usually be removed by burnishing the root with EDTA. Also, multiple very small grooves have been noted on the root surfaces when the videoscope is used that are not visible with other forms of magnification. These have been termed "microgrooves" and have been noted in 79% of all osseous defects [11]. The frequent association of microgrooves with areas of bone loss is suggestive of pathologic association, but this has yet to be proven. In all instances, the removal of the small microislands of calculus and the very small imperfections on the root surface by root planing is an important part of VMIS. It is postulated that the removal of these previously undetected islands of calculus and imperfections may be a contributing factor in the highly favorable results reported following the use of VMIS. The

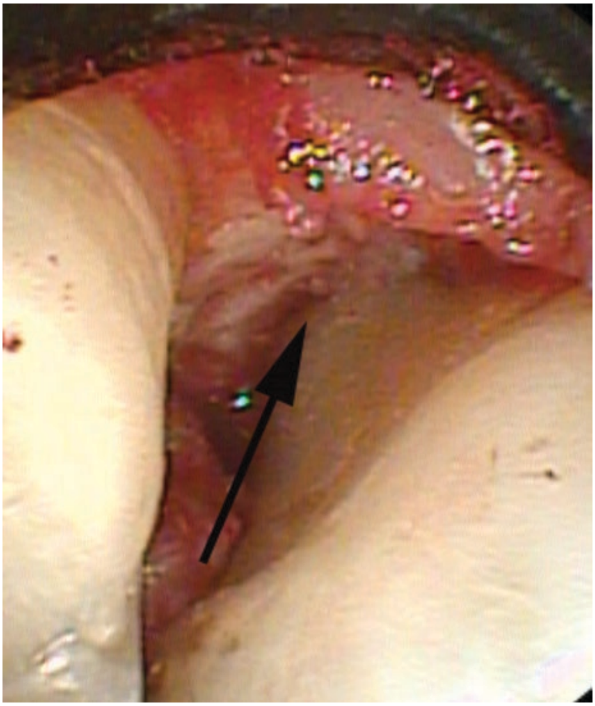

Fig. 6.5 A videoscope image of a debrided defect. A 10-mm two-walled intrabony defect is present with the arrow at the deepest point of the defect

level of root and defect debridement possible with the use of the videoscope appears to be more complete than is possible with other means of visualization.

Following the debridement of the bony lesion and meticulous cleaning and smoothing of the root surface shown in Fig. 6.5, regenerative material can be placed in the defect. As previously stated, EDTA is burnished on the root surface with a cotton pellet to remove the last of the microislands of calculus and to modify the root surface. This step is followed by placing EMD on the root surface following the manufacturer's instructions. A bone allograft is first hydrated with sterile saline and then blotted dry with sterile gauze followed by mixing with EMD. The bone and EMD mixture is then placed into the bony defect taking care to not overfill the defect so that primary closure of the small flap is possible. Figure 6.6 shows demineralized allograft mixed with EMD inserted into the bone defect. The bone graft material will be slightly compressed to allow primary closure of the small VMIS incisions. It should be emphasized that no membranes are used in VMIS. The small incisions used would have to be greatly enlarged to be able to place a membrane. The very small flaps used with VMIS allow for the stabilization of the bone graft without the use of any type of membrane.

The surgical site is closed using a simple vertical mattress (Fig. 6.7) suture of moderate diameter (4–0 or 5–0). The long-term VMIS study used plain collagen suture. However, while the type of suture material is not believed to be critical, the

Fig. 6.6 Bone graft (DFDBA) mixed with enamel matrix derivative placed in the bone defect. The graft material will be slightly compressed to allow primary closure of the small VMIS incisions

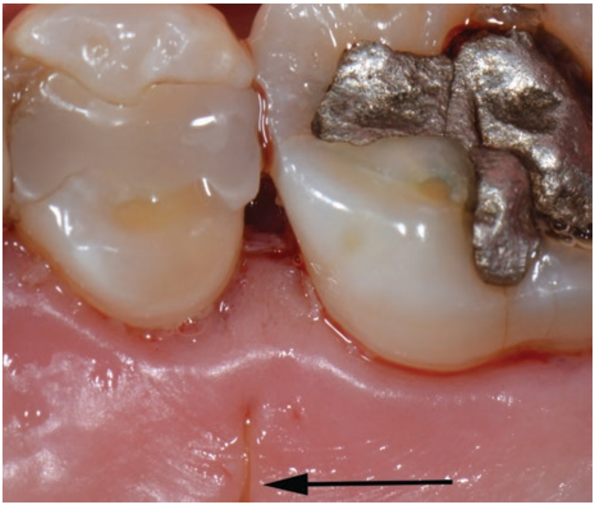

Fig. 6.7 A VMIS incision that has been closed after placement of a bone graft and EMD. A single simple vertical mattress suture (arrow) at the base of the papilla is used to close the incisions. No suture is placed in the tip of the papilla. The papilla tip is approximated by finger pressure only

placement of the suture is very important. The vertical mattress is placed in the thicker base of the incised papilla. No sutures are placed in the thin portion or "tip" of the papilla close to the incision. Placing suture in this area and especially in the most coronal portion of the papilla is associated with more postoperative recession. The suture that is placed in the thicker base of the papilla stabilizes the flap and allows the incision to be closed passively with pressure only. Saline-soaked gauze is used to close the incision with pressure. By using this approach, postsurgical recession rarely occurs. In fact, the long-term reports on VMIS show an overall decrease in recession compared to pre-surgical levels (Table 6.1). Figure 6.8 shows the

Table 6.1 Pocket probing depth and recession in mm following VMIS (from Harrel et al. [12])

Clinical measure	Mean ± SD
Probing depth	
Baseline	6.42 ± 0.73
6 months	2.72 ± 0.68
12 months	2.20 ± 0.64
36 months	2.73 ± 1.12
Change: baseline to 36 months	3.69 ± 1.17
Recession	
Baseline	0.70 ± 0.96
6 months	0.61 ± 0.74
12 months	0.16 ± 0.34
36 months	0.21 ± 0.45
Change: baseline to 36 months	0.49 ± 0.60

Statistically significant improvements were noted in pocket depth, attachment level, and recession at all measurements postsurgery

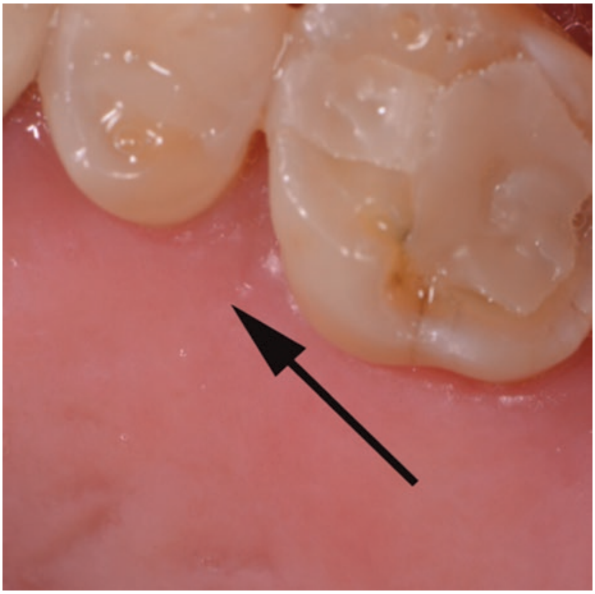

Fig. 6.8 The surgical site pictured in Fig. 6.7 at 2 years postoperative. The former defect site is noted at the arrow. The pocket probing depth which was initially 10 mm is now less than 3 mm with an increase in soft tissue and papilla height. The lack of recession following VMIS is routine

surgical area pictured in Fig. 6.7 after 2 years. This site demonstrates no postsurgical recession from the VMIS surgical procedure. The complex suturing of the papilla preservation procedure is not necessary to preserve the soft tissue contours of the papilla when the VMIS approach is utilized.

The patient is given routine postsurgical instructions. As with all bone grafting procedures, they are placed on a broad spectrum antibiotic that is compatible with their medical history. Mechanical oral hygiene is avoided for 1 week, and they are placed on a chlorhexidine mouthwash for this period. Gentle physical oral hygiene is resumed at 7–10 days postsurgery. Initial healing is usually complete by this time. Many patients indicate that they have no pain following VMIS. In the long-term VMIS study, 93% of patients indicated they had no pain on the day of surgery or at anytime following the surgical procedure [12].

The results of the large VMIS study have been published in three papers. The 3- to 5-year long-term results were published in 2017 (Table 6.1) [12]. Of the patients followed for this period of time, no failures were reported. The mean pocket probing depth was 2.8 mm at 3–5 years, and no bone-grafted site was deeper than 4 mm. Additionally, no recession was noted, and there was actually a 0.36-mm increase in soft tissue height. The lack of recession following a bone regenerative procedure has not been previously reported.

6.2 The VMIS Approach for Peri-Implant Bone Loss

The videoscope and the original VMIS procedure were developed for the treatment of periodontal bone loss around natural teeth. Recently, the VMIS approach has been utilized in regenerative treatment of bone loss around dental implants. The cause of peri-implant bone loss is not completely understood. Traditionally, inflammation and bone loss around implants have been assumed to be caused by the bacterial plaque that is associated with periodontal bone loss around natural teeth. However, there is growing concern that implant bone loss may be partially associated with a foreign body reaction [13]. Wilson showed that particles of cement and titanium were embedded in the soft tissue surrounding failed implants [13]. Further, these particles were surrounded by inflammatory cells indicating the chronic nature of the lesion. While not proven, it is postulated that the inflammatory response of the foreign body reaction plays a role in bone loss and failure of implants. The modification of the VMIS procedure described here was developed to remove tissue with embedded foreign bodies as part of regenerative surgery around implants.

The basic techniques described previously for using VMIS to treat periodontal defects on natural teeth such as small incision, minimal reflection, and retaining blood supply by not using a periosteal elevator are followed in the use of VMIS for treating peri-implant bone loss. Sulcular incisions are made in the areas of bone loss surrounding the implant, and split thickness incisions are extended to the line angle of the adjacent teeth (Fig. 6.9). The videoscope is inserted and the implant evaluated for excess cement (Fig. 6.10). The bony defect is debrided of granulation tissue

Fig. 6.9 When treating bone loss on an implant, a sulcular incision is made in the area of bone loss, and then a split thickness incision is extended to the line angle of the adjacent teeth. The papillae are not elevated

taking care to not touch the surface of the implant with an instrument. All contact between an instrument and the implant surface is avoided to retain as much of the fragile titanium oxide layer on the implant as possible. The implant surface is not instrumented in any way, and no harsh decontamination chemicals such as hydrogen peroxide, citric acid, or tetracycline solution are used. All acidic decontamination solutions have been shown to cause corrosion of the implant surface and may contribute to the loss of the titanium oxide layer that is integral to the process of osseointegration. Instead, the implant surface is gently burnished with a saline-soaked gauze strip. Following removal of granulation tissue and cleaning of the implant with saline, bone grafting material, preferably demineralized freeze-dried human bone, mixed with EMD is placed in the bony defect. No membrane is used with any VMIS technique, including the treatment of implants. The incisions are closed with the same vertical mattress suture as used for periodontal defects. While no formal studies have been completed on the outcomes of this technique, multiple cases have been completed, and the regenerative results are encouraging. A 1-year postoperative radiograph is shown in Fig. 6.11 that appears to show bone regeneration and, based on the lack of a "black line" between the new bone and the implant, possibly re-osseointegration. The pocket depth on the implant in Fig. 6.11 went from 10 mm to less than 3 mm and is considered a clinical success. A study is currently in progress to evaluate the results of this approach.

6.3 Summary

The videoscope has made the VMIS approach possible by utilizing smaller incisions than have previously been described. It is also felt that the magnification and ability to better visualize the bony defect and debride the root surface are factors in

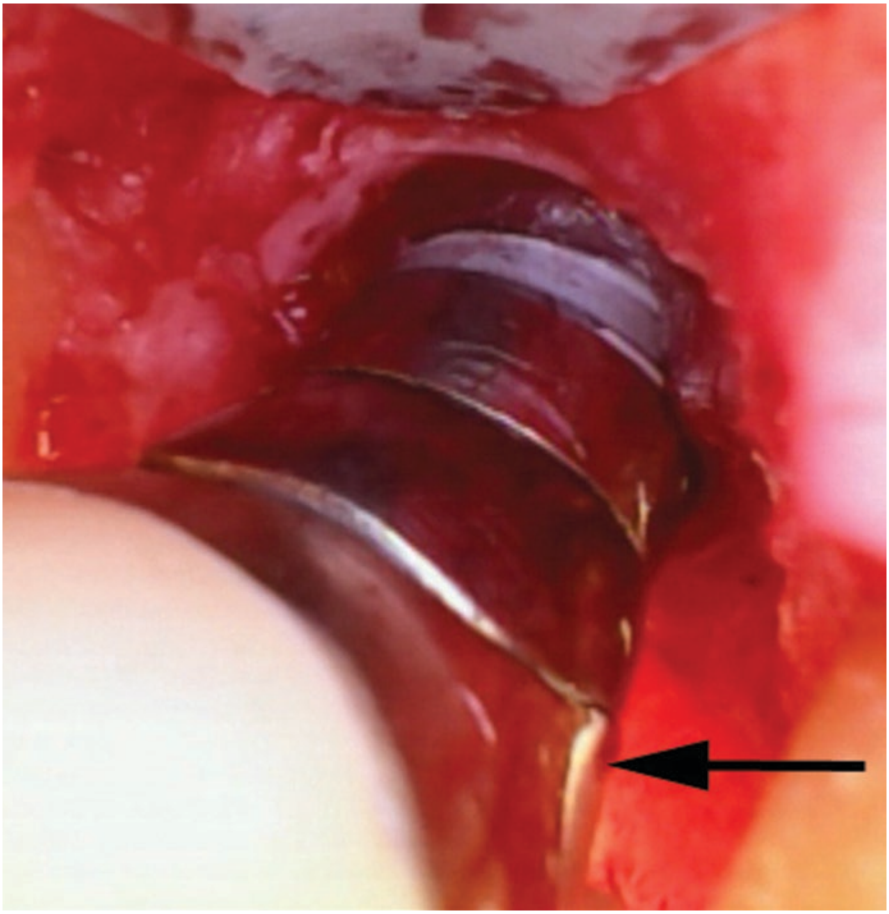

Fig. 6.10 Granulation tissue is removed from the area of bone loss, and the implant is evaluated for excess cement (arrow). The implant is not scaled and no harsh disinfection solutions are used. Every effort is made to protect the remaining titanium oxide layer

the predictable and favorable results that have been reported in the literature. In addition, the videoscope is being used for other procedures beyond the VMIS procedure. These include routine nonsurgical scaling by hygienists, open flap debridement using smaller incisions than traditionally used because of the improved visualization of the defects, and visualization of the sinus membrane and floor during lateral window sinus augmentation and during surgical and nonsurgical endodontic procedures. While the VMIS procedure was designed to take advantage of the improved visualization made possible by the videoscope and most clinical documentation has been of the VMIS procedure, it appears that the videoscope will allow for the use of smaller incisions and more “minimally invasive procedures” in many periodontal procedures beyond VMIS as well as in other areas of dentistry.

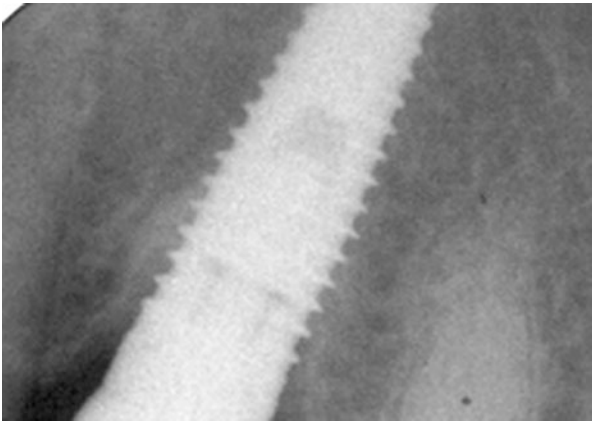

Fig. 6.11 In the radiograph taken 1 year after regenerative treatment, there is apparent bone fill to the first thread of the implant in the preoperative areas of bone loss. It is possible that re-osseointegration has occurred based on the absence of a black line next to the implant. Other regeneration procedures will frequently show some bone fill, but there will be a prominent black line (space) next to the implant, possibly indicating that re-osseointegration has not occurred

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Regeneration of Intrabony Defects Utilizing Stem Cells Allograft

7

Richard T. Kao and Mark C. Fagan

7.1 Introduction

Periodontitis is commonly characterized by the formation of intrabony defects. Pioneering research on the use of autogenous bone grafts of both extra- and intra-oral sources has been used successfully for periodontal regeneration [1]. This has been accepted as the gold standard for grafting materials. However, critical limitations for autogenous bone use include limited supply and possible need for multiple donor sites, and donor site morbidity can make this therapeutic approach less than desirable. Several surgical approaches shown to be effective in improving clinical and radiographic parameters such as clinical attachment level (CAL) and defect depth utilizing bone replacement grafts and/or guided tissue regeneration (GTR) are well documented in the literature [2–5]. However, these approaches have limitations in the predictability and effectiveness of regenerative therapy, inability to achieve vertical bone growth beyond the existing bony walls and therapeutic inconsistencies. This has resulted in the search for alternative regenerative strategies.

More recently, tissue engineering approaches for periodontal regeneration involving grafting with scaffolding material (i.e., demineralized or mineralized freeze-dried bone allograft materials (DFDBA, FDBA) or tricalcium phosphate (TCP)), grafting and/or recruitment of mesenchymal stem cells (MSCs, also known as multipotential stromal cells), and the use of signaling molecules (i.e., growth factors such as recombinant human platelet-derived growth factor (rhPDGF), recombinant human fibroblast growth factor (rhFGF), and enamel matrix derivative

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(EMD)) have been proposed to potentially overcome some of these limitations [6]. This has resulted in the extensive study of the use of biologics, like enamel matrix derivative (EMD) and recombinant human platelet-derived growth factor-BB plus β-tricalcium phosphate (rhPDGF-TCP) [7–12]. The past 15 years of studies have concluded that these biologic agents generally enhanced periodontal regeneration with comparable results similar to DFDBA and GTR. Additionally, it has been shown that these methods are superior to open flap debridement procedures in improving clinical parameters [13]. Long-term studies indicate that the improvements are maintainable up to 10 years, even in severely compromised teeth, consistent with a favorable, long-term prognosis.

In search of improved healing response in advanced compromised periodontal intrabony defects, we have explored if augmentation of all three components of tissue engineering variables, namely, the addition of stem cells, scaffolding graft material, and signaling molecules, will singularly or in combination enhance periodontal regeneration. In this chapter, we describe the use of stem cell allograft for the correction of intrabony defects and address whether the results can be improved if used in combination with guided tissue regeneration and/or recombinant human platelet-derived growth factor. Specifically, we examined if a commercially available MSCs preparation seeded on DFDBA when used singularly or in combination with rhPDGF +/− with GTR membrane will enhance periodontal regeneration.

7.2 Use of MSCs for Periodontal and Dental Implant Applications

There are more than two million bone graft procedures performed annually to repair osseous defect in orthopedics, neurosurgery, and dentistry [14]. One of the problems associated with the use of typical allograft is the removal of osteogenic cells during tissue processing. In 2005, tissue processing was modified such that viable osteogenic, nonimmune cells can be harvested. Osteocel® (Ace Surgical Supply, Brockton, MA, USA) is a commercially available osteogenic cell preparation that has been used for spine, maxillofacial, and long-bone applications [15–18]. For Osteocel® processing, cadavers are processed within 24 h and undergo rigorous safety screening, physical examination, and medical-social history assessment. The harvested bones are separated into cortical and cellular cancellous bone. The cellular cancellous bones are processed by immunodepletion and wash procedures which selectively removes immune cell components (i.e., red blood cells and lymphocytes are depleted by >2000-fold) preserving the osteogenic, nonimmune cells. In parallel, the cortical bones are processed into DFDBA. The DFDBA are added back to the immunodepleted cellular cancellous bone preparation which contains native MSCs and osteoprogenitor cells (Fig. 7.1).

Stem cell protocols have the potential to improve current bone regeneration methods through increased bioactivity of grafting scaffolding, targeted growth factor delivery, and cell recruitment [6]. The concentration of MSCs in a cellular bone allograft compared with fresh age-matched iliac crest bone and bone marrow (BM)

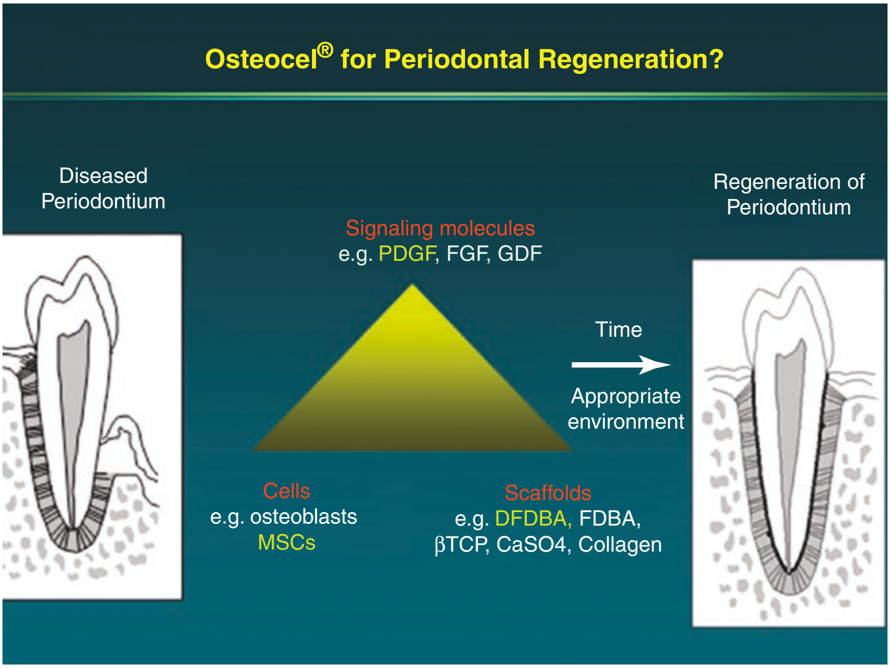

Fig. 7.1 Periodontal regeneration by applying tissue engineering principles

aspirate has been investigated [19, 20]. In these studies, the authors reported that without cultivation or expansion, the allograft displayed an osteoinductive molecular signature and the presence of CD45 − CD271 + CD73 + CD90 + CD105 + MS Cs with a purity over 100-fold that of iliac crest bone. In comparison with BM, MSCs numbers enzymatically released from 1 g of cellular allograft can contain MSCs equivalent to approximately 45 mL of BM aspirate. They concluded that MSCs cellular allograft bone represents a unique "living" nonimmune matrix rich in MSCs and osteocytes. This osteoinductive cellular graft represents an attractive alternative to autograft bone, which reduces supply and morbidity issues. When used in the manner as we have described in the case series design, the cost of the material can be reduced to $100–150 per defect site depending on the size of the defect. Our experience is that a 1 g unit can be used to correct at least four large intraosseous defects. If the defects are narrow or have furcation involvement, a single unit can be used to manage additional cases.

Early application of MSCs preparations in dentistry has focused on its application for implant site preparation. Pioneering work by McAllister first demonstrated the usefulness of MSCs preparations for sinus augmentation procedures [15]. In a histomorphometric study, a comparison of bone formation following sinus augmentation procedures using either a MSCs allograft cellular bone matrix containing native MSCs or a conventional allograft was assessed. Results over a 3.7 months.

Follow-up healing period of the test group revealed a mean of 32.5 and 4.9% for vital bone and remaining graft content, respectively. In the control group, only 18.3% of the bone content was vital, and 25.8% of residual conventional graft remained [15]. Rickert et al. [21] reported similar results when they compared bovine-derived mineral bone seeded with mononuclear stem cells with bovine-derived mineral bone mixed with autogenous bone. Significantly greater bone formation was observed in the test group when compared with the control group at 14 weeks (17.7% vs. 12%, respectively). Another application of MSCs for implant site preparation were case reports whereby MSCs preparations were used to increase vertical and horizontal bone volume. In these case reports, the MSCs allograft combined with a titanium mesh created space maintenance for ridge augmentation in both width and vertical dimensions [22, 23].

To date, there have been limited case reports on the use of MSCs for periodontal regeneration. Pioneering animal studies have demonstrated that MSCs can enhance the regeneration of periodontal defects in dogs [24]. The clinical use of MSCs cellular allograft for treatment of human periodontal defects was first reported in both a single-rooted and a multi-rooted tooth [22]. In the single-rooted case, a significant reduction in probing was obtained with radiologic evidence of approximately 4 mm of vertical bone fill at 6 months following grafting. In the multi-rooted case, clinical evidence showed decreased probing depths and radiographic bone improvement at 6 months. A CBCT scan taken at 14 months demonstrated three-dimensional bone fill. A similar result was presented in a case report by Koo et al. [25], which describes the use of allograft cellular bone matrix containing MSCs in the treatment of a severe periodontal defect. These case reports indicate a potential resolution of periodontal defects using cellular allograft material. There is limited information regarding the use of MSCs for the correction of furcation defects other than a case report by Rosen [26], where a Class III furcation defect on a mandibular molar was corrected utilizing MSCs in conjunction with a resorbable GTR membrane. On reentry for implant placement, the regeneration of the furcation defect was confirmed radiographically, as well as clinically.

Though these case reports and series are encouraging, there has been no thorough examination of whether MSCs can enhance the potential of regenerative strategies (rhPDGF and/or GTR membrane) either singularly or in combination.

7.3 Clinical Assessment of MSCs for Periodontal Regeneration

7.3.1 Case Series Design

In this first comprehensive study of the use of MSCs seeded on DFDBA, we ask the question if this alone, or in combination with other regenerative strategies (rhPDGF and/or GTR membrane), can enhanced the regenerative results.

In this study, 77 subjects who had advanced periodontal defects were enrolled into one study center (Dr. Richard Kao). Despite pre-treatment endodontic

Table 7.1 Patient enrollment, adverse event, and periodontal defect demographics

	Group 1: MSCs	Group 2: MSCs + GTR	Group 3: MSCs + rhPDGF	Group 4: MSCs + rhPDGF + GTR
Patients enrolled Male/female	20 10/10	17 9/8	20 11/9	20 11/9
Adverse event*	3	0	1	3
Patients' completed study	17 8/9	17 9/8	19 11/8	17 9/8
Intrabony defect Depth × width (mean)	6.6 m × 3.9 mm	6.8 mm × 3.6 mm	6.7 mm × 3.5 mm	6.6 mm × 3.9 mm
Defect characteristics (mean)	3—Circumferential 11—3 walls 3—2 walls	2—Circumferential 10—3 walls 5—2 walls	6—Circumferential 10—3 walls 3—walls	4—Circumferential 11—3 walls 2—2 walls

*Patient(s) withdrawn from study due to perio-endo complications

assessment, seven patients were lost during the course of this study due to perio-endo complications. For the 77 subjects, intrabony defects were treated with MSCs with or without rhPDGF and a commercially available bioresorbable guided tissue regeneration (GTR) membrane. The subjects were randomized into four treatment groups using variable block sizes (Table 7.1).

- Group I: MSCs seeded on DFDBA.
- Group II: MSCs + GTR.
- Group III: MSCs + rhPDGF-BB (0.3 mg/mL rhPDGF-BB).
- Group IV: MSCs + rhPDGF-BB (0.3 mg/mL rhPDGF-BB) + GTR.

The duration of this study was 12 months following implantation of the study device. Subjects had a maximum of 13 visits, which included a screening visit, 2 pre-surgery visits (if necessary), baseline visit, surgical visit, and 8 post-op visits. The design was similar to those previously used to evaluate regenerative properties of rhPDGF [27–29]. Before study treatment, each subject completed full-mouth scaling and root planing to control the disease process and minimize lesion variability.

Surgical treatment consisted of the administration of local anesthesia followed by reflection of full thickness buccal and lingual flaps to allow visualization of the treatment site. Following debridement of the interproximal defect, conditioning of the root surfaces with a tetracycline paste, and measurements of the intrabony defects, the patients were randomized into the treatment groups. MSCs are commercially available as Osteocel® (Ace Surgical Supply, Brockton, MA, USA) and delivered to our clinical practice frozen on dry ice and stored in a − 80° refrigerator. If a − 80° refrigerator is not available, it can be stored for 2–3 days on dry ice. To utilize the MSCs, the cell preparation is thawed in a room temperature water bath. This takes approximately 15–20 min. The MSCs are delivered in 1 cc aliquots in a plastic container with a Millipore filter screen. The MSCs are washed twice with room temperature sterile saline. After washing, the cells may be used for a period of 5 h. In our office, we will "stack" the surgeries for the 1 cc of MSCs for use in multiple cases. It is important to maintain good sterile tissue management. It should be noted that the particles may be larger than what is normally use for periodontal surgery and we have found that the larger particles may be cut into smaller pieces with an orthodontic scissor. Application of rhPDGF and GTR membrane (RCM membrane, Osteogenic, Texas) for treatment group was applied as previously described [27–29]. The duration of the study was 12 months following surgery. Supragingival cleansing of the test sites was provided as needed. Supportive periodontal therapy was provided every 3 months post-surgically.

The primary goal of this clinical trial was to compare the safety and effectiveness of MSCs ± rhPDGF with or without GTR into intraosseous periodontal defects. Primary endpoints for the study included CAL (clinical attachment level) between baseline and 3, 6, 9, and 12 months; PD (probing depth) reduction between baseline and 6, 9, and 12 months; and GR (change in gingival recession) between baseline and 6, 9, and 12 months. Secondary endpoints consisted of a comparison of increased radiopacity (radiographic fill) of the intrabony defects based on monitoring radiographic films taken at 3, 6, 9, and 12 months as compared to baseline.

7.3.2 Case Series Results

Subjects and Demographics

Seventy-seven subjects were screened and randomized in this study. Approximately 9.01% of enrolled patients had perio-endo complications, and the prognoses of these teeth were deemed hopeless. These patients proceeded with extraction and plans for an implant support crown replacement [30]. No other adverse events or patient withdrawal occurred. The majority of the subjects had defects classified as 3-wall or 2–3-wall combination defects in the apical and coronal portion and located at DB aspects of mandibular second molars (Table 7.1).

Primary and Secondary Endpoints

Primary endpoints consisted of clinical measurements for PD, GR, and CAL (Table 7.2). These probing measurements were assessed at the surgical visit (baseline) and post-periodontal surgery at the 3-, 6-, 9-, and 12-month visits. The improvements in PD and CAL were consistent and were first observable at 3 months posttreatment. There was no statistical difference between the various treatment groups, but the use of resorbable collagen GTR membrane resulted in less than optimal trends than if the defects were treated with either MSCs or MSCs + rhPDGF.

Secondary endpoints consisting of radiographic fill of the intrabony defects were assessed with periapical films at the post-periodontal surgical visits at 6, 9, and 12 months post-surgery as compared to surgical visit (baseline). For these cases, radiographic fill was present after 3 months, and increased radiopacity was evident during the first 12 months (Fig. 7.2). In the selected case, evidence of furcation fill was also seen for maxillary Class III (Fig. 7.4) and mandibular Class II furcation defects.

Table 7.2 Clinical endpoint for treatment population

	Group 1: MSCs	Group 2: MSCs + GTR	Group 3: MSCs + rhPDGF	Group 4: MSCs + rhPDGF + GTR
Initial PD	8.5 ± 1.3 mm	9.1 ± 1.5 mm	8.8 ± 1.3 mm	8.8 ± 1.3 mm
PD at 3 months	3.6 ± 0.7 mm	4.0 ± 4.1 mm	3.8 ± 0.5 mm	3.8 ± 0.5 mm
PD at 6 months	3.2 ± 0.4 mm	3.6 ± 0.9 mm	3.4 ± 0.7 mm	3.4 ± 0.7 mm
PD at 9 months	3.1 ± 0.2 mm	3.5 + 0.9 mm	3.1 ± 0.3 mm	3.1 ± 0.3 mm
PD at 12 months	3.0 ± 0.2 mm	3.5 ± 0.9 mm	3.2 ± 0.4 mm	3.2 ± 0.4 mm
CAL gain at 12 months	5.5 ± 1.2 mm	5.4 ± 1.1 mm	5.5 ± 1.4 mm	4.6 ± 1.7 mm
Gingival recession at 12 months	−0.2 ± 0.7 mm	−0.5 ± 0.9 mm	−0.1 ± 0.3 mm	−0.3 ± 0.7 mm

Other Assessments

Supragingival cleansing of the surgical site was performed 1.5, 3, 6, 9, and 12 months post-surgery. Periapical radiographs were obtained on the day of surgery, as well as 3, 6, 9, and 12 months post-surgery to define bone architecture of the intrabony defects.

Seven subjects experienced adverse events consisting of mild-to-moderate site pain, and two had swelling distal to the study tooth. Though patients with advanced intrabony defects that may be in proximity of the radicular apices were screened by endodontists, seven of the subjects experienced abscesses secondary to putative conversion to a perio-endo infection. These teeth were deemed hopeless and extracted. At the time of this report, four of the patients had these sites restored with implant-supported crowns, and three were awaiting adequate healing to proceed with similar treatment. It should be noted that in trying to "rescue" teeth with poor prognosis and advanced periodontal defects, the risk of some of these teeth progressing into a perio-endo lesion is a risk that must be discussed with your patients. In our practice, by forewarning the patient, they are usually grateful for our efforts to attempt to "rescue" the tooth.

Exemplary Cases

Three cases are presented to demonstrate the regenerative properties of Osteocel®. In the first case, a deep and wide intrabony defect was present on the distal aspect of the mandibular left second molar (Fig. 7.2). There was a 9 mm pocket depth with radiographic presentation of an intrabony defect (Fig. 7.2a, e). Surgical debridement indicated a 7 mm deep and 5 mm wide circumferential defect that wrapped around to the buccal aspect ending in the buccal furcation (Fig. 7.2b). This case was treated with MSCs preparation (Fig. 7.2c). After 12 months of healing, there was improvement in PD and CAL, which was consistent with radiographic fill of the defect (Fig. 7.2d, f). The clinical pattern that we observed with the use of MSCs for periodontal regeneration is large wide defect filled consistently, and the fill is radiographically distinct after 3 months of healing. With other regenerative strategies, this usually will take 6–13 months. This suggests that healing and maturation of the regenerative tissue is accelerated, but this observation needs further confirmation.

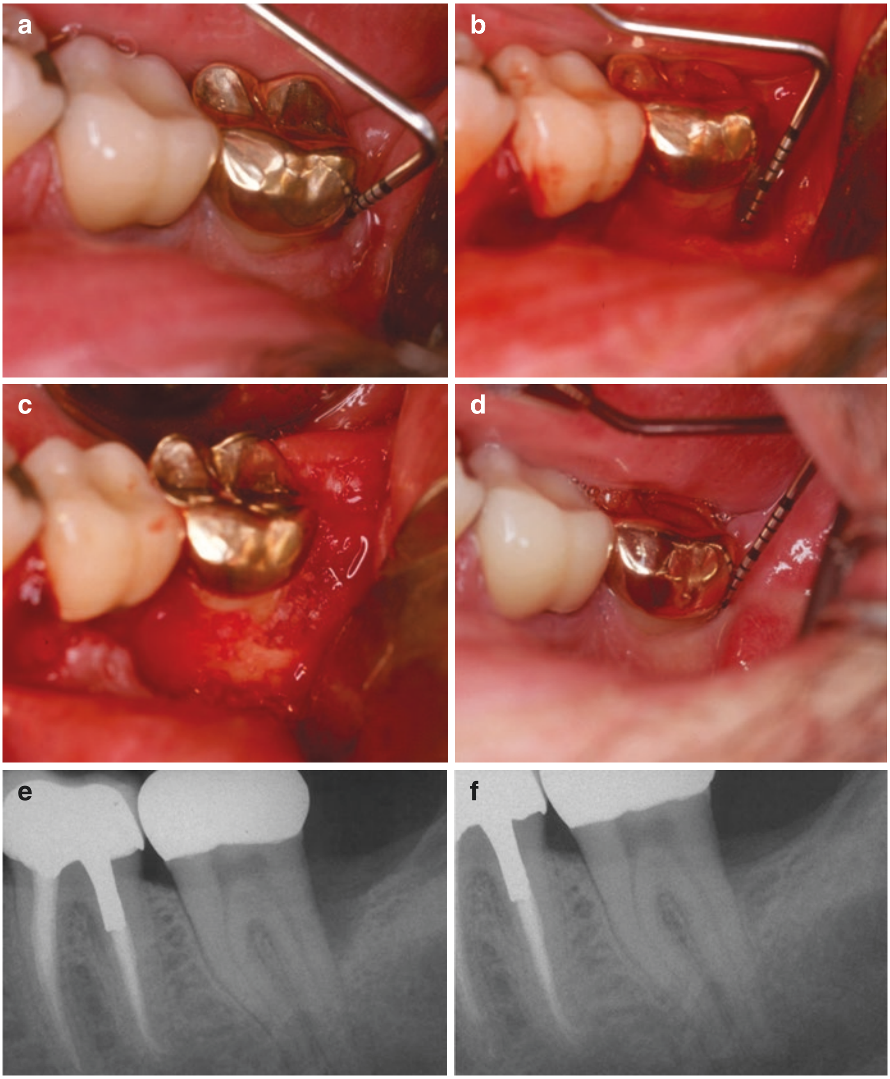

Fig. 7.2 This is a representative case of a deep intrabony defect on the distal aspect of the mandibular left second molar (**a**, **b**). The defect was degranulated and grafted with MSCs or MSCs + rhPDGF (**c**). Clinical improvement was observed 12 months after surgical treatment (**d**). Pre-surgical (**e**) and 12 months posttreatment (**f**) radiographs are presented

The second clinical case involved a strategically important tooth for the patient. This tooth was the mesial abutment of a three-unit fixed prosthesis (Fig. 7.3). Although some may advocate extraction and implant placement, the patient elected to proceed with regenerative therapy due to financial reasons. The initial PD was 8 mm with radiographic presentation of an intrabony defect (Fig. 7.3a, b). Surgical

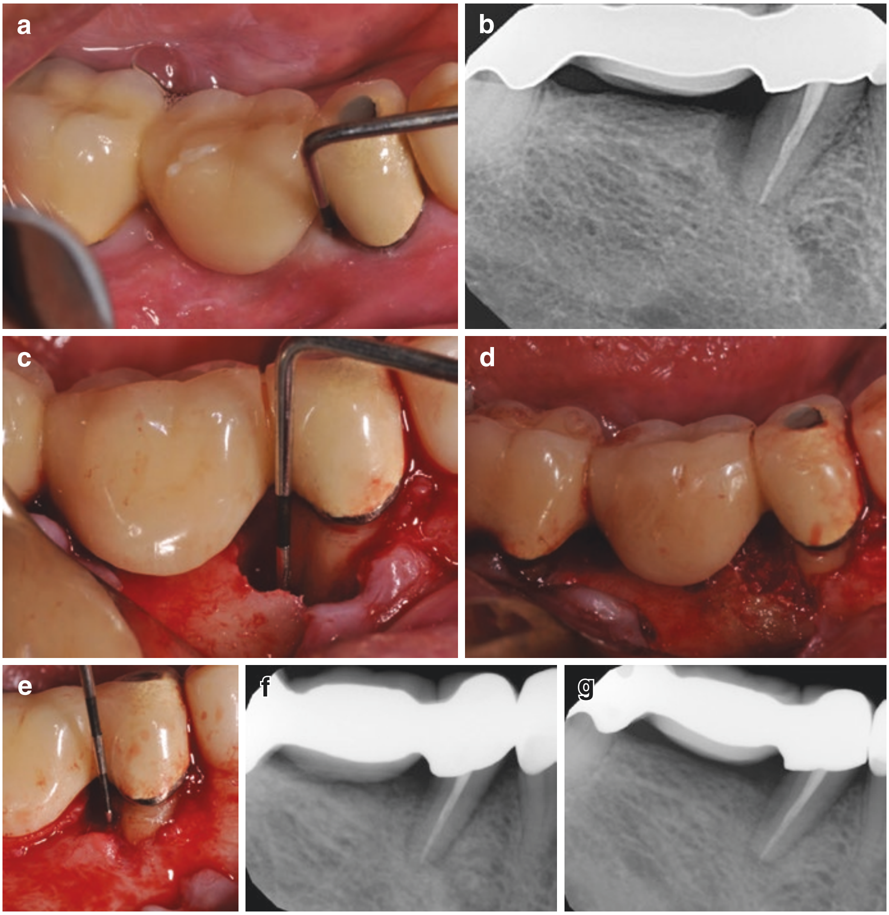

Fig. 7.3 In this case, initial clinical (**a**) and radiographic (**b**) presentation of the mesial abutment of a fixed partial denture. This case was flapped and degranulated (**c**) and grafted with MSCs + rhP-DGF (**d**). At reentry after 1 year to correct the mucogingival defect (**e**), one can see that the initial 8 mm by 5 mm circumferential defect was regenerated to a 1 mm defect. Radiographs at initial visit (**b**) at 3 months (**f**) and after 12 months (**g**) are presented

reflection exposed an 8 mm by 5 mm 3-wall circumferential osseous defect (Fig. 7.3c) that was grafted with MSCs + rhPDGF (Fig. 7.3d). With this wide and deep intraosseous defect, radiographic evidence of regeneration was more apparent after 6 months following the surgery. Due to the lack of attached gingiva, the area was subsequently reentered for mucogingival grafting. This provided an opportunity to visualize the healed defect. Osseous fill was observed and was consistent within the defect (Fig. 7.3e). It can be seen that radiographic bone fill was present at 3 months (Fig. 7.3f) and 12 months (Fig. 7.3g) post-surgery compared to baseline (Fig. 7.3b). This case was impressive, but it should be noted that no supercrestal/

vertical bone growth was observed as reported with the use of iliac crest [1] or MSCs preparation [31].

The third case demonstrated the potential for MSCs preparation to correct furcation defects (Fig. 7.4). This initial observation was reported by Rosen [26] for the correction of a Class III mandibular molar furcation defect. In this case, there was a furcation defect on the upper right first maxillary molar (Fig. 7.4a) that had a buccal

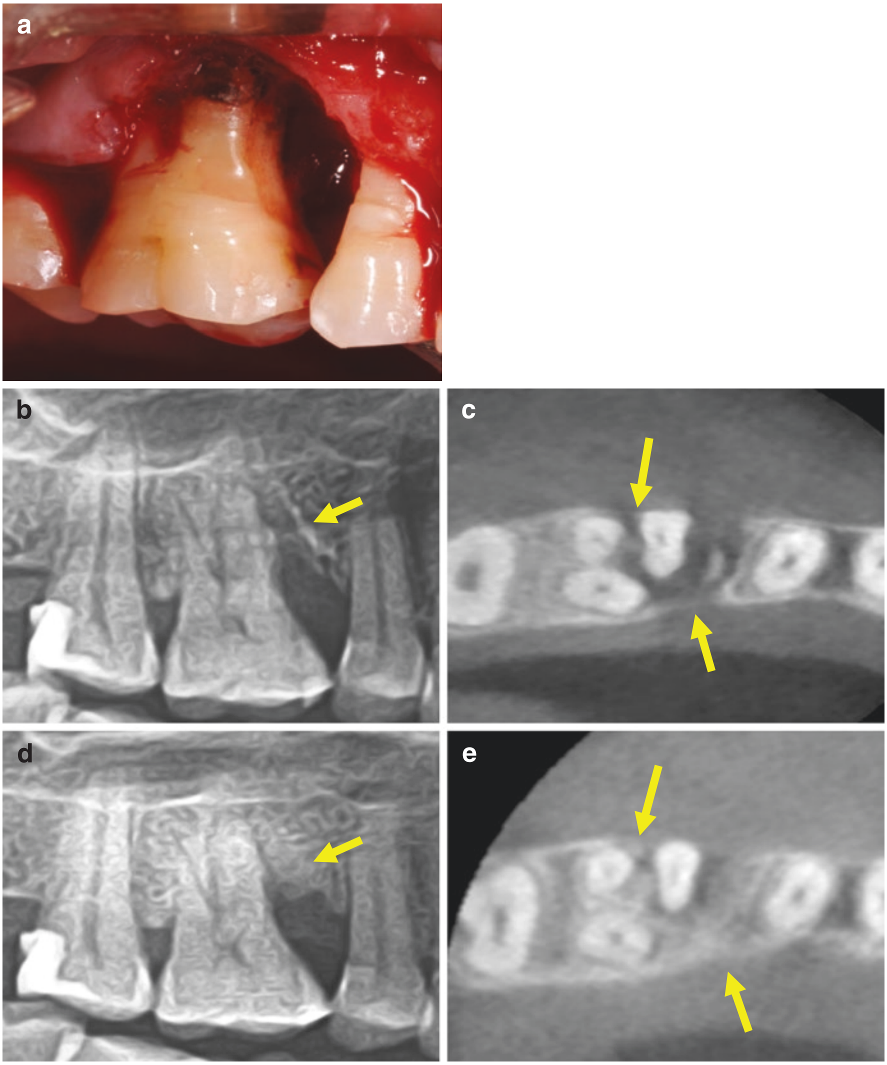

Fig. 7.4 In this clinical case of the upper right first maxillary molar (**a**), one can see there is a Class III B-M furcal communication on both the periapical and CBCT cross-sectional view (**b**, **c**, arrows). After treatment, one can see radiographic fill for this defect (**d**, **e**, arrows). The corrective results are still stable 2 years after the surgical treatment

and mesial communication (Fig. 7.4b, c, arrows). After healing, cone beam computed tomography (CBCT) suggested that the furcation defect was regenerated (Fig. 7.4e, arrows). The corrective results are still stable 2 years after the surgical treatment.

7.4 Discussion

This is a preliminary report of an ongoing case series exploring the attributes of using a commercially available stem cell preparation for periodontal regeneration. This is the first comprehensive examination of the use of MSCs preparation used singularly and in combination with rhPDGF with or without a bioresorbable GTR collagen membrane for correction of periodontal intrabony defects. To date, we have demonstrated that the MSCs preparation resulted in good periodontal regeneration as measured by improvement in pocket depth, CAL gain, and radiographic fill. The resulting clinical outcomes are comparative, or better, to most regenerative approaches (Table 7.3) [3, 5, 13]. The use of MSCs was able to correct deep and wide intrabony defects. Some of the intrabony defects that were contiguous with furcation defects suggests that this MSCs preparation may be a superior grafting material for furcation defects, but this needs further evaluation. Nevertheless, this confirms the recent case report of the correction of a Class III furcation [26] as well as 2- and 3-wall defects [31]. With the addition of rhPDGF and/or the use of GTR membrane, it was found that no additive nor synergistic improvement was observed. This is consistent with other regenerative approaches utilizing FDBA, DFDBA, or EMD and rhPDGF [3, 5, 13].

In this first comprehensive examination of MSCs for periodontal regeneration, the use of MSCs has been shown to be effective for the correction of intrabony defects (Table 7.3). However, it is important to recognize that there are a variety of alternative regenerative strategies. The consideration for using or not using this approach should be based on achievable results on short-term (1–3 years) and long-term (10+ years) outcomes. To date, we have shown that MSCs are effective on the short term (1–3 years). In this prospective clinical study, we will continue to monitor our patient base and define the extent of periodontal breakdown post-MSCs treatment and the putative etiology. The initial apparent advantage of using MSCs is that it is able to correct extremely large defects that are quite wide and deep in morphology. However, a challenging complication observed when trying to treat these types of defects is that a small percentage of these defects may be early perio-endo lesion which may progress to pulpal necrosis. In our study, we observed that 7 of the initial 77 patients had perio-endo complications which converted the poor prognosis to a hopeless prognosis, requiring extraction as per the decision tree previously outlined [13]. Despite these types of complications, the rescue of a tooth, such as that seen in Case 2 (Fig. 7.3), may provide patients with a good treatment option that is both cost effective and more conservative than previously reported regenerative strategies. The results achieved to date suggest that MSCs are as effective as previously reported regenerative strategies.

Table 7.3 Comparison of selected reported regenerative results as compared to regeneration utilizing MSCs

Study	Time (months)	Study design	Treatment (number of defects)	PD change (mm)	*P*	CAL change (mm)	*P*	Linear bone fill (mm)	*P*
Pontoriero et al. [32]	12	Split-mouth	OFD (10)	3.5	<0.001	1.8	<0.001	ND	
			EMD (10)	4.4		2.9			
Silvestri et al. [33]	12	Parallel	OFD (10)	1.4	<0.01	1.2	<0.01	ND	
			EMD (10)	4.8		4.5			
Sculean et al. [34]	12	Parallel	OFD (14)	3.3	<0.05	1.7	<0.05	ND	
			EMD (14)	4.6		3.4			
Silvestri et al. [33]	12	Parallel	GTR (10)	5.9	NS	4.8	NS	ND	
			EMD (10)	4.8		4.5			
Sculean et al. [34]	12	Parallel	GTR (14)	4.2	NS	3.1	NS	ND	
			EMD (14)	4.1		3.4			
			EMD + GTR (14)	4.3		3.4			
Rosen and Reynolds [35]	6	Case series	EMD + DFDBA (10)	8.4	NS	9.2	NS	ND	
			EMD + FDBA (12)	8.9	NS	9.1	NS	ND	
Nevins et al. [28]	6	Parallel	rhPDGF- β-TCP (60)	4.43	NS	3.8	NS	2.6 mm	<0.001
			β-TCP (60)	4.20		3.5		0.9 mm	
Nevins et al. [28]	12	Parallel	rhPDGF- β-TCP (43)	4.46	NS	3.80	NS	2.88 mm	<0.001
			β-TCP (45)	4.08		3.65		1.42 mm	
	24		rhPDGF- β-TCP (29)	4.09	NS	4.09	NS	3.32 mm	<0.001
			β-TCP (29)	3.80		3.31		1.81 mm	
	36		rhPDGF- β-TCP (27)	4.57	NS	4.31			
			β-TCP (28)	4.14		3.44			
Jayakurnar et al. [36]	6	Parallel	rhPDGF- β-TCP	4.3	<0.005	3.7	<0.05	3.7 mm	<0.01
			β-TCP	3.2		2.8		2.8 mm	
Kao and Fagan [This Volume]	6	Case series	MSCs (20)	5.3	NS			ND	
			MSCs + GTR (17)	5.5					
			MSCs + rhPDGF (20)	5.4					
			MSCs + rhPDGF + GTR (20)	5.4					
			MSCs (20)	5.5	NS	5.5	NS	ND	
	12		MSCs + GTR (17)	5.6		5.4			
			MSCs + rhPDGF (20)	5.6		5.5			
			MSCs + rhPDGF + GTR (20)	5.6		4.6			

PD probing depth; *CAL* clinical attachment level

The difficulty with using the combination of MSCs in addition to rhPDGF with/without GTR membrane is that this treatment represents a significant therapeutic cost. These results suggest MSCs to be a superior regenerative material capable of resulting in regeneration in large wide and deep defects. However, the lack of synergistic or additive improvement suggests that there is no basis of utilizing the addition of rhPDGF or GTR approach. This study found no evidence of periodontal regeneration that extended coronally above the adjacent bony walls even when GTR was used. One aspect that may merit further study is whether defects that are 2- or 1-wall defects may be improved with the addition of GTR approach. Use of GTR may improve MSCs regeneration potential in these types of defect as predicted by Reynolds [11].

Clinical application of MSCs as a regenerative device has resulted in several practical implementation approaches in our practice. First is the issue of cost containment. In using MSCs, the use of rhPDGF and GTR membrane may not be indicated and could increase implementation cost. Each allotment of 1 cc of the MSCs can be used in approximately 3–5 large intrabony defects; however, this would require pooling patients needing this procedure so that the MSCs preparation could be effectively distributed. Since the MSCs preparations are shipped on dry ice or require a − 80 °C freezer, equilibration to room temperature will only provide a limited 4–5 h of working time. This must be taken into consideration when performing multiple cases. In this study, we did not dilute the MSCs preparation, but fellow clinicians who use this preparation have done so with DFDA up to 33%. This is a possibility, but we recommend that it be done mostly for implant site preparation. Lastly, the architectural nature of the intrabony defect should be considered. These factors include number of walls containing the defects, extent of defect, blood supply, accessibility for oral hygiene access, and other variables discussed by Reynolds [11].

In situations where there is complete wall containment (i.e., 3-wall and circumferential defects) no GTR membrane is needed. For 1 or 2 walls, or furcation defects, one may consider the use of bioresorbable membrane for defect containment of the graft materials. Lastly, the use of MSCs does not appear to regenerate bone beyond the area supported by bone. To date, only extraoral autogenous bone graft appears to permit significant supra-crestal bone regeneration [1, 3, 11].

Cellular grafting materials and biologics have ushered in an opportunity for clinicians to provide their patients with predictable results that achieve not only quantitative clinical results but also qualitative histologic results demonstrating regeneration of lost periodontium. Clinicians must weigh the benefits versus the risks and cost to determine the best course of treatment for their patients. It should be noted that much of the evidence available is based on limited patient pools. Controlled prospective studies with larger study populations are needed to further determine the clinical promise for stem cell use in regeneration of intrabony defects.

7.5 Conclusions

Tissue engineering is an emerging technology that may significantly improve our ability for regenerating intrabony periodontal defects. Through the use of biologics such as rhPDGF-BB and EMD along with stem cells, we may be able to provide more consistent results and increase periodontal regeneration without the need for secondary surgical donor site. This is an emerging field that requires additional research, but clinicians should be aware of the potential of tissue engineering and monitor its progress.

Conflict of Interest Statement No conflicts of interest have been reported by the above authors.

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Management of Furcation Defects

8

Acela A. Martinez Luna and Fatemeh Gholami

8.1 Introduction

Management of teeth with furcation involvement (FI) has always been a challenge for the clinician. Multi-rooted teeth are difficult to treat and maintain due to the complex anatomy that enhances plaque accumulation and limits access for instrumentation and oral hygiene [1]. In addition, tooth-related factors such as enamel projections (Fig. 8.1) and accessory pulpal canals contribute to FI [2]. Unfortunately, furcation lesions respond differently to periodontal treatment than do flat surfaces [3]. Furthermore, longitudinal studies of periodontal therapy have demonstrated that the prognosis for teeth with FI is worse following traditional scaling, and they are at higher risk of future attachment loss [4].

The grade of FI is an effective factor in determination of the course of treatment and prognosis [5]. Diagnosis of FI is based on clinical examination with a Nabers probe, with the use of two-dimensional radiographs serving as an adjunct. According to a recent systematic review, cone beam computed tomography (CBCT) has high accuracy for furcation involvement detection [6]. However, there is limited evidence to support and justify the use of CBCT for the diagnosis and treatment of teeth with FI at this time [7]. Treatment planning of teeth with FI remains a difficult process for the clinician. This chapter will review and discuss the diverse therapeutic modalities for teeth with FI.

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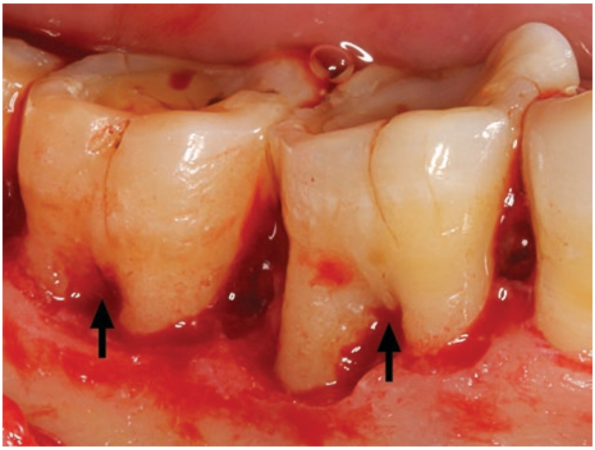

Fig. 8.1 Clinical view of mandibular first and second molars, showing furcation involvement and cervical enamel projections (arrows)

8.2 Resective Therapy

Root resective therapy is a well-known treatment modality for the management of teeth with advanced FI. The main resective procedures utilized to treat FI include root amputation, hemisection, and bicuspidization. Over the years, the use of these techniques has decreased considerably. Some of the possible reasons of this decrease are the reported complications and failure rates and the fact that more predictable therapies such as periodontal regeneration and dental implants are available.

Survival rates of teeth with FI have been published in the literature with heterogenous results. A recent investigation on the retention of molars after root resective therapy over an observational period of 30 years reported a median survival of 20 years and a cumulative survival rate of 90.6% at 10 years that decreased considerably thereafter. The complications that led to tooth extraction included periodontal problems (50%), endodontic problems (26.7%), and caries (16.7%) [8]. If this therapy is selected, it is important to understand that a long-term successful outcome relies on case selection and adequate maintenance, as well as endodontic and restorative treatment [9]. One of the disadvantages of this technique is that after extraction of the root, alveolar bone resorption occurs, leading to a decrease in ridge height and width [10]. This could result in an alveolar ridge deformity and food impaction under the prosthesis and may also compromise the site for future dental implant placement. To decrease the possibility of these complications, guided bone regeneration (GBR) could be used after root extraction to minimize ridge remodeling [9]. Nevertheless, this interesting combination technique (root amputation with GBR) needs to be further studied.

Root resective therapy could be a good treatment option when implant placement is not feasible or needs to be postponed, in cases of severe furcation involvement that cannot be regenerated and in situations that the tooth must be strategically maintained as an abutment of a prosthesis. Another treatment modality for the management of FI is biologic shaping. This technique was introduced as an alternative to traditional crown lengthening and possible use during osseous resective surgery for the treatment of periodontal disease. This procedure removes tooth surface irregularities including concavities, grooves, cementoenamel projections, and FI [11]. In the treatment of FI, class I and II furcation lesions may be decreased or eliminated, and by consequence oral hygiene and maintenance are facilitated. This technique is described in the chapter by Melker et al., in this volume.

8.3 Regenerative Therapy

The scientific literature indicates that regeneration is a more effective surgical approach for treatment of FI in comparison to non-regenerative approaches and is discussed below [12–16].

8.3.1 Guided Tissue Regeneration (GTR) vs. Open Flap Debridement (OFD)

A systematic review and meta-analysis by Murphy and Gunsolley compared GTR to OFD for treatment of intrabony defects and FI. The results of this study revealed that the GTR group had statistically significant higher horizontal defect fill (0.8 mm) and vertical attachment level (VAL) gain (0.86 mm) compared to the OFD group [17]. Another systematic review and meta-analysis by Jepsen et al. evaluated the treatment of FI by regeneration vs. OFD. Fourteen studies were included based on the inclusion criteria. The authors concluded that GTR is a better treatment approach for class II mandibular (mean difference, 1.5 mm) and maxillary molar (mean difference, 1.05 mm) defects [18]. Reynolds et al. assessed bone replacement grafts vs. OFD for treatment of intrabony defects and FI. From this systematic review, they concluded that bone replacement grafts are more effective than non-regenerative treatments such as OFD for FI treatment and intrabony defects [16]. The long-term survival rate associated with GTR has been reported to be as high as 83–100% after 5–12 years, which is better than other treatment modalities such as OFD, tunneling, root amputation, and hemisection [19].

8.3.2 Membrane vs. No Membrane

A systematic review published by Kinaia et al. compared the effectiveness of GTR using a resorbable membrane vs. OFD, non-resorbable membrane vs. OFD, and resorbable membrane vs. non-resorbable membrane for treatment of FI. This study concluded that GTR with resorbable membrane has significantly better vertical clinical attachment level (VCAL) gain in comparison to OFD (mean combined difference, 0.88 mm) and greater reduction in vertical pocket depth (VPD) (mean combined difference, 0.73 mm), greater horizontal bone fill (HBF) (mean combined difference, 0.98 mm), and vertical bone fill (VBF) (mean combined difference, 0.78 mm). For non-resorbable membranes in GTR, better results were reported compared to OFD in terms of VPD reduction (mean combined difference, 0.75 mm), VCAL gain (mean combined difference, 1.41 mm), HBF (mean combined difference, 1.16 mm), and VBF (mean combined difference, 0.58 mm). This study indicated that resorbable membranes were better than non-resorbable membranes in vertical bone fill for the treatment of FI [14].

8.3.3 Combination Therapy: GTR + Bone Graft

A meta-analysis performed by Chen et al. assessed GTR with or without bone grafting for the treatment of class II FI. In mandibular molars, it was shown that VCAL was significantly better using GTR with bone graft compared to OFD (weighted mean difference, 1.53 mm), while GTR with bone graft was a better treatment option than GTR alone (weighted mean difference, 0.47 mm). Regarding maxillary furcations, GTR and bone graft were better than GTR alone (0.86 mm in favor of GTR and bone graft vs. GTR alone). Therefore, this analysis concluded that GTR and bone grafting are the best treatment modality for class II FI [15].

8.3.4 Biologic Agents

Recently more attention has focused on the use of biologic agents such as enamel matrix derivative (EMD), recombinant human platelet-derived growth factor-BB (rhPDGF-BB), and autologous plasma concentrates for regenerative treatment of FI.

8.3.5 Enamel Matrix Derivative (EMD)

In a randomized control trial (RCT) by Casarin et al., the application of EMD was compared to OFD for treatment of FI. It was concluded that EMD therapy promoted a reduction in the number of proximal furcations presenting a diagnosis of class II after 24 months of treatment compared with OFD therapy [20]. A second RCT compared the use of EMD to a membrane. The EMD group showed significantly more improvement in horizontal furcation defect (HFD) than the membrane group [21]. Unfortunately, there are few RCTs on the use of EMD for treatment of FI at this time.

8.3.6 Recombinant Human Platelet-Derived Growth Factor-BB (rhPDGF-BB)

Nevins et al. evaluated effects of rhPDGF-BB on FI treatment in a RCT. They compared rhPDGF-BB with OFD and reported significant CAL gain and PD reduction in the test group compared to baseline ($P < 0.001$) but demonstrated no significant differences between the test and control groups. In the other hand, Howell et al. reported significant radiographic bone height gain with the use of rhPDGF-BB at 9 months compared to OFD (54% BF vs. 12% BF). The authors concluded that application of rhPDGF-BB is beneficial for treatment of intrabony defects and FI [22–24].

8.3.7 Autologous Plasma Concentrates (PCs)

Autologous PCs have been utilized in periodontal regeneration and treatment of FI alone or in combination with grafting materials with the aim to enhance the healing capacity of soft and hard tissues. The rationale behind the use of PCs is to capitalize on the polypeptide growth factors (PGFs) such as PDGF (platelet-derived growth factor), transforming growth factor-β (TGF-β), and insulin-like growth factor (IGF) contained in the concentrates. These growth factors have an important role in chemotaxis and cell proliferation and differentiation [25]. There is limited evidence regarding the use of PCs alone for the treatment of FI. This section will focus on the use of PC alone due to the confounding factors when utilized in combination with grafting materials and/or membranes.

A randomized clinical trial evaluated the effectiveness of autologous platelet-rich plasma (PRP) in the treatment of mandibular degree II furcation defects compared with OFD using a split-mouth approach. There was a statistically significant difference in all clinical and radiographic parameters at furcation sites treated with PRP as compared to OFD alone. However, there was incomplete closure of the furcation in both groups [26]. Another randomized clinical trial from the same institution evaluated the effectiveness of platelet-rich fibrin (PRF) alone in the treatment of mandibular degree II furcation defects compared with OFD using a split-mouth approach. At 9 months postoperatively, all the clinical and radiographic parameters showed statistically significant improvement at the sites treated with PRF as compared to OFD. An important finding of this study is that 66.7% of FI defects treated with PRF had complete clinical closure [27]. Interestingly, a randomized clinical trial compared the use PRP or PRF alone to OFD in the treatment of mandibular degree II furcation defects. Clinical and radiographic parameters demonstrated statistically significantly improvement for both PCs as compared to OFD. However, there was no statistically significant difference between the PRP and PRF groups [28]. The limited current evidence shows improvement in clinical and radiographic parameters that could be beneficial in the treatment of FI. However, further clinical and histologic studies are needed to confirm the regeneration potential of autologous PCs.

8.3.8 Class II Furcation Involvement

In 2015, Graziani evaluated OFD for the treatment of class II FI by a systematic review of RCT studies. They assessed tooth survival and change in the horizontal clinical attachment level (HCAL), vertical clinical attachment level (VCAL), reduction of pocket probing depth (PPD), recession increase (REC), horizontal bone level (HBL), and vertical bone level (VBL). The weighted mean differences for HCAL were 0.96 mm [CI: (0.60, 1.32), $p < 0.001$] and 0.55 mm [CI: (0.00, 1.10), $p = 0.05$] for VCAL gain. PPD reduction over 6 months was 1.38 mm [CI: (0.91, 1.85), $p < 0.01$]. The authors concluded that the clinical performance of conservative surgery, such as OFD, in the treatment of furcation defects may represent a valid cost-effective treatment solution for class II, particularly mandibular defects, mainly when other therapeutic options are not applicable either for anatomical or patient-related factors [29].

The current systematic review from American Academy of Periodontology (AAP) regeneration workshop assessed the available evidence for effectiveness of different regenerative approaches. Avila-Ortiz et al. selected 150 articles of which 6 were systematic reviews, 109 were clinical trials, 27 were case series, and 8 were case reports. In this review, they examined specific clinical scenarios and revealed that regenerative approaches are predictable treatment options for class II furcation (Fig. 8.2a–d) defects on the buccal, mesial, and distal of maxillary molars and

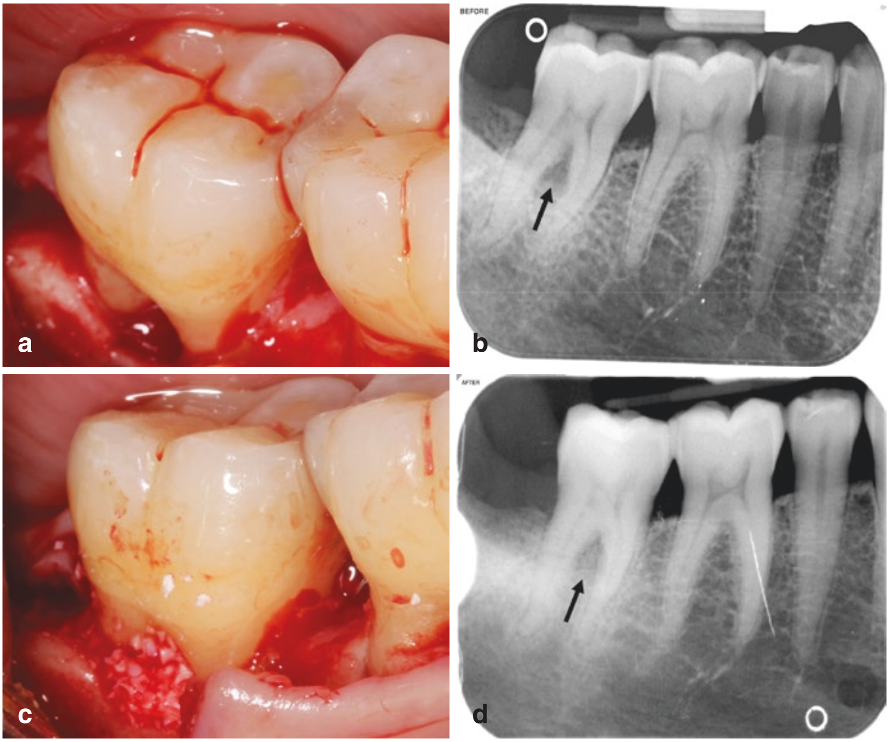

Fig. 8.2 Regeneration procedure performed on a mandibular second molar with furcation involvement. (**a**) Preoperative radiograph and (**b**) flap reflection demonstrating class II furcation involvement. (**c**) Placement of EMD and xenograft. (**d**) Postoperative radiograph taken at 6 months demonstrating radiographic evidence of bone fill in furcation. Photos courtesy of Dr. Bruno Herrera

buccal and lingual of mandibular molars. However, regeneration for class III molars is not predictable based on current evidence [12].

According to a consensus report from the AAP Regeneration Workshop and based on available evidence, it was concluded that "(1) Regeneration has been demonstrated histologically and clinically for the treatment of Class II furcation defects (2) Although periodontal regeneration has been demonstrated histologically for the treatment of mandibular Class III defects, the clinical evidence is limited to one case report (3) Evidence supporting regenerative therapy in maxillary Class III furcation defects in molars and premolar furcation defects is limited to clinical case reports, which reported unpredictable outcomes; and (4) In Class I furcation defects, regenerative therapy may be beneficial in certain clinical scenarios, although most Class I furcation defects may be successfully treated with non-regenerative approaches" [30].

8.3.9 Endoscope

The use of an endoscope in periodontology was proposed to overcome the limitations of closed scaling and root planing (SRP). This device was designed to explore and visualize subgingival deposits and serve as an adjunct in SRP thanks to magnification of the root surface (24–28×) and visualization through a monitor [31]. Ultrasonic scalers, curettes, explorers, and probes have been modified for use with the dental endoscope. Due to the difficulties encountered during instrumentation, the use of an endoscope could theoretically serve as a useful adjunctive tool for treatment of molars with FI. Unfortunately, the literature is scarce. A study on multi-rooted teeth showed that the use of an endoscope provided no significant improvement in calculus removal when used as an adjunct to SRP [32]. Even though furcations can be visualized with this device, the ability to instrument this area is difficult due to anatomy and limited access [33]. However, endoscope therapy could be effective around single-rooted teeth, but not as effective for multi-rooted teeth [34, 35]. Further clinical studies reporting on clinical parameters are needed to justify the use of the endoscope in the nonsurgical treatment multi-rooted teeth.

8.3.10 Laser Therapy

The use of lasers in the treatment of periodontal disease has been controversial. According to the 2018 AAP best evidence consensus on the efficacy of laser therapy on the treatment of periodontitis, lasers show similar or slightly improved clinical outcomes when utilized as an adjunct to mechanical therapy. In addition, when utilized as adjunct to periodontal surgery, most of the evidence suggest no additional benefit [36].

In regard to the use of lasers for the treatment of FI, the literature is very limited as the majority of the available literature does not report if laser-treated sites included lesions with FI. In a double-blind RCT, clinical parameters and bacterial reduction of class II furcation lesions treated with conventional SRP only or SRP

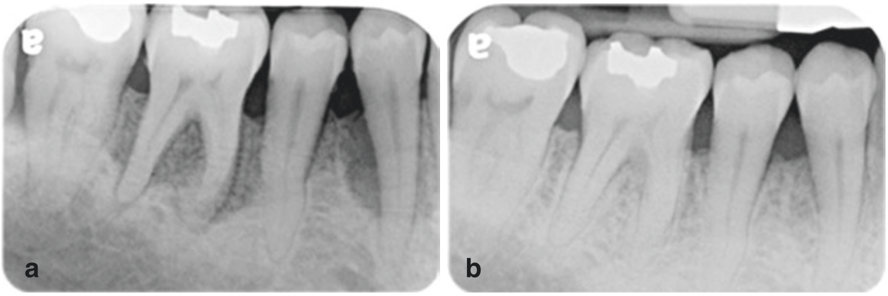

Fig. 8.3 Laser therapy in the treatment of furcation lesions. (**a**) Preoperative radiograph showing mandibular first molar with class II furcation involvement. (**b**) 2-Year postoperative radiograph after treatment with LANAP® protocol (Nd:YAG laser) showing increased radiographic bone fill. Images courtesy of Dr. Steve Hamrick

followed by neodymium:yttrium-aluminum-garnet (Nd:Yag) laser were evaluated. The results demonstrated that Nd:YAG laser significantly reduced the total bacteria colony-forming units (CFU) immediately after irradiation. However, there were no significant differences in bacterial reduction or clinical parameters between both groups at 6 weeks [37]. To date only one human histologic study showed some evidence of furcation regeneration following the use of an Nd:YAG laser (Fig. 8.3a, b) [38]. A few animal studies have assessed the use of lasers for the treatment of FI. A study in dogs investigated the use of a CO_2 laser for the treatment of experimentally induced class III furcation defects. This study showed that the use of laser promoted regeneration was superior to GTR and SRP in terms of attachment gain [39]. Another dog study investigated the effect of an erbium-doped yttrium aluminum garnet (Er:Yag) laser in experimentally induced periodontitis in the furcation as compared to traditional debridement. New bone formation was significantly greater in the laser group. However, both groups showed similar amounts of cementum formation and connective tissue attachment [40]. Lastly, a study of experimentally induced periodontitis in rats showed greater bone formation in the furcation area when an erbium, chromium:yttrium-scandium-gallium-garnet (Er, Cr:YSGG) was utilized for subgingival treatment [41]. In regard to human studies, a split-mouth clinical trial was conducted to assess the clinical efficiency of an Er,Cr:YSGG laser in the treatment of FI classes II and III as compared to manual subgingival debridement at 6 and 12 weeks. This study concluded that the use of an Er,Cr:YSGG laser significantly decreased PD and BOP, as well as the pain score [42]. In summary, further studies are needed to justify the use of lasers in the treatment of FI.

8.3.11 Photodynamic Therapy

Photodynamic therapy (PDT) is a noninvasive therapeutic method that has been utilized in periodontology as an adjunct to mechanical debridement during initial phase, nonsurgical therapy, and maintenance phase. In theory, PDT could serve as an adjunct to the treatment of teeth with FI due to the limited access for instrumentation. This technique consists of light-mediated activation of a photoactivable non-toxic chemical agent, such as toluidine or methylene blue, that is applied into the pocket. The lethal photosensitization of microorganisms causes changes in the bacterial membrane and DNA damage [43]. The main advantage of this technique is that it possesses an antimicrobial effect without the side effects associated with systemic antibiotics and the risk of microbial resistance [44]. According to the current evidence, when PDT is utilized as an adjunct to mechanical therapy, modest improvements in probing depths and clinical attachment levels can be obtained [36]. Unfortunately, there is a limited number of studies regarding the use of PDT in the treatment of FI. A histomorphometric study evaluating the effect of PDT on furcal bone loss in rats with experimentally induced periodontitis showed that the group treated with PDT demonstrated less bone loss as compared to other groups [43]. In contrast, a randomized clinical trial showed that PDT did not provide additional improvements in terms of clinical parameters in the treatment of class II furcation lesions. However, PDT demonstrated a reduction in periodontopathogens and pro-inflammatory cytokines [45]. Further clinical studies with longer follow-up periods are necessary to justify the use of this therapy for the treatment of FI.

8.3.12 Local Antimicrobials

The use of local antimicrobials as an adjunct to subgingival debridement in deep and recurrent pockets has demonstrated improvements in clinical parameters (PD reduction and CAL gain) [46]. However, there is no evidence to support the use of local antimicrobials in furcation lesions during initial or supportive periodontal therapy (SPT). Human studies have found that the use of tetracycline fibers in conjunction with SRP in class II mandibular furcations during SPT did not show CAL gain [47]. Further, the use of locally delivered doxycycline did not enhance any improvement in furcation lesions [48] or reduced the frequency of reinstrumentation up to 12 months at furcation sites [49]. Subgingival ultrasonic instrumentation irrigated with essential oils (EO) or chlorhexidine does not improve clinical parameters, with the exception of BOP, which was reduced by the use of EO [50]. Similarly, the use of topically applied polyvinylpyrrolidone and iodine (PVP-I) during initial therapy in class II furcation lesions did not provide any clinical benefit [51].

8.3.13 Systemic Antimicrobials

The adjunctive effect of systemic antimicrobials on the treatment of periodontitis has been widely studied. Meta-analyses have demonstrated that there is additional PPD reduction and CAL gain when systemic antibiotics are used in conjunction with mechanical therapy [52, 53]. It could be assumed that this combination therapy could have a beneficial effect on teeth with FI. To the best of our knowledge, the adjunctive effect of systemic antibiotics at furcation sites has been addressed in only one study that evaluated the clinical effect of amoxicillin and metronidazole as an adjunct to mechanical debridement. In spite of the fact that there was a significant attachment gain and decrease in PPD and BOP, the change of furcation degrees was small. Therefore, the use of systemic antimicrobials did not show a clinically relevant benefit in the treatment of FI [54].

8.3.14 Statins

Statins are mainly utilized as lipid-lowering drugs to prevent cardiovascular disease. In addition, these drugs also possess properties relevant to the treatment of periodontitis [55]. Statins are anti-inflammatory [56], antimicrobial [57], and antioxidative [58], and they also have anabolic and anti-resorptive effects in the bone [59–61]. Due to the aforementioned effects, these drugs have been used as an adjunct to nonsurgical and surgical periodontal therapy for the treatment of periodontitis and intrabony defects. Systematic reviews and meta-analyses have found significant additional clinical and radiographic improvements when locally delivered [55, 62]. However, there is a paucity of data in regard to the use of statins for the treatment of FI. A recent RCT evaluated the effect of rosuvastatin (RSV) gel combined with autologous PRF and hydroxyapatite (HA) bone graft in the surgical treatment of mandibular class II furcation defects as compared to OFD + placebo gel and OFD + PRF + HA. There were statistically significant differences among the groups; the use of 1.2 mg in situ gel with PRF and HA bone graft showed greater PD reduction, horizontal and vertical CAL gain, IBD reduction, and bone defect fill [63]. Another RCT investigated the efficacy of 1.2% RSV and 1.2% ATV gel as an adjunct to SRP for the treatment of class II furcation defects. Both statin gels were applied at the time of SRP and at a 6-month recall appointment. The RSV group showed significant improvement in PD reduction, vertical and horizontal CAL gain, and defect depth reduction as compared to the ATV group [64]. The use of RSV appears to be promising in the treatment of FI. However, further studies are required.

8.3.15 Prognosis

Several studies have assessed the risk factors associated with the longevity of multi-rooted teeth. In these studies, particular attention was given to the degree of FI in relation to the risk of molar loss. A retrospective study of multi-rooted teeth in patients that received active and SPT found that class I FI was not associated with tooth loss when compared to teeth with no FI. However, FI class II (Fig. 8.4), FI class III (Fig. 8.5), smoking, and lack of compliance represented risk factors for molar tooth loss, especially in combination [65]. It is important to point out that this group of patients was treated with a variety of therapeutic approaches including OFD, periodontal regeneration, tunneling, and root resection. Another retrospective

Fig. 8.4 Class II furcation involvement on a mandibular first molar

Fig. 8.5 Class III furcation involvement on maxillary first molar. Photos courtesy of Dr. Salvador Nares

study evaluated the long-term prognosis factors for the loss of molars with different degrees of FI during SPT. In contrast to the previous study, this group was treated with conservative non-regenerative treatment. FI, bone loss, mobility, pocket depth, and age were strong predictors of tooth loss. Molars with FI class III and advanced bone loss presented a worst prognosis. However, long-term retention of periodontally compromised molars was achieved [66].

A recent systematic review and meta-analysis investigated the risk of tooth loss in molars with FI treated with different treatment modalities. Unfortunately, it was not possible to analyze the risk of tooth loss based on the treatment provided. Nevertheless, it was concluded that the presence of FI doubles the risk of tooth loss of molars during SPT for up to 10–15 years. A gradual increase in the risk of tooth loss was observed in molars with FI classes II and III. Despite these findings, most molars even with FI class III responded well to periodontal therapy (only 30% were lost in a follow-up period of 10–15 years) [67].

Studies on FI have focused on the horizontal component as a predictive value for tooth survival. Since the residual periodontal support on each root of teeth with FI is likely to influence tooth survival, recent studies have evaluated the impact of vertical subclassification on tooth retention. A clinical study on retention of molars with class II FI found that the vertical subclassification of furcation involvement was a good predictor of survival. This evidence suggests that a vertical subclassification should be considered when assigning prognosis and developing treatment protocols for teeth with FI [68]. Similarly, a retrospective analysis that assessed the effect of horizontal and vertical FI on molar survival of teeth treated with several therapies and under SPT also found that the vertical component is associated with increased risk of tooth loss [69]. The aforementioned investigations agree with previous studies in the fact that teeth with FI have a poorer long-term prognosis [70, 71]. But most importantly, they provided additional information on the prognosis of teeth with FI.

Significant heterogeneity in survival rates of teeth with FI was reported in a systematic review that evaluated the effect of various periodontal therapeutic approaches after an observation period of at least 5 years. The survival rate of molars treated nonsurgically was >90%, 43.1–96% for surgical therapy, 42.9–92.9% for tunneling procedures, 62–100% for resective procedures, and 83.3–100% for guided tissue regeneration (GTR). Vertical root fractures and endodontic failures were the most frequent complications following resective procedures [19]. Since novel techniques such as lasers and diverse regenerative materials are being utilized in contemporary practice, randomized clinical trials and long-term studies are needed in order to evaluate patient-related outcomes and tooth survival of teeth with FI based on the treatment performed. This information is required to decide on the type of therapy for retaining a molar with FI or possibly extract the tooth.

8.3.16 Furcation Treatment vs. Dental Implant Placement

To date, there is scarcity of data on tooth survival in surgical furcation therapy vs. extraction and implant placement, and there are no clear guidelines for the treatment of FI [19]. In addition, it is important to consider the prosthetic and endodontic status in the decision to retain or extract a tooth [66]. Since treatment costs may influence the patient's decision, a study assessed the cost-effectiveness of retaining teeth with FI via periodontal therapy vs. tooth replacement with implant-supported crowns (ISCs). Within the limitations of the study, the authors concluded that most strategies for retaining molars with FI were more cost-effective than implant and ISCs [72].

Replacement of teeth with dental implants is initially expensive [73], and additional procedures such as GBR and sinus elevation may be required. A pilot study analyzed the interfurcal bone height in relation to the need of sinus floor elevation in periodontal patients with FI in case tooth replacement with an implant was planned. This investigation found that the majority of these molars had a significantly reduced interfurcal bone height, particularly with at least two sites with residual PPD of ≥6 mm. Therefore, it was concluded that this was a predictor for further sinus elevation [74].

Complications with dental implants generate additional and potentially high costs [75], especially if technical and biological complications arise [76]. This may be particularly relevant to patients with a history of periodontal disease. Indeed, despite conflicting reports, the majority of longitudinal and cross-sectional studies show that a history of periodontitis constitutes a risk factor and indicator for peri-implantitis [77]. This recent evidence could serve as an aid in the decision-making process of treating molars with FI or replacing them with an implant. From the literature it appears that despite the high success rates of dental implants, every effort should be made to retain teeth with FI. However, further studies are needed in order to design treatment algorithms and clinical guidelines.

8.4 Conclusions

This chapter reviewed the multiple therapeutic approaches as well as the most recent evidence for the treatment of FI. It can be concluded that resective techniques can be considered as a viable option for the treatment of FI, given that case selection and maintenance are adequate. In general, most of the regeneration literature and novel techniques focus on infrabony defects or combined defects (Fig. 8.6) rather than FI alone. Further studies with longer follow-up periods are needed to elucidate the regenerative potential of lasers, autologous PCs, biologic agents, and statins in the treatment of FI. Overall, there is solid evidence to support the treatment of teeth

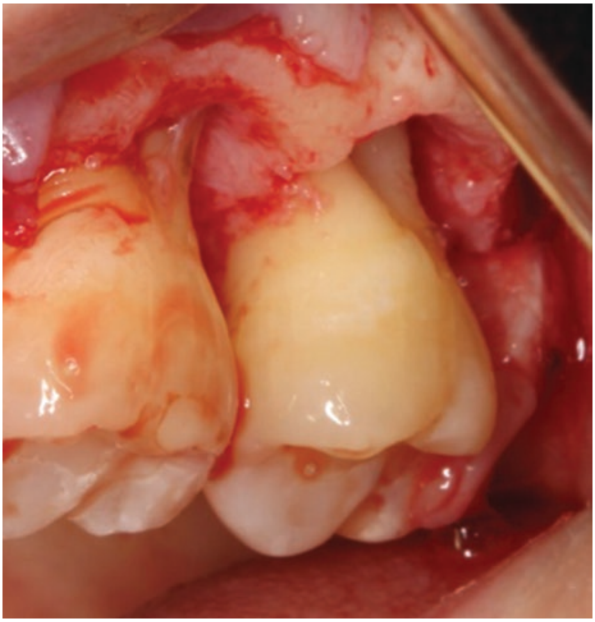

Fig. 8.6 Class II furcation involvement and infrabony defect on maxillary second molar. Photos courtesy of Dr. Justin Valentine

with FI especially classes I and II and that every attempt must be made by the clinician and patient to increase tooth retention and longevity after consideration of patient desires and overall treatment goals.

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Part IV

Mucogingival and Periodontal Plastic Surgery

9 Coronally Positioned Flaps and Tunneling

Homayoun H. Zadeh and Alfonso Gil

9.1 Introduction

Patients often present with a variety of soft tissue defects around teeth and implants that can lead to functional and esthetic problems. An array of surgical procedures has been developed to manage these soft tissue defects. The initial procedures were mainly resective in nature and aimed at correcting aberrant frenum attachments, shallow vestibules, and inadequate attached gingiva. These procedures were collectively referred to as "mucogingival surgery" [1]. In recent years, surgical procedures to deal with soft tissue deficiencies have been refined and have incorporated regenerative therapies, as well as adopted the goal of esthetic enhancement. This broadening of the range of surgical procedures leads to the introduction of "periodontal plastic surgery," as a new term, coined by Miller [2]. Soft tissue abnormalities could be treated in a predictable manner, improving soft tissue health, function, and esthetics [3].

9.2 Scope of the Problem: How Common Is Gingival Recession?

Gingival recession is characterized by apical migration of the gingival margin from the cementoenamel junction (CEJ), with concomitant exposure of the root surface. The root exposure associated with gingival recession can have negative

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esthetic sequelae, as well as predispose the site to dentinal hypersensitivity and root caries [4].

The prevalence of gingival recession can vary substantially among the specific study populations. In North America, it has been described in one epidemiological study in 78–100% of middle-aged individuals, potentially affecting 22–53% of the teeth [5]. In another study, the prevalence of 1 mm or more recession in American population aged 30 years and older was 58% and increased with age [6]. In Brazil, a more recent study showed that 89% of the adults presented with gingival recession [7]. In addition, other epidemiological studies demonstrated that adult subjects showed a prevalence of gingival recession of 51% in Norway [8] and of 68% in Finland [9]. Overall, gingival recession is a highly prevalent condition, which progressively increases with age.

9.3 Etiology

The identification of potential etiological factors in the induction of gingival recession is critical in managing those risk factors in the course of therapy. The literature has described many possible factors, though their causality has not been established. Anatomical, physiological, pathological disease-related, and mechanical factors have been suggested [10, 11].

Periodontal or tooth anatomy can play a role in the apical migration of the gingival margin. Inadequate zone of attached gingiva, high frenum or muscle insertions, tooth malalignment, and excessive root prominences with associated thin alveolar bone are believed to predispose to the development of recession. Ectopic positioning of roots outside of the alveolar bone envelope, following orthodontic tooth movement, may also lead to gingival recession. Mechanical trauma encompasses various forms of injury to the tissue, including improper tooth brushing, intraoral piercings, prosthetic appliances, aggressive tooth preparation procedures, overhanging restorative margins, invading the biologic width, and tobacco chewing.

Pathologic conditions, such as inflammation associated with periodontitis, lead to apical migration of periodontal attachment and in some cases, resulting in gingival recession.

Successful therapy is predicated on effective removal of the causative factors prior to any periodontal plastic procedure to avoid recurrence.

9.4 Risk Assessment

In addition to the etiological factors, there are certain patient- and site-related factors that can put patients at a greater risk for developing gingival recession. Increased age, male gender, high plaque index, tobacco smoking, and number of missing teeth are patient-related factors that have been associated with the extent and severity of gingival recession [12, 13]. Malpositioned teeth (rotated or too buccally/lingually inclined), teeth with a thin gingival biotype, with excessive frenum pull, with advanced periodontal disease, and/or with subgingival restorative margins have also been correlated with a higher possibility of gingival recession. Although each of these factors has been associated with gingival recession, the presence of multiple factors may significantly increase the risk of developing or exacerbating gingival recession. Therefore, risk assessment should consider each of the elements as well as the number of risk indicators identified in order to develop an effective strategy to mitigate those risks.

9.5 Classification of Gingival Recession Defects

Different classification systems have been used throughout the years to describe gingival recession. Initial attempts at classification measured recession width and depth to classify recession into four categories using the descriptive terms "shallow," "deep," "narrow," and "wide" [14]. The index of recession (IR) was later introduced and was mainly used in cross-sectional and longitudinal epidemiological studies to describe the prevalence, incidence, and severity of gingival recession [15]. It categorized recession by two digits, separated by a dash, such as "F3–6." The letter F or L referred to facial or lingual recession, respectively. The digits denote the horizontal width and vertical height of the recession. The classification proposed by Miller is currently the most widely used classification [16]. This system is based on vertical soft tissue loss in relation to the mucogingival junction (MGJ), as well as the level of interproximal periodontal tissue loss. It categorizes defects into four classes. Miller Class I describes gingival recession, which ends coronal to the MGJ, whereas the denuded root defect extends to the MJG in Class II. The interproximal attachment and bone are intact in Class I and II gingival recession defects, while it is mild/moderate in Class III and severe in Class IV, extending beyond the midfacial recession. Miller correlated the classification to the expected prognosis of root coverage, where complete root coverage was predicted in Class I and II, while only partial root coverage was expected in Class III defects, and unpredictable outcome was anticipated in Class IV sites.

The scientific community has expressed some doubts of this classification system, including the uncertainty of the amount of interproximal attachment loss, the unknown influence of tooth malposition, and the difficult distinction between Class I and II gingival recession. To solve such limitations, Cairo introduced a new classification system, based on the identification of the interproximal clinical attachment level to predict the outcome of therapy [17]. Three recession categories were described in this classification: RT1, exhibiting no interproximal attachment loss; RT2 showing interproximal attachment loss equal or less than the facial defect; RT3 presenting with interproximal attachment loss greater than the facial defect. The degree of facial root coverage anticipated by the RT classification was projected to be limited by the interproximal attachment level. Therefore, root coverage has been suggested to be more predictable in RT1 and RT2 than RT3.

9.6 Rationale for Therapy

9.6.1 Progression of Gingival Recession with or Without Therapy

Multiple lines of evidence have suggested that gingival recession defects are progressive in nature. A longitudinal study with 12-year follow-up demonstrated that gingival recession increases with age and sites with existing gingival recession are at the greater risk of progression [18]. In a retrospective 10- to 27-year follow-up split-mouth study, gingival recession defects, lacking attached gingiva treated with free gingival graft on one side of the mouth, were compared with untreated contralateral sites [19]. Results demonstrated that treatment was effective, since all treated sites exhibited reduced gingival recession and increased stable keratinized gingiva. In contrast, untreated sites showed increased gingival recession during follow-up period.

A systematic review and meta-analysis of untreated gingival recession defects has indicated increased risk of progression of recession during long-term follow-up [20]. There is also some limited evidence to support a protective role for keratinized gingiva in reducing the likelihood of gingival recession progression. As a result, the surgical correction of these defects via soft tissue augmentation and root coverage appears as an important intervention to be considered during the clinical decision-making process.

There are four main indications for the surgical treatment of gingival recession [21–23]:

1. Esthetic purposes
2. To reduce dentinal hypersensitivity
3. To augment a deficient keratinized tissue
4. To correct root abrasion defects or caries

Esthetic Reasons

The main reason that drives many patients to seek periodontal treatment are esthetic concerns. Patients demand treatment when excessively long teeth and/or a lack of harmony in the gingival margins are evident while smiling. The most feasible treatment to correct this esthetic gingival imbalance is root coverage procedures. A recent systematic review of randomized controlled trials demonstrated that periodontal plastic surgery procedures for the treatment of single and multiple gingival recessions improve esthetics, both perceived by patients and objectively assessed by professionals [24].

Hypersensitivity

Teeth with gingival recession often experience pain in response to thermal, chemical, and tactile stimuli to the exposed dentine. This phenomenon is known as "dentinal hypersensitivity." The pain is commonly sharp, short, and localized and can severely affect performance of proper oral hygiene. The treatment for dentinal hypersensitivity can be complex and may include local application of desensitizing agents to occlude exposed dentinal tubules for mild cases with no esthetic concerns. Cervical restoration can be performed in cases where there has been enamel loss, exposing dentine coronal to the CEJ. Surgical intervention to achieve root coverage is another strategy, primarily indicated when complete root coverage can be predicted. A systematic review has suggested that there is not enough evidence to prove that mucogingival surgical procedures can resolve dentinal hypersensitivity [25].

This is attributed to the fact that dentinal hypersensitivity has not been consistently evaluated in clinical studies. Nonetheless, several studies have demonstrated improvement in dentinal hypersensitivity. One reason why dentinal hypersensitivity is not consistently resolved is because incomplete root coverage can be associated with residual dentinal hypersensitivity. Therefore, root coverage can be proposed as a viable therapeutic option for patients who complain of dentinal hypersensitivity, only if complete root coverage is technically feasible.

Keratinized Tissue Augmentation

Gingival recession defects with thin, minimal, or no keratinized gingiva have been considered to be at greatest risk of progression [26]. Therefore, keratinized tissue gain has been considered one of the therapeutic objectives of periodontal plastic surgery. However, it may be debatable whether gingival thickness or the keratinized phenotype of the gingiva is the most important element of risk. The fact that many types of grafting, which do not necessarily mediate clinically significant increase in keratinized gingival zone, are associated with periodontal attachment level stability may argue that gingival margin thickness is more important than keratinization phenotype. Moreover, some of the therapies aimed at increasing keratinized gingival zone, such as free gingival graft, are associated with diminished esthetic and suggest a secondary role for keratinized gingiva in periodontal plastic surgery.

Cervical Caries and Non-carious Cervical Lesions

In the elderly population, radicular caries and/or deep root abrasion are common findings and can pose oral hygiene challenges for patients [27]. These can lead to dentinal hypersensitivity and/or endodontic involvement. The combination of root coverage surgery and restorative treatment in these teeth can help prevent future caries development and render an easier situation for plaque control for the patient. However, one needs to consider that dentinal bonding is not as predictable as enamel bonding. Therefore, bonded restorations in dentin may be more prone to leakage or failure.

9.7 Techniques for Gingival Recession Therapy

Multiple approaches to the treatment of gingival recession defects have been described in the literature, including the coronally advanced flap (CAF) with or without an additional graft, intra-sulcular tunneling (IST), pedicle flaps, free gingival graft (FGG), guided tissue regeneration (GTR), and vestibular incision subperiosteal tunnel access (VISTA). Each of these techniques has advantages and disadvantages.

9.7.1 Free Gingival Graft

A number of investigators have pioneered the technique of free gingival graft [28], as well as its application for vestibular extension [29], root coverage [30], and for pre-prosthetic augmentation of attached gingiva [31]. In 1968 Sullivan and Atkins [32] outlined the biologic basis of FGG and the wound healing process, subsequent to FGG therapy.

Free gingival graft offers a number of advantages and disadvantages. The advantages include increase in zone of keratinized attached gingiva and vestibular depth. The disadvantages include limited ability for root coverage and mismatch of surface contour, texture, and color, which can result in compromised esthetics.

The clinical case in Fig. 9.1 illustrates severe gingival recession (Miller Class III and IV recession defects) in the mandibular incisor area, with thin mucosa and

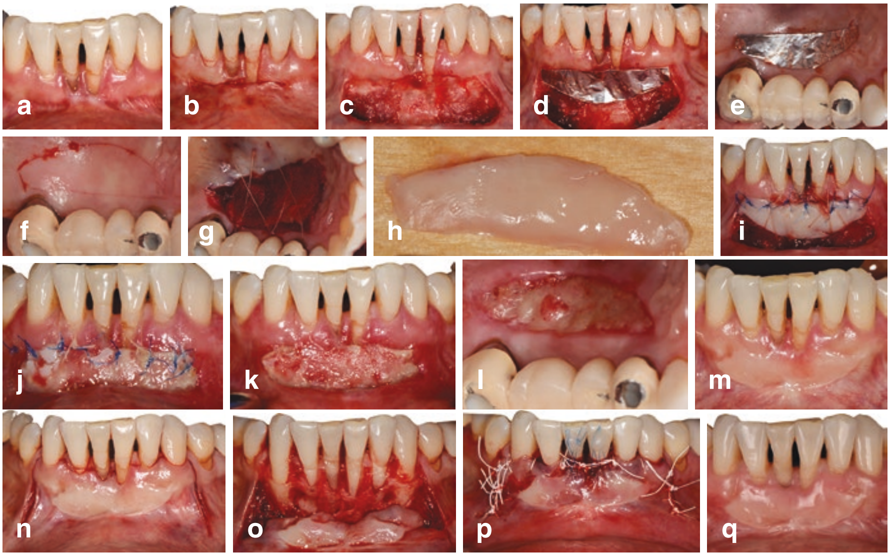

Fig. 9.1 Clinical case of a patient with severe gingival recession defects in mandibular anterior region. The preoperative view shows Miller Class IV in central incisors and Class III recession in lateral incisor area (**a**). Initial horizontal incision was made (**b**), followed by partial-thickness dissection to remove all loose alveolar mucosa, elastic fibers, and muscle attachments (**c**). A template was trimmed to define the planned dimensions of the FGG relative to the recipient bed (**d**) and donor site (**e**). The donor site was outline (**f**), and a thick FGG (approximately 1.5 mm in thickness) was harvested (**g**, **h**) and fixated to the recipient bed (**i**). One week healing results before (**j**) and after suture removal (**k**) showed excellent graft incorporation and donor site healing (**l**). The clinical results after 3 months showed increase in gingival margin thickness and increase in attached keratinized gingiva zone (**m**). To harmonize the gingival margins, coronal positioning of the gingival margins was attempted. A trapezoidal flap was made by two distal vertical releasing incisions (**n**) with split thickness dissection (**o**) and coronal positioning of the flap (**p**). Postoperative results show harmonized gingival margins (**q**). Clinical case, courtesy of Dr. Goncalo Carames

shallow vestibule. The treatment objectives in this case were to increase gingival margin thickness, increase attached gingiva, and deepen vestibular depth. To that end, FGG was performed to increase marginal gingival thickness, which was probably the most important therapeutic objective. In an effort to harmonize the gingival margins, limited root coverage was attempted by coronal positioning of the margin, by coronally advanced flap.

9.7.2 Coronally Advanced Flap

CAF is perhaps the most documented procedure for the treatment of single and multiple gingival recession defects. Norberg is credited as describing a procedure that involved coronal positioning of gingiva. Bernimoulin et al. were the first to report on CAF in 1975 for the treatment of gingival recessions [33]. This procedure has undergone a number of refinements, including by Allen and Miller in 1989 [34], Pini Prato et al. in 1992, Zucchelli and De Sanctis in 2000, and De Sanctis and Zucchelli in 2007. CAF has been performed either without additional graft, subsequent to FGG, in conjunction with a barrier membrane as GTR, or most commonly along with the subepithelial connective tissue graft (SCTG).

The coronally advanced flap for the treatment of single-tooth recession defects is designed with two horizontal beveled interproximal incisions on each side of the recession defect [35]. The incisions are made at a level which measures the recession depth plus 1 mm apical to the papillae tips. Additionally, two relatively short beveled vertical releasing incisions are made. These incisions, which are elevated by partial-thickness dissection, start coronally at the lateral ends of the horizontal incisions and extend apically to the alveolar mucosa. A trapezoid-shaped flap is elevated, starting with partial-thickness dissection of the surgical papilla. Full-thickness flap elevation of the soft tissue apical to the gingival recession zenith is carried out to approximately 3 mm apical to the bone dehiscence. Partial-thickness flap elevation is carried out to mobilize the flap in order to coronally position the flap with minimal tension. The papillae are de-epithelialized in order to create a vascular bed for the elevated flap which will be sutured coronal to the CEJ in the papillae, using sling sutures.

To treat multiple recession defects, interdental submarginal incisions and an envelope flap using split–full–split are employed [36]. The flap is extended at least one to two teeth on either side of the affected teeth to allow for low-tension coronal advancement of the flap.

This technique offers many advantages, including the ability to treat single, as well as multiple recession defects. CAF provides good access to the treatment site, allowing the operator the flexibility to perform full- as well as partial-thickness flaps in an effort to reduce the flap tension for optimal coronal advancement. The main drawback of this technique includes the scar formation associated with the incision line [37]. Previous studies have demonstrated that flap tension is a negative predictor of root coverage, and procedures which reduce flap tension can lead to better root coverage. Similarly, positioning of the gingival margin at least 2 mm coronal to the CEJ can lead to increased likelihood of achieving complete root coverage [38]. One of the major risk factors for root coverage outcome is flap thickness [39]. In cases where flap thickness is less than 0.8 mm, there is decreased likelihood of root coverage. In a recent prospective clinical study, it has been demonstrated that flap thickness was a negative predictor of root coverage only in those cases where CAF was performed without additional graft [40]. In cases where SCTG was used in conjunction with CAF, flap thickness was not a risk factor. Therefore, clinicians can use this information to conclude that in cases with thin mucosa, additional grafting may be utilized.

9.7.3 Intra-sulcular Tunneling (IST)

In 1985, Raetzke pioneered the "envelope" flap that was created by partial-thickness dissection for covering localized areas of root exposure [41]. The envelope flap was formed by an undermining partial-thickness incision in the tissues surrounding the defect and a free SCTG positioned directly over the root dehiscence. In 1994, Allen offered a modification of the Raetzke envelope by creating a partial-thickness supraperiosteal envelope for the treatment of multiple gingival recession defects [42]. This approach entailed partial-thickness undermining dissection through the papillae to allow for coronal advancement of the flap. In 1999 Zabalegui et al. coined "the tunnel" technique by offering a more detailed protocol [43]. This report outlined a strategy to undermine the papillae with partial-thickness dissection through intra-sulcular incision without any surface incisions. The partial-thickness dissection is carried out beyond the mucogingival junction, not to reposition the flap but to allow for insertion of SCTG. Further refinements of the tunnel technique have been offered by coronal reposition of the gingival margin, using double-crossed sutures, which are slung over interproximal embrasures that are blocked with temporary bonded resin restorations [44].

The clinical case in Fig. 9.2 shows a patient with Miller Class I multiple recession defects. Following scaling and root planning, intra-sulcular supra-periosteal tunnel was elevated with the aid of microsurgical blade and extended past the mucogingival junction. A subepithelial connective tissue graft was harvested from the anterior lateral aspect of the palate, inserted into the tunnel, and secured with resorbable 5.0 polyglycolic acid (PGA) sutures. Single sling sutures were performed with 6.0 polypropylene sutures for coronal positioning of the gingival margin. Postoperative follow-up after 2 years shows stable gingival margins with complete root coverage.

Intra-sulcular tunneling has many advantages, including lack of surface incision, which can be less disruptive to the blood supply, potentially leading to faster healing and avoiding esthetic complications. However, the major disadvantages of this technique include the technical challenges of working through the small sulcular area, particularly in cases with exostosis, potentially limiting the ability of flap release.

The clinical case in Fig. 9.3 shows a patient with Miller Class I and II recession defects in the posterior maxilla. The initial presentation shows non-carious cervical lesions. Cervical restorations are noted in various conditions. The restorations in the

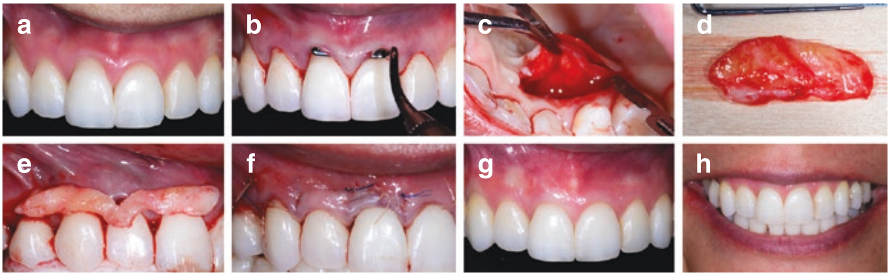

Fig. 9.2 Clinical case of a patient with Miller Class I multiple recession-type defects in the esthetic zone (**a**). Scaling and root planning were performed to remove the biofilm. An intrasulcular tunnel was elevated split thickness from right first premolar to left central incisor (**b**). A connective tissue graft was harvested from the anterior lateral palate (**c**). The connective tissue graft was approximately 2 mm in thickness and 18 mm in length (**d**). A horizontal incision was made in the graft to cover the four teeth with recession defects (**e**). The graft was then inserted into the tunnel through the sulcus of the canine, which had the deepest recession, and secured in position with at the mesial and distal ends with resorbable PGA sutures. Single sling sutures were performed with 6.0 polypropylene sutures for coronal advancement of the final gingival margin (**f**). The 2-year follow-up shows stable gingival margins with complete root coverage (**g**). The patient was satisfied with the esthetic result of the root coverage procedure (**h**)

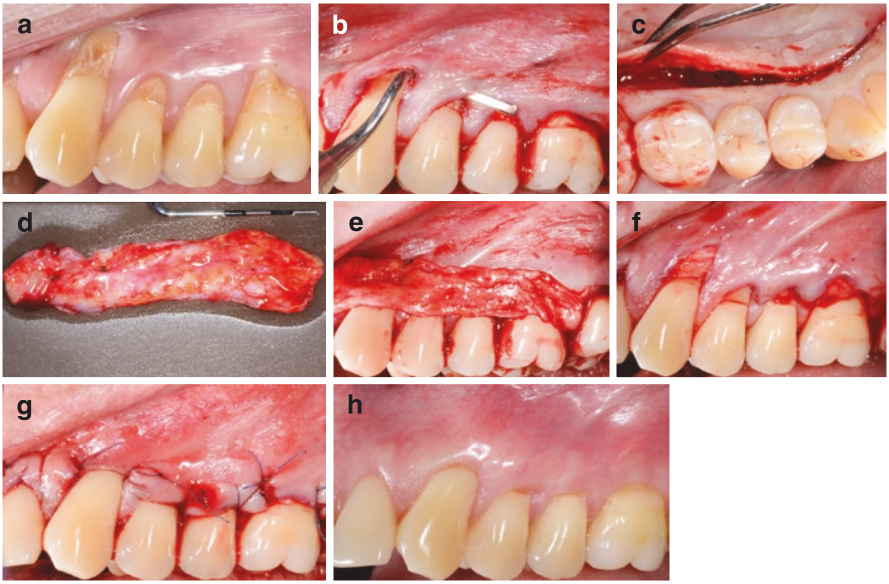

Fig. 9.3 Clinical case of a patient with combination of Miller Class I and Class II recession defects (**a**). Following root preparation, which included scaling and root planning and removal of composite from root surfaces, subperiosteal tunnel was created from sulcular access (**b**). An initial partial-thickness flap was made on the palate to provide access to the subepithelial connective tissue (**c**), which was harvested (**d**). The dimensions of the subepithelial connective tissue graft extended slightly beyond the recession defects laterally and apically (**e**). The subepithelial connective tissue graft was inserted in the tunnel and was positioned at the level of the CEJ (**f**). Gingival margins were coronally positioned, using 6.0 polypropylene sling sutures (**g**). Postoperative results of the case after 3 years with 100% root coverage (**h**)

premolars appear to have fractured off with the only portion remaining adherent to the enamel portion. The restorations in the molar appear to have intact margin in enamel, with leakage in the region extending to the root. These observations verify the point made earlier that dentinal bonding, despite claims to the contrary, is not reliable and often leads to restorations, which leak or are displaced. Some authors have recommended to restore the cervical portions of non-carious cervical lesions prior to surgery and then cover the recession with coronally advanced flap [45]. The problem with this approach is that if part of the restoration, which may be subgingival, may have marginal leakage with resultant gingival inflammation. In the case illustrated in Fig. 9.3, all restorations apical to the CEJ were removed. This was followed by thorough scaling and root planning. Intra-sulcular subperiosteal tunneling was carried out from the gingival sulcus and carried out past the mucogingival junction to achieve passive coronal advancement of the gingival margin. Subepithelial connective tissue graft was obtained from the palate and inserted within the recipient tunnel. The SCTG was positioned as coronally as possible within the tunnel. The gingival margins were subsequently coronally positioned with the aid of sling sutures. Postoperative follow-up after 3 years shows complete root coverage and a stable gingival tissue.

9.7.4 Vestibular Incision Subperiosteal Tunnel Access (VISTA)

The vestibular approach to soft tissue augmentation started with the semilunar coronally positioned flap technique [46]. The approach entailed a semilunar incision made parallel to the facial free gingival margin and coronally positioning this flap over the exposed root. The vestibular approach for bone augmentation has been described by several investigators [47–49]. The vestibular incision and subperiosteal tunneling for soft tissue augmentation have also been reported [50]. The rationale and detailed protocol for VISTA for the treatment of multiple recession defects was described in 2011 [51]. This approach entails thorough root instrumentation, including odontoplasty to remove portions of the root, which protrude beyond the gingival housing. Root prominence, as well as other site-specific charecteristics, have been demonstrated to be negatively correlated with periodontal root coverage [52].

The clinical case in Fig. 9.4 illustrates treatment of patient with multiple recession defects. In this case, following root preparation, a vertical vestibular incision was made in the midline frenum area. Sometimes, it is necessary to make multiple vestibular incisions to facilitate tunnel access. The vertical incision originates in the vestibular fornix and can extend to the base of the papillae. The incision should not approach closer than 5 mm away from the nearest gingival margin, in order to avoid tearing of the gingival margins. Subperiosteal tunnel was created to elevate the mucogingival complex away from the bone. The tunnel was extended coronally under attached gingiva and interdental papillae, to the extent possible, without making any surface incisions. The apical extent of the tunnel was beneath alveolar mucosa and released muscle attachments and elastic fibers, in an effort to achieve low-tension coronal positioning of the gingival margin. Laterally, the tunnel was

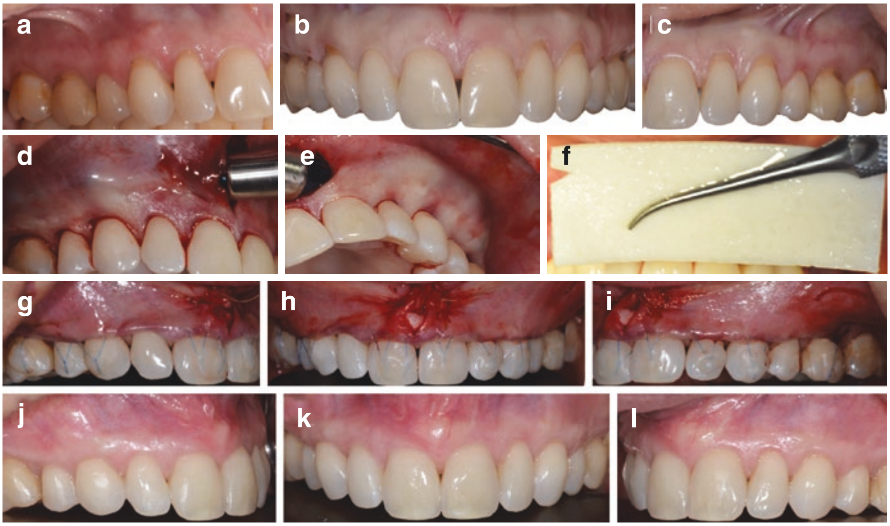

Fig. 9.4 Clinical case of a patient with combination of Miller Class II and Class III recession defects (**a**–**c**). Following root preparation, which included scaling and root planning with odontoplasty to reduce root prominence, an initial vertical vestibular incision was made in the midline, from which point, a subperiosteal tunnel was elevated elevated (**d**, **e**). The tunnel was elevated from the anterior region, extending to the first molar area. Acellular dermis allograft hydrated with platelet-derived growth factor was utilized in this case (**f**). Gingival margins were coronally positioned, and the gingival position was fixated, using 6.0 polypropylene sutures which were bonded in the coronal position with flowable composite (**g**–**i**). Once the gingival margins were fixated in coronal position, the allograft was inserted inside the tunnel. Postoperative results of the case after 1 year with complete root coverage (**j**–**l**)

extended to the adjacent posterior tooth (second molar), in order to facilitate coronal advancement, as well as to harmonize the gingival margin position and mucosal thickness with that of adjacent teeth. The gingival margins were coronally advanced at least 2 mm beyond the CEJ and fixated in that position, using sutures that were bonded to each tooth's midfacial coronal structure.

To treat teeth in the mandibular posterior region, the vestibular incisions are generally positioned anterior of the canine. Tunnel elevation in the mandibular posterior region is performed only in attached gingiva to the mucogingival junction in order to avoid injury to the mental neurovascular bundle. In addition, care must be taken to avoid occlusal interference with the additional of composite bondings. This may be particularly a problem in the mandibular posterior areas. In some cases, addition of composite to the central fossa of maxillary posterior teeth can open the bite to avoid interference with the bonded sutures. Once the sutures are removed after 3 weeks, the occlusal composites can also be removed.

The advantages of VISTA include avoidance of surface incisions near gingival margins or papillae, thus avoiding vascular disruption, esthetic complications, and accelerating healing. Moreover, there is better access to the apical areas for low-tension flap release. The main disadvantage includes potential scar formation in the location of vertical incision, though this is usually in an area, which is not readily visible.

9.7.5 Guided Tissue Regeneration (GTR)

Barrier membranes have been utilized in guided tissue regeneration for periodontal regeneration [53]. This concept has also been applied for the treatment of gingival recession. GTR has had variable results, primarily as a result of potential complications of membrane exposure and infection. SCTG has been shown to be more effective than GTR for root coverage [20].

9.7.6 Orthodontic Extrusion

Orthodontic tooth movement can modulate gingival position. In particular, orthodontic extrusion may be employed to coronally reposition gingival margin position [54]. This will require slow application of orthodontic forces at a rate of 1 mm or less per month.

In the case illustrated (Fig. 9.5), a patient with a history of advanced periodontitis, who completed periodontal therapy, had advanced gingival recession defects

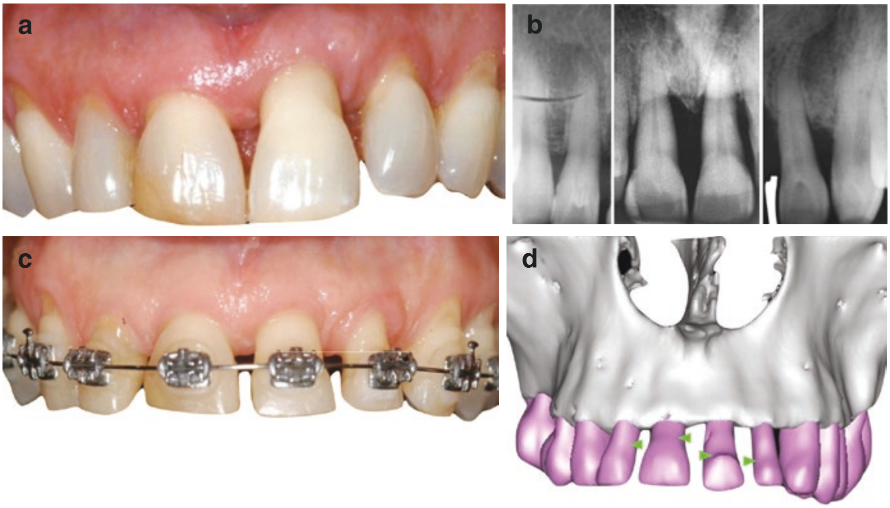

Fig. 9.5 Clinical (**a**) and radiographic (**b**) preoperative images of a patient with history of aggressive periodontitis with advanced gingival recession (Miller Class III) and marginal bone loss around maxillary incisors. Orthodontic-forced eruption was undertaken (**c**) to coronally advance and harmonize the gingival margins of the maxillary anterior teeth. Follow-up cone beam CT scan images with 3D rendering illustrate the harmonized alveolar bone margins with correction of the intraosseous defects (**d**). The positions of CEJ in the maxillary incisors (green arrow heads) have been altered in an effort to harmonize the alveolar bone crest

with associated severe vertical bone loss. Slow orthodontic extrusive forces were applied during approximately 9-month period. The patient was maintained in the final position without tooth movement for an additional 6 months. This leads to harmonization of gingival margin positions. The postoperative CBCT shows the discrepancies in the positions of right and left incisors created (green arrow heads).

9.8 Material Selection

An array of different materials is used for the treatment of gingival recession defects, including donor tissue (autologous, allogenic, and xenogenic), enamel matrix derivative (EMD), xenogenic collagen matrix (XCM), recombinant growth factors, autologous platelet concentrates, and living cell constructs (LCC).

9.8.1 Donor-Derived Tissue

Donor tissue has included skin graft [55], epithelialized palatal graft [14, 32], subepithelial connective tissue graft from palate or tuberosity [56], acellular dermal matrix (ADM) allograft [57], and xenogenic dermis [58]. In a comparative study to examine the composition of autologous mucosal grafts harvested from the lateral palate or the tuberosity, it has been shown that tuberosity grafts have more lamina propria and less submucosa [56]. The tuberosity has been demonstrated to have SCTG composition which is best suited for volume augmentation.

9.8.2 Xenogenic Collagen Matrix (XCM)

In an attempt to find viable alternatives to human donor-derived autogenous and allogenic graft material, XCM has been developed. There are both native [59] and cross-linked [60] XCM material, each of which has advantages and disadvantages. Native collagen may be applied to recipient sites, prepared by partial-thickness dissection and allowed to heal in an exposed manner, similar to FGG [61]. In that capacity, available data indicate favorable augmentation of both width and thickness of the zone of keratinized tissue [62–64]. Native porcine XCM has also been employed in conjunction with coronal advancement flap [65], as well as VISTA [66] with favorable outcomes. In a large multicenter randomized clinical trial, comparing CTG to native XCM, it was demonstrated that autogenous CTG had higher probability of achieving complete root coverage. However, the degree of root coverage was 1.7 ± 1.1 mm for CMX and 2.1 ± 1.0 mm for CTG. Therefore, the difference between the two groups was only 0.4 mm. Moreover, surgical time was 15.7 min shorter, the procedure was perceived to be lighter by patients, and the recovery time was 1.8 days shorter for XCM, compared to CTG.

Volume-stable cross-linked collagen matrix (VCMX) has been developed to increase mucosal thickness [60, 67]. VCMX is intended to be applied in submerged fashion. Results have demonstrated that the thickness gain with VCMX and CTG are equivalent [60, 67].

9.8.3 Enamel Matrix Derivative (EMD)

A large body of clinical and experimental evidence has demonstrated that enamel matrix proteins (EMPs) mediate periodontal regeneration. EMPs have been exploited therapeutically, through the use of EMD, which is clinically available as Emdogain. Treatment of gingival recession has been conducted with EMD plus CAF, not only to cover the roots but also to mediate periodontal regeneration [68]. There is available animal and human histologic evidence to demonstrate the re-formation of true periodontal regeneration with new bone, new PDF, new cementum, and functional fibers [68]. Randomized controlled studies have also demonstrated a mean root coverage of 84–94% [69]. Clinical trial data have demonstrated that, compared with CAF alone, CAF plus EMD yields increased root coverage, as well as keratinized gingiva width [69].

9.8.4 Autologous Platelets

Several generations of autologous platelet concentrate, along with various other components of blood (fibrin, leukocytes), have been utilized, using different protocols. These have included platelet-rich plasma (PRP), platelet-rich growth factor (PRGF), or platelet-rich fibrin (PRF). Each of these can also include leukocytes, e.g., leukocyte-platelet-rich fibrin (L-PRF).

There are mixed results, when L-PRF has been used in conjunction with CAF [70]. Comparison of L-PRF to SCTG by meta-analysis has demonstrated similar outcomes, namely, PD reduction (0.2, 0.3 mm, $p > 0.05$), CAL gain (0.2, 0.5 mm, $p > 0.05$), KTW (0.3, 0.4 mm, $p > 0.05$), and recession reduction (0.2, 0.3 mm, $p > 0.05$) [70].

9.8.5 Growth Factors

Recombinant human platelet-derived growth factor-BB (rhPDGF-BB) has been evaluated clinically and histologically for the treatment of gingival recession defects. Clinical results showed 90.8% root coverage with rhPDGF, compared with 98.6% root coverage with SCTG [71]. Histologic evidence demonstrated de novo alveolar bone, cellular cementum, and PDL regeneration mediated by rhPDGF-BB [72].

9.8.6 Living Cell Construct

Living cellular construct (LCC) is a combination of allogenic human keratinocytes, fibroblasts, human extracellular matrix proteins, and bovine collagen. This material has been used as a substitute for FGG for the treatment of gingival recession defects, where root coverage is not required. In a randomized controlled trial, comparing LCC to FGG [73], results have shown more keratinized gingiva generated by FGG (mean 4.5 mm) than LCC (mean 3.2 mm). LCC regenerated keratinized gingiva of 2 mm or more in 95.3% of the patients.

9.9 Conclusions

Untreated gingival recession is at higher risk of progression. Periodontal plastic surgery is an effective therapeutic strategy in achieving root coverage with improvement in periodontal clinical attachment level. Overall, no single therapy can be considered superior to all the others. The treatment strategy has to consider the following:

- Patient's esthetic demands
- Local site characteristics: gingival keratinized gingiva width, gingival thickness, root prominence, recession depth and width
- Restorative, orthodontic, and surgical plan
- Availability of donor tissue
- Patient's acceptance of graft material, i.e., donor tissue harvesting, allograft, xenograft, and animal-derived material
- Extent of treatment area: single vs multiple area vs full arch
- Clinician's experience, skills, and preference

Through systematic risk assessment, as well as consideration of above factors, the clinician and patient can select an appropriate treatment protocol and material.

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Rationale for Gingival Tissue Augmentation and Vestibuloplasty Around Teeth and Dental Implants

10

Leandro Chambrone, Francisco Salvador Garcia Valenzuela, and Luciano Oliveira

10.1 The Dilemma of Whether or Not to Augment the Band of Keratinized Tissue

As defined by the *American Academy of Periodontology* (AAP), gingiva [1] is a term that designates "the fibrous investing tissue, covered by keratinized epithelium that immediately surrounds a tooth and is contiguous with its periodontal ligament and with the mucosal tissues of the mouth." Microscopically, the oral epithelium of the gingiva presents four layers with the corneum stratum consisting of squamous keratinocytes that are believed to serve as a "mechanical barrier" against mechanical/environmental trauma to the gingival tissues (Fig. 10.1). For instance, in a recent systematic review, Chambrone and Tatakis [2] evaluated the long-term outcomes of untreated buccal gingival recessions through the assessment of potential factors influencing the development and progression of these defects. These authors found that (1) within individuals presenting good oral hygiene standards, approximately 80% of the untreated gingival recessions progressed/worsened (i.e., experienced recession depth increase) during long-term follow-up and (2) the keratinized tissue (KT) band appears as an important component in preventing such detrimental

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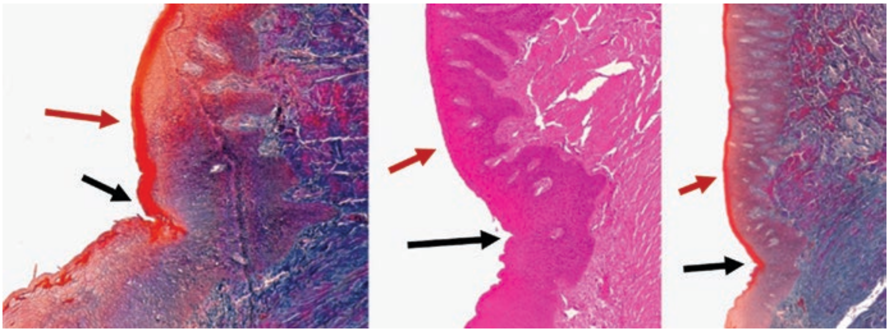

Fig. 10.1 Microscopically, the human buccal gingiva is formed by four epithelial layers (i.e., basale, spinosum, granulosum, and corneum) and a connective tissue layer. Note that the corneum stratum (red arrow) is no longer seen in an apical direction beyond the mucogingival junction (black arrow)

changes in the gingival margin position overtime (i.e., sites lacking KT seemed to be more prone to additional clinical attachment loss) [2].

Regarding to the importance of KT, it has long been suggested that a minimum 2 mm band of KT (with at least 1 mm of attached tissue) appears to be required to preserve the health of periodontal tissues [3]. Furthermore, the dilemma as to the need to augment the band of KT was thoroughly reviewed by the AAP in 2015 during its most recent Regeneration Workshop. According to the authors of that systematic review [4] and the base of evidence available to October 2013, there are unprecise definitions on the least extent of KT necessary to maintain periodontal stability (i.e., there are no specific dimensions fully acceptable in the literature). On the other hand, clinical data included in this AAP commissioned paper [4] provided conclusions/responses to the five most common clinical scenarios found in daily practice (these are reproduced as reported in the original publication):

1. ***What circumstances require an increased zone of KT, or is KT important?*** [4]

   Conclusions/Response: "Authors have noted the limitation of recent clinical studies, randomized clinical trials (RCTs), and systemic reviews to answer this question. However, clinical observations would suggest that sites with minimal or no gingiva and associated with restorative margins are more prone to gingival recession and inflammation. Thus, gingival augmentation is indicated for sites with minimal or no gingiva that are receiving intracrevicular restorative margins based on clinical observations (SORT [Strength-of-Recommendation Taxonomy criteria] level B [inconsistent or limited-quality patient-oriented evidence])" [4].
2. ***What is the ideal thickness of an autogenous gingival graft? Is a thick autogenous gingival graft more effective than a thin autogenous gingival graft?*** [4]

   Conclusions/Response: "A palatal graft should be ≥1-mm thick. Thin grafts tend to result in more esthetic outcomes, whereas thick grafts provide more functional resistance. Thick grafts tend to follow significant primary contraction, whereas thin grafts are more prone to secondary contraction. The type of biotype may play an important role in maintaining optimal periodontal health, but disagreements exist among clinicians when describing the types of biotypes (SORT level B [inconsistent or limited-quality patient-oriented evidence])” [4].

3. ***What are the alternatives to autogenous gingival grafting to increase the zone of attached gingiva?*** [4]

   Conclusions/Response: “Modified apically positioned flap may be an effective technique in increasing the apico-coronal dimension of the KT and attached gingiva without donor areas or use of commercial products”….“alternative methods and materials (i.e., acellular dermal matrix grafts, extracellular matrix, xenogenic porcine bilayer collagen matrix and living cellular construct) have been shown to provide enough attached KT to correct areas lacking or with minimal gingiva (<2 mm) around teeth in short-term and in small–sample size studies. The advantages of these approaches are avoidance of donor areas and unlimited supply. However, long-term follow-up studies and RCTs should be conducted to strengthen this treatment approach (SORT level C [consensus, disease-oriented evidence, usual practice, expert opinion, or case series for studies of diagnosis, treatment, prevention, or screening])” [4].

4. ***Does orthodontic intervention affect soft tissue health and dimensions?*** [4]

   Conclusions/Response: “Historic clinical observations and recommendations can be referenced to answer this question. The direction of the tooth movement and the bucco-lingual thickness of the gingiva play important roles in soft tissue alteration during orthodontic treatment. There is a higher probability of recession during tooth movement in areas with <2 mm of gingiva. Gingival augmentation can be indicated before the initiation of orthodontic treatment in areas with <2 mm (SORT level C [consensus, disease-oriented evidence, usual practice, expert opinion, or case series for studies of diagnosis, treatment, prevention, or screening])” [4].

5. ***What is the patient-reported outcome for minimal KT compared with that for an enhanced zone of KT?*** [4]

   Conclusions/Response: “Alternative methods and materials appear to result in less patient discomfort after gingival augmentation procedures when compared with FGG. They have also shown to result in better color and texture match to surrounding tissue when compared with FGG. However, study investigators need to standardize how they collect the patient-reported outcomes so the obtained results can be compared with other studies (SORT level C [consensus, disease-oriented evidence, usual practice, expert opinion, or case series for studies of diagnosis, treatment, prevention, or screening])” [4].

Furthermore, recent clinical long-term data (18–35 years) by Agudio et al. [5, 6] reported in several practice-based studies comprising of patients with high standards of oral hygiene shed light on the importance of gingival/KT augmentation. In the first study, it was found that teeth with single recession defects and lacking a minimum KT band of 2 mm undergoing gingival augmentation (via free gingival graft-based procedures) may display a phenomenon called “creeping attachment” (i.e., a coronal shift of the gingival margin), leading to noteworthy gingival recession reduction 10–27 years after treatment [5]. In the second publication, the authors confirmed that gingival augmentation might influence the biologic remodeling of periodontal dimensions associated with the aging process, as well as that use of free gingival grafts can produce more beneficial KT band proportions and reduce gingival recession depth [6]. The second study also reported that some degree of shrinkage will occur, thus "the corono-apical dimension of the graft should be calculated on the basis of the KT width of adjacent untreated teeth plus an additional 1.00–1.50 mm considering an estimated tissue contraction during the early healing, and long follow-up period" [6]. As a result, the authors suggested that clinicians prepare grafts with an additional apical dimension of 1.00–1.50 mm of the mucogingival junction of adjacent untreated teeth [6].

Similar to the concepts established for natural teeth, current evidence (even though minimal) clearly indicates the positive gains of increasing the KT band at dental implant sites [7, 8]. Improvements in KT width and thickness at periodontal and peri-implant sites may be essential to create a "mechanical/physical and biological epithelial barrier" that will give protection to peri-implant structures in view of cytokine, chemokine, and antimicrobial peptide production (i.e., interleukin-1α, interleukin-1β, interleukin-6, interleukin-8, and tumor necrosis factor-α) in response to toothbrushing trauma and dental biofilm [8, 9]. In general terms, it has been shown that an increase in KT in areas of elastic peri-implant mucosa by gingival augmentation procedures (i.e., free gingival graft and apically positioned flap) may promote the formation of a firm KT band and thus reduce the probability for gingival recession [7, 8].

Consequently, the above reported studies and reviews support the key role of KT dimensions in the maintenance of the gingival margin stability around natural teeth and dental implants. In addition, these aspects rationally indicate that such grafting procedures will promote a "biotype modification" (i.e., KT width and thickness gain) and should be considered when deemed necessary.

10.2 Surgical Procedures Used for Gingival Augmentation Around Natural Teeth and Dental Implants

As stated above, accumulating evidence supports the importance of KT around dental implants. Recent systematic reviews have demonstrated that the lack of KT is related to plaque accumulation, gingival recession, and attachment loss, which indicates that implants with insufficient KT may be prone to developing peri-implant mucositis and peri-implantitis [10, 11].

The following treatment modalities can be selected to attain a sufficient dimension of KT and vestibular depth: apically positioned flap (vestibuloplasty), free gingival graft (FGG), and use of collagen matrix (CM). Regarding the use of CM, this xenograft was developed to compensate for the disadvantages of free gingival grafts in terms of the reduction of patients' morbidity and esthetic enhancement. However, there has been limited evidence on the stability of the reestablished tissue long-term [12–15].

10.3 Free Gingival Graft-Based Procedures

Reports on the use of palatal soft tissue graft (harvested from "the region located behind the third molar") were originally described in 1902 at the *American Dental Club of Paris* meeting and published in 1904 in *Dental Cosmos* [16]. Nonetheless, the use of palatal free gingival grafts (FGG) and deepening the vestibular fornix was reported in 1963 [17], with surgical standardization occurring some years later [18].

10.3.1 Indications

The following types of defects or conditions may benefit from FGG-based procedures:

- Treatment of periodontal or peri-implant sites lacking a minimum 2 mm band of attached KT
- Treatment of periodontal or peri-implant sites presenting a “thin periodontal biotype” (i.e., “delicate and tiny highly scalloped gingival and osseous architecture and few or non-keratinized tissue” [8, 19–21])
- Treatment of periodontal or peri-implant sites associated with toothbrushing or other environmental discomfort (i.e., pain)

10.3.2 Contraindications

The following types of defects or conditions may not benefit from FGG-based procedures:

- Treatment of periodontal or peri-implant sites located in esthetic areas—these sites may be improved by the use of FGG-based procedure, but the final tissue color will be different from adjacent gingiva.
- Treatment of sites presenting attached KT width ≥2 mm.
- Treatment of sites presenting “thick and flat” (i.e., “dense, flat gingival and osseous architecture and ample width of KT tissue” [8, 19–21]) or even “thick and scalloped” (i.e., “a clear thick fibrotic gingiva and narrow zone of KT” [8, 19–21]) periodontal biotypes.

10.3.3 Principles of the Surgical Sequence

As previously reported in a prior Springer publication [8], the general basic principles involving FGG-based procedures are noted below (Figs. 10.2, 10.3, 10.4, and 10.5):

- Local anesthesia.
- A number 15C surgical scalpel blade should be used to perform a horizontal incision in the interdental papillae at the level of the cement enamel junction (for marginal FGG), and an intrasulcular incision is made at the tooth/teeth receiving the graft (i.e., it should encompass the entire operative site). A submarginal approach may be used when the free gingiva is considered “thick” [5, 6].
- Two vertical incisions made at the ends of the horizontal incision and extended to the alveolar mucosa follow, and a thin, partial-thickness flap is dissected up to the apical limits of the vertical incision and afterward completely excised.

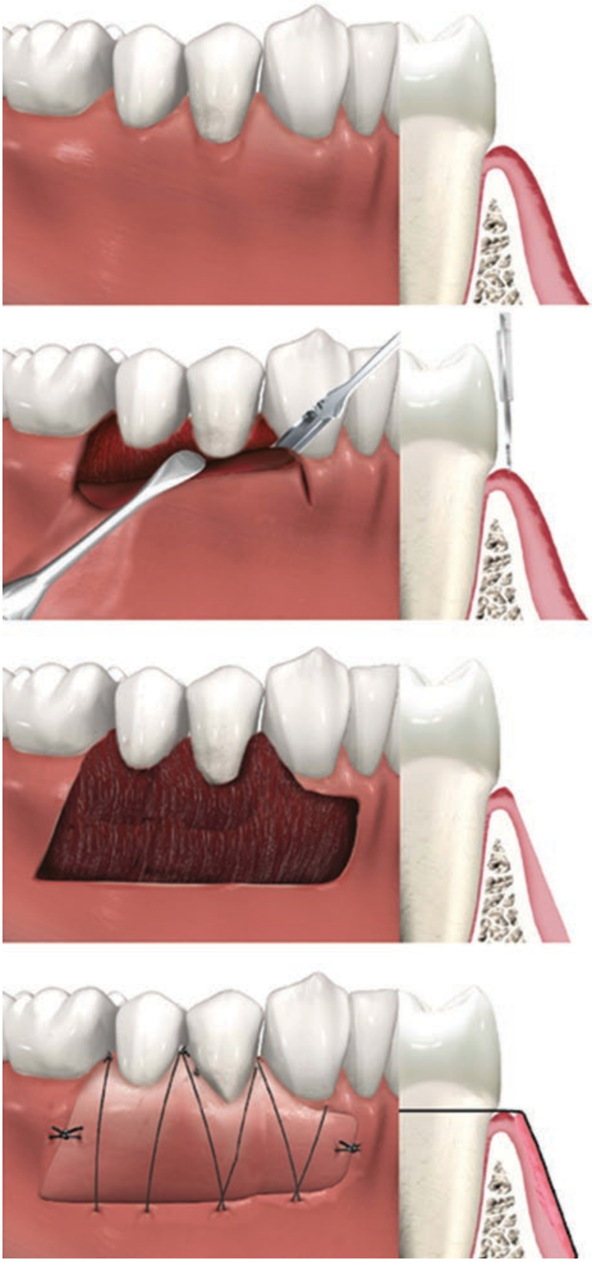

Fig. 10.2 Basics of the surgical sequence (i.e., de-epithelialization of the site and graft sutured over the recipient bed). See text for description

Fig. 10.3 Gingival recession on mandibular anterior teeth associated with advanced interproximal tissue loss. The patient reported discomfort/pain during toothbrushing (note the lack of KT prior to treatment). The patient underwent nonsurgical periodontal therapy (i.e., scaling and root planning) and FGG prior to orthodontic therapy. Six months after FGG, the patient reported improvements in clinical and patient-reported outcomes

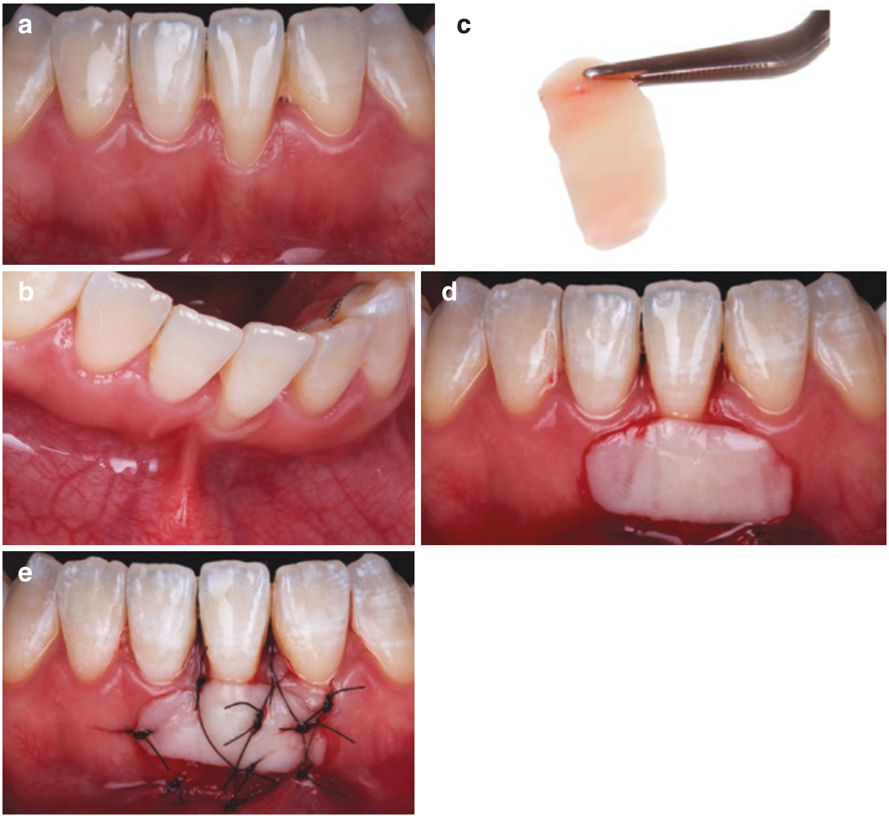

Fig. 10.4 Single gingival recession associated with fixed orthodontic retainer—(**a**) baseline, frontal view; (**b**) baseline, view of the location of the muscle insert following lower lip retraction; (**c**) free gingival graft harvested from the palatal vault; (**d**) graft positioned at the previously prepared recipient site; (**e**) flap sutured at the recipient site; (**f**) 2 weeks follow-up, frontal view; (**g**) 2 weeks follow-up, occlusal view; (**h**) 2 weeks follow-up, lateral view; (**i**) 6 months follow-up

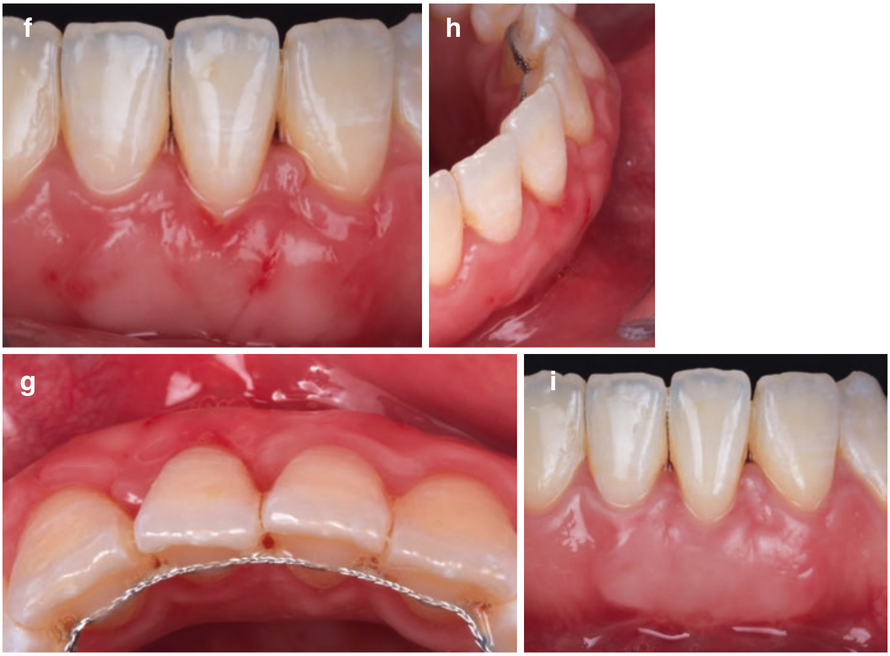

Fig. 10.4 (continued)

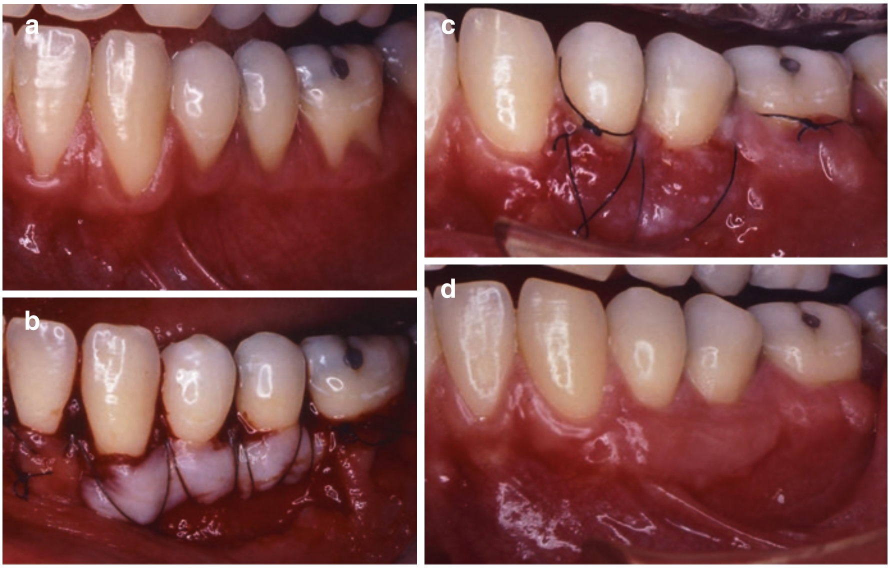

Fig. 10.5 Mandibular site presenting multiple teeth with gingival recession and a thin periodontal biotype. A free gingival graft was used to decrease recession depth and to increase the width and thickness of keratinized tissue—(**a**) baseline; (**b**) graft sutured at recipient bed; (**c**) 7 days follow-up; (**d**) 3 months follow-up

- After the recipient site/bed is completely de-epithelized, a FGG is harvested from the palate according to the size required to cover the recipient bed (Fig. 10.4c). However, the graft harvest may be influenced by the palatal vault anatomy. Reiser et al. [22] found that the average distance from the cementoenamel junction to the neurovascular bundle varies according to the size and shapes of hard palate, from 7 mm for shallow to 17 mm for high (U-shaped) palates. Usually, FGG can be harvested between the distal aspect of the canine and the midpalatal region of the second molar, in order to prevent potential damage and complications associated with severing the greater palatine artery and their major branches, such as hemorrhage.
- The graft should be sutured to the recipient site using 5-0 or 6-0 interrupted/suspensory nylon/Teflon sutures and without leaving “dead spaces” between the *lamina propria* and the connective tissue side of the graft and root surface (Figs. 10.4e and 10.5b).
- The sutures may be carefully removed 7–14 days after surgery to avoid injury to the graft (Fig. 10.5c). Patients should be instructed not to perform toothbrushing of the treated area during this period and directed to rinse gently with a mouthwash containing 0.12% chlorhexidine gluconate twice a day for 2–3 weeks, or until safe and comfortable, toothbrushing can be performed.
- Analgesics, anti-inflammatory drugs, and/or systemic antibiotics may be prescribed if necessary.
- Pain and bleeding may occur at the donor site during the early phase of healing due to exposure of the connective tissue layers of the palatal gingival tissue. On the other hand, these adverse effects will not promote alterations in the final anticipated outcomes.

10.4 Vestibuloplasty-Based Procedures

A 25-year longitudinal study conducted by Tallgren revealed a continuing reduction in the height of the maxilla after tooth extraction in complete denture wearers. In the mandible, this reduction was particularly marked in the height of the anterior ridge, being approximately four times as great as that of the anterior maxilla [23]. The lack of an adequate residual alveolar ridge and basal seat severely compromises the success of prosthodontic treatment. It has been suggested that expansion of the denture-bearing area by means of a vestibuloplasty would reduce denture load per square unit of supporting bone and thus reduce the bone resorption caused by transfer of occlusal force [24]. Other authors also reported important ridge alterations after tooth extraction and related these findings to the loss of periodontal ligament where the alveolar bone is unable to reform leading to resorption [25–27]. This phenomenon shows variation in rate with rapid bone loss noted at the first 6 months after extraction and the following 2 years [28].

The oral rehabilitation of patients after tooth loss has made much progress, and many different methods have been described for regenerating or replacing bone for secondary implant placement. Vestibuloplasty, ridge augmentation, and different types of implants were used to overcome the challenges of a flat alveolar ridge [29], but until now, little substantial progress has been made in soft tissue management.

Vestibuloplasty techniques can be generally categorized as mucosal advancement, secondary epithelization, and grafting vestibuloplasty. Physical status and age of patient are prime factors for the selection of the surgical technique to be utilized [30]. Success of the submucosal vestibuloplasty depends on availability of adequate bone and free mobile mucosa so that deepening can be achieved without tension [31, 32]. If available mucosa is not adequate or of poor quality, then submucosal vestibuloplasty is not indicated. Instead, secondary epithelization technique is preferred [31, 33].

There are two basic techniques of vestibuloplasty by secondary epithelization with several variations. In one technique (Kazanjian) a mucosal flap is raised to the lip and transferred to align with the osseous side of the deepened sulcus [33]. In the other (Clark) a flap of alveolar mucosa is raised and transferred to align with the soft tissue side of the sulcus [31]. Variations in these two basic techniques relate to the periosteum. The aim is therefore to create adequate vestibular depth and limit the traction of fiber and muscle attachments [29, 34].

10.4.1 Indications

The following types of defects or conditions may benefit from vestibuloplasty-based procedures:

- Treatment of advanced alveolar resorption
- Treatment of sites with a narrow band of remaining keratinized mucosa
- Treatment of sites with a shallow vestibule
- Treatment of areas presenting prominent muscle attachments, particularly the vestibular mentalis, the lingual mylohyoideus, and the genioglossus
- Treatment of sites requiring jaw optimization for prosthesis integration
- Treatment of sites lacking sufficient height of the residual alveolar ridge

10.4.2 Contraindication

The following types of defects or conditions may not benefit from vestibuloplasty-based procedures:

- Treatment of small, localized areas
- Treatment of non-edentulous/dentate areas
- Treatment of sites requiring alveolar ridge height gain
- Treatment of areas where morbidity control might be required [22, 35, 36]

10.5 Basic Principles of the Surgical Sequence: Kazanjian Vestibuloplasty

The general basic principles involving the use of Kazanjian vestibuloplasty are reproduced below:

- Local anesthesia.
- An incision is made through the mucosa from one premolar region via the inner lower lip to the contralateral premolar region.
- The mucosa is reflected to the highest part of the alveolar crest, which is followed by epiperiosteal dissection of the mental muscles into the vestibular depth.
- The pedicle flap is sutured to the periosteum at the depth of the vestibulum. At this point a rubber catheter stent can be placed into the deepened sulcus and fixed through the lip to the outer surface with percutaneous sutures. The catheter helps to hold the flap in its new position and to maintain the depth of vestibule during the initial stages of healing.
- The catheter is removed after 7 days and the wound in the vestibulum and inner lip is left to heal secondarily. The patient is directed to rinse gently with a mouthwash containing 0.12% chlorhexidine gluconate twice a day for 2–3 weeks, or until safe and comfortable, cleansing can be performed. This method can be used with or without simultaneous insertion of dental implants.
- Analgesics, anti-inflammatory drugs, and/or systemic antibiotics may be prescribed if required.

10.6 Basic Principles of the Surgical Sequence: Clark Vestibuloplasty

This can be considered as the reverse of Kazanjian's technique using the following principles:

(a) Raw surfaces on connective tissue contract, whereas the same surfaces undergo minimal contraction when covered with epithelium.
(b) Raw surface on the overlying bone cannot contract.
(c) Epithelial flaps must be undermined sufficiently to permit repositioning and fixation without tension.
(d) Soft tissues undergoing plastic revision have a tendency to return to their former position, so overcorrection and firm fixation are necessary.

The general basic principles involving the use of Clark vestibuloplasty are reproduced below [31] and highlighted in Fig. 10.6:

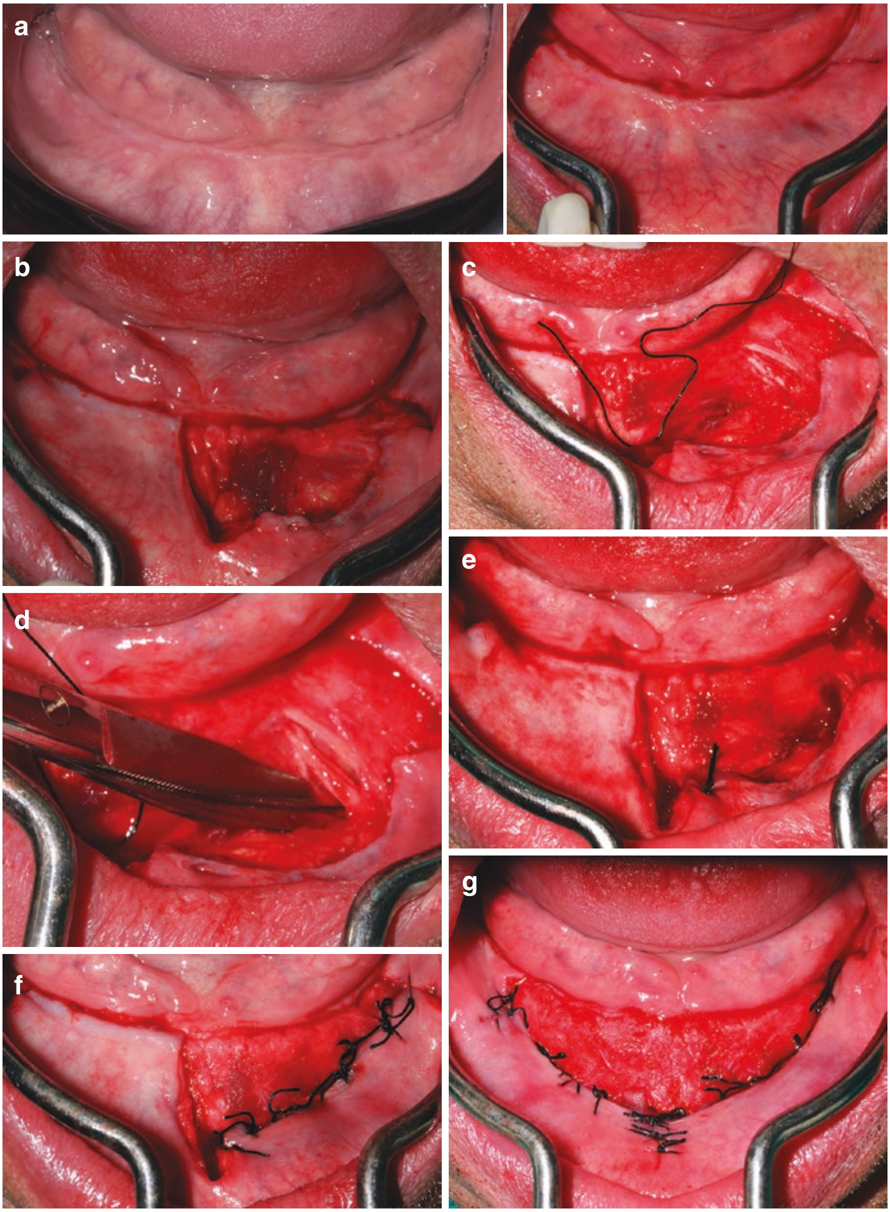

Fig. 10.6 Mandibular alveolar ridge displaying advanced atresia, shortening of the vestibule, and a narrow band of attached keratinized mucosa—(**a1** and **a2**) baseline; (**b**) a crestal incision is performed and connected by a mesial and distal vertical incision extending to the bottom of the vestibule. Thereafter, dissection of the mucosal plane and exposure of the underlying musculature was carried out; (**c**) the mucosal flap was apically repositioned and partially fixed with periosteal suture; (**d**) mental nerve dissection and release; (**e**) apically positioned flap after dissection; (**f**) flap fully repositioned in an apical position and sutured; (**g**) overview of both mandibular sites ready to receive the free gingival graft; (**h1**) free gingival graft harvested from the palatal vault; (**h2**) graft sutured to the recipient site; (**i**) 4 weeks follow-up; (**j**) 6 weeks follow-up; (**k**) 8 weeks follow-up

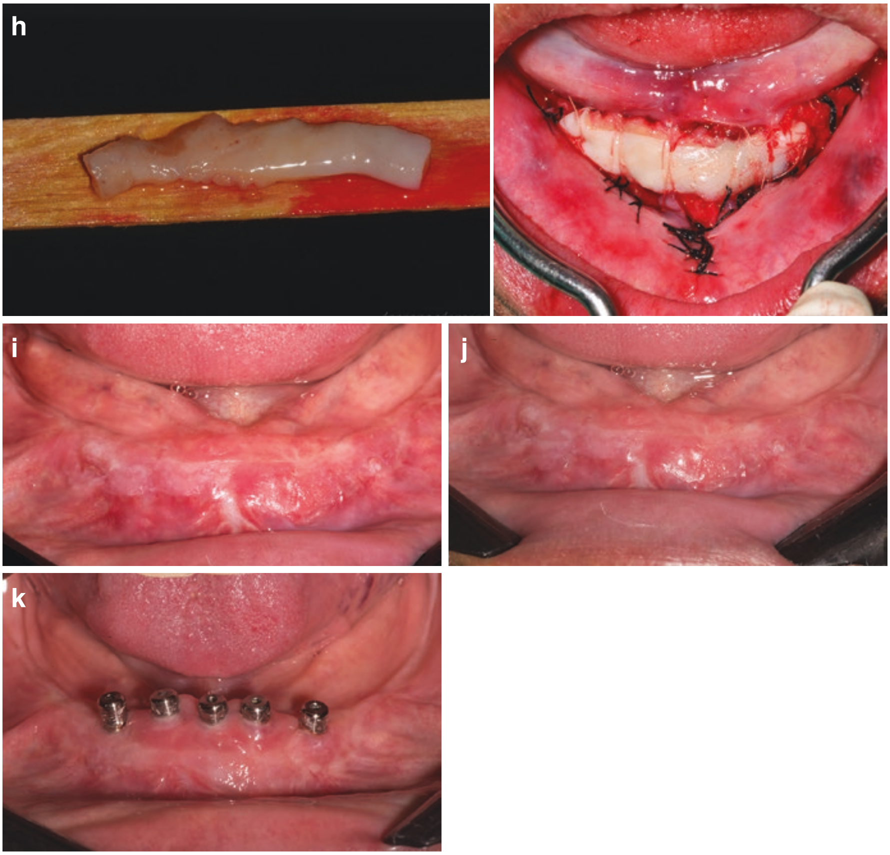

Fig. 10.6 (continued)

- Local anesthesia.
- An incision is made on the alveolar ridge, and a supraperiosteal dissection is performed to the desired depth (the mucosa of the lip is undermined to the vermilion border) (Fig. 10.6c).
- Nonabsorbable mattress sutures are placed in the free margin of the mucosal flap (Fig. 10.6g–i) and are carried through the skin and tied over a cotton roll.
- The soft tissue side of the sulcus is covered with mucosa, whereas, on the osseous side, the raw periosteal surface is left to granulate and epithelialize. Additionally, a free gingival graft may be associated with the procedure (Fig. 10.6j, k).
- The sutures may be removed 7–14 days after surgery. The patient is directed to rinse gently with a mouthwash containing 0.12% chlorhexidine gluconate twice a day for 2–3 weeks, or until safe and comfortable, cleansing can be performed. Analgesics, anti-inflammatory drugs, and/or systemic antibiotics may be prescribed if required.

10.7 Additional Vestibuloplasty Procedures

A third option has gained an important role in preprosthetic surgery, the standardized Edlan vestibuloplasty. In this technique, an incision is made through the mucosa from one premolar region to the inner lower lip and to the contralateral premolar region. The mucosa is reflected to the highest point of the alveolar ridge; the periosteum is incised at the alveolar ridge and prepared under direct vision of the mental nerve down to the required vestibular depth. The periosteum is sutured to the mucosal crest of the inner lip. The pedicled mucosal flap is sutured to the periosteum at the vestibular depth [37]. This method is mainly used in combination with the insertion of acrylic stents, graft materials, or implants.

One should note that after vestibuloplasty, a short period of rapid bone resorption can occur. Subperiosteal preparation in Edlan-plasty cases was followed by a considerable rate of bone resorption up to 2 years postoperatively [34, 35]. In a prospective study of Edlan- and Kazanjian-plasty, a high amount of bone resorption was not observed. The authors suggest that this procedure when combined with implant placement might have prevented progressive bone resorption. Nevertheless, the Edlan-plasty was followed by a small amount of bone resorption, which was even less so in the Kazanjian-plasty. On the other hand, the Kazanjian-plasty was followed by an increased loss of attached mucosa. However, 10% of implants of the study showed a total loss of attached mucosa, necessitating a repeat vestibuloplasty [34].

10.8 Clinical Highlights on the Use of Gingival Augmentation Procedures at Periodontal and Peri-implant Sites

Although the periodontium and peri-implant supporting structures share similar histologic and clinical features, there are several fundamental differences between the anchorage and attachment of teeth and implants. A key difference is that there is no periodontal ligament or cementum around dental implants, with the alveolar bone in direct contact with the implant surface. As is the case with teeth, the transmucosal component of implants needs to provide a physical and physiological barrier between the external oral environment and the underlying tissues. The implant-mucosa interface also includes a sulcus resembling that associated with teeth, as well as an attachment apparatus. Indeed, the architecture of the supra-alveolar transmucosal components, consisting of a sulcus, junctional epithelium, and connective tissue attachment, is similar around implants and teeth. Although both the transmucosal component of implants and the transgingival component of teeth have a sulcus (in health) or pocket (in disease) and a connective tissue attachment, important differences exist, which have clinical implications for the maintenance of peri-implant mucosal health, as well as for the diagnosis and management of peri-implant disease [38].

Soft tissue around teeth is subdivided into gingiva and mobile mucosa. The attached keratinized gingiva is composed of a keratinized epithelium, dense connective tissue, and periosteum which plays an essential role in the protection of periodontal structures. The attached gingiva provides increased resistance of the periodontium to external injury, contributes to the stabilization of the gingival margin position, and aids in the dissipation of physiological forces that are exerted by the muscular fibers of the alveolar mucosa onto the gingival tissues [39]. The width of keratinized tissue around natural teeth does not seem to be correlated with the maintenance of periodontal health. According to several reports, a 2.0 mm of attached gingiva is sufficient for the maintenance of periodontal health [3, 40] even in cases in which subgingival restoration margins are placed [41–43]. Apically repositioned flap as described by Friedman [44] has been successfully used to increase the width of attached gingival around natural teeth. Moreover, this procedure can be modified and used around implants in cases where a thick gingival biotype is present (when there is no need of improving peri-implant mucosa thickness) (Fig. 10.7), with the advantages of promoting low morbidity to the patient (as it precludes the need of second surgical site) and better esthetic color blending [45]. The characteristics of the transmucosal passage-junctional epithelium and connective tissue attachment of the implant are established when healing of the ridge mucosa following implant surgery is in progress. In this context it should be realized that an essential role of epithelium in wound healing is to cover any connective tissue surface that is severed, such as during surgery. Thus, the epithelial cells

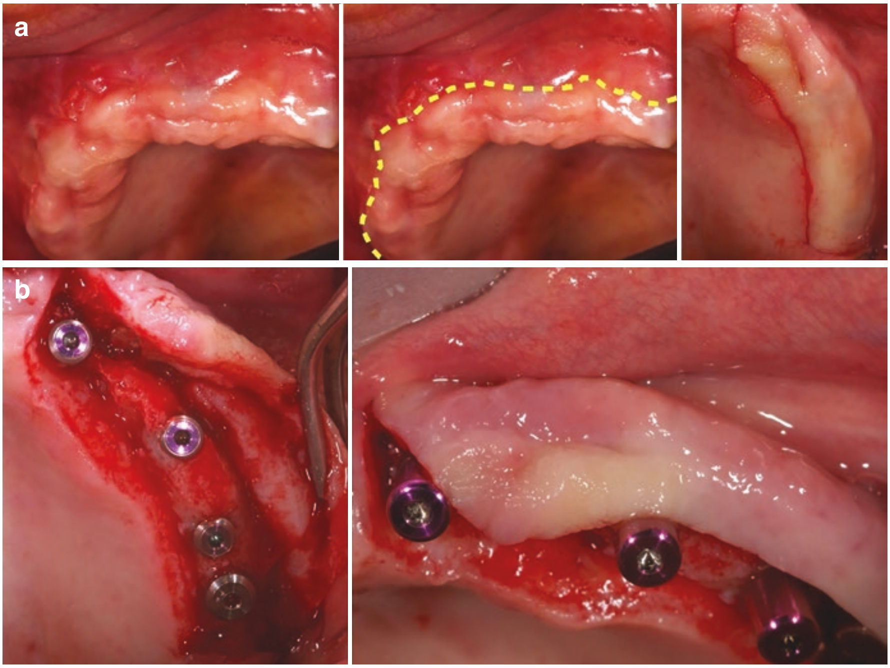

Fig. 10.7 (**a**) Maxillary alveolar ridge demonstrating lack of attached keratinized tissue. Note the presence of palatal roughness and shallow palate with evidence of significant maxillary atresia—(**a**) baseline; (**b**) paracrestal incision associated with anterior and posterior vertical releasing incisions followed by mucoperiosteal flap elevation and its apical repositioning; (**c**) buccal and apical mobilization of the flap followed by its stabilization using the surgical adhesive, as well as interposition of collagen type I sponge on the palatine wound; (**d**) sutures; (**e**) 3 weeks follow-up, occlusal view; (**f**) 3 weeks follow-up, frontal view; (**g**) 6 weeks follow-up, note the ample keratinized tissue band surrounding the implants, as well as the maintenance of the nonkeratinized mucosa close to its original position

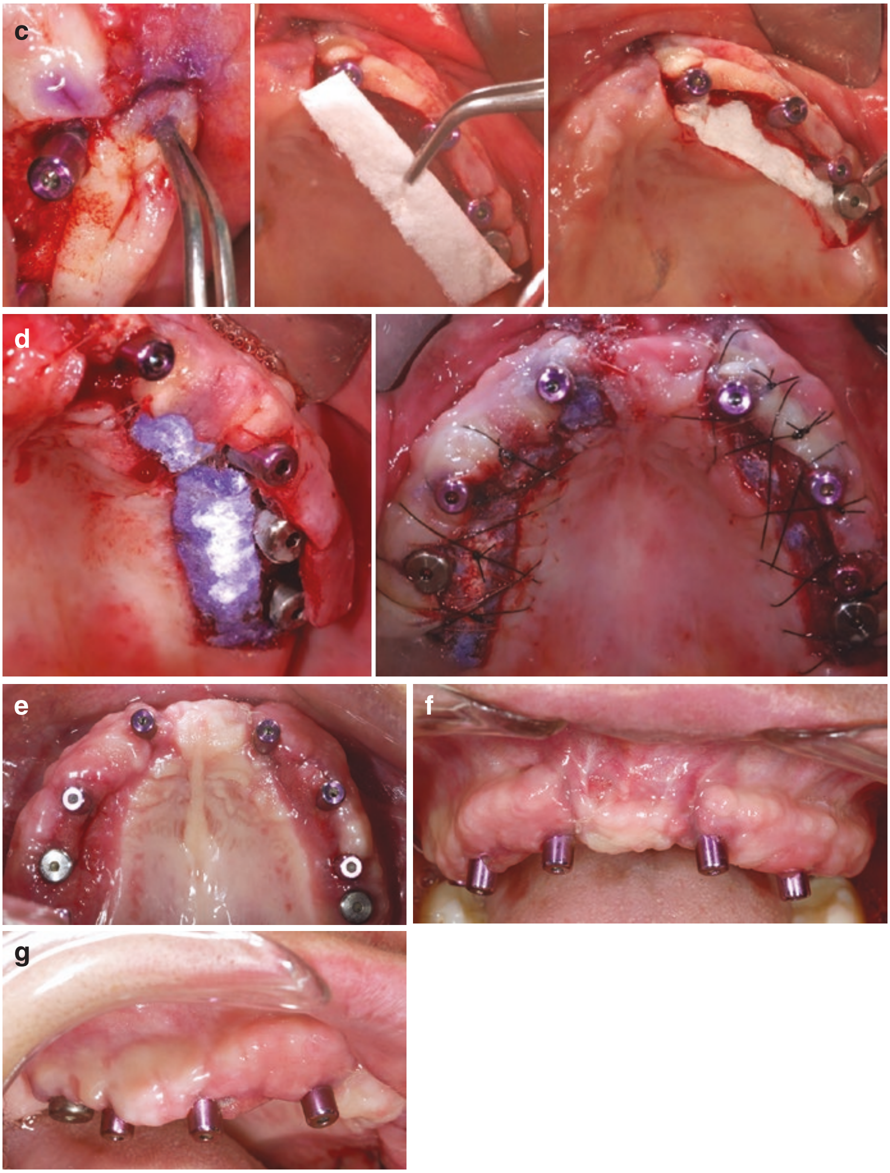

Fig. 10.7 (continued)

at the periphery of the mucosal wound, produced at implant installation, are genetically programmed to divide and migrate across the injured part until epithelial continuity is restored. The epithelial cells also have the ability to adhere to the implant surface, synthesize basal lamina as well as hemidesmosomes, and establish an epithelial barrier that has features in common with a junctional epithelium. Equally important is the capacity of a normal, uninflamed connective tissue to form an attachment to the titanium surface below the epithelium and in a more superficial location to support the junctional epithelium. The maintenance of normal connective tissue is of critical importance for normal turnover of the epithelial and connective tissue attachments to the titanium implant [46].

10.9 Concluding Remarks on Gingival Augmentation (KT Increase) and Vestibuloplasty: Implications for Practice and Clinical Decision-Making

Gingival augmentation procedures have long been used in clinical practice and appear as an important factor for maintaining periodontal health. The use of FGG can safely increase the keratinized tissue width and modify the periodontal biotype (Fig. 10.8). Although the results of FGG may be improved over time by the coronal displacement

Fig. 10.8 Anterior mandibular site presenting a single recession defect and a thin periodontal biotype. A free gingival graft was used to decrease recession depth and to increase the width and thickness of keratinized tissue—(**a**) baseline; (**b**) 21 days follow-up; (**d**) 12 months follow-up

of the gingival margin (creeping attachment), the amount of this “beneficial” outcomes may not be anticipated [5, 6]. On the other hand, some degree of soft tissue shrinkage may be anticipated during the initial phase of healing, as well as during long-term follow-up. The available evidence suggests that this KT contraction seems more evident at implant sites (up to 50%) in the short-term (up to 3 months) [7]. For natural teeth, nearly 82% of KT gain achieved at short-term (i.e., 6 months) may be maintained long-term (i.e., up to 25 years). With respect to implant sites, early animal [47] and human studies [48, 49] reported no correlation between implant success and the presence of keratinized mucosa (KM). In contrast, recent systematic reviews concluded that an inadequate width of peri-implant KM is associated with more plaque accumulation, signs of inflammation, soft tissue recession, and attachment loss [2, 3, 18, 50]. Furthermore, the peri-implant mucosa appears to possess less potential for an immune response against external irritants (plaque accumulation) [51].

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11 Mucogingival and Periodontal Plastic Surgery: Lateral Sliding Flaps

David H. Wong

11.1 Introduction

Gingival recession associated with root exposure affects a large portion of the adult population. It is estimated that more than 50% of the population has one or more teeth with at least 1 mm of recession [1].

Similar prevalence among adults has been reported in other studies. For example, Albandar and Kingman [2] reported the prevalence of 1 mm or more recession in people aged 30 years and older was 58%. Other findings were that gingival recession is more frequently found in men compared to women and recession tends to increase with age.

Gingival recession may be caused by a number of factors. It may be a result of the pathogenesis of periodontal diseases related to inflammation caused by bacteria. Perhaps more commonly, gingival recession is attributed to trauma from aggressive or vigorous use of a toothbrush [3–5]. In fact, gingival recession is found more frequently in people who brush their teeth more frequently and who have good oral hygiene compared to people who have poor oral hygiene [6].

Patient anatomical factors also play a role. For example, crowding or a facial tooth position is often cited as an explanation for root exposure [7]. Tooth morphology itself may even be considered. Long, tapered teeth are more highly associated with root exposure than short, square-shaped teeth. Other findings associated with increased risk of recession include teeth with a thin gingival biotype or underlying bony dehiscences or fenestrations. Occasionally, the buccal-lingual width of a tooth may be wider than its alveolar process [8]. Finally, the presence of a high frenum attachment or frenum pull may place a tooth at higher risk for root exposure [9, 10].

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Fig. 11.1 Image of the donor site (left lateral incisor) free of gingival inflammation and a wide band of keratinized tissue (≥4 mm)

In exploring treatment options to treat or correct gingival recession, two types of flap surgery techniques are primarily used: the coronally advanced flap and the lateral sliding flap. The focus of this chapter will be on the lateral sliding flap as well as its various modifications and advancements.

The lateral sliding flap was first described by Grupe and Warren in 1956. It is also known as a laterally positioned flap or a lateral pedicle flap. Since its introduction, modifications and additions have been made to the technique [11], which will be explored later. As with any periodontal plastic surgery procedure for root coverage and the correction of mucogingival deficiencies, the goals of the lateral sliding flap are the following:

- Establish a sufficient band of keratinized and attached gingiva.
- Cover the exposed root surface.
- Establish a new gingival attachment to the previously denuded root surface.

The lateral sliding flap accomplishes these goals when certain conditions exist [12–14]. Of critical importance is the donor site (the adjacent tooth) which must have an abundance of keratinized and attached gingiva (Fig. 11.1, arrow). It is preferable to not have excessive frenum attachments in the area as flap stability and immobility is important. Shallow vestibular depths offer a larger challenge for this procedure due to excessive flap tension as well as their association with thinner tissue. Other factors that maximize predictability include the position of the exposed root in the arch and the position of the tooth that is serving as the donor site.

11.2 Surgical Technique for the Lateral Sliding Flap [15]

The following is a general description for performing a lateral sliding flap procedure to treat gingival recession on a single tooth. A general description is illustrated in Figs. 11.2 and 11.3.

1. First, it is important for the teeth to be clean and the gingival tissues free of inflammation (Fig. 11.1).

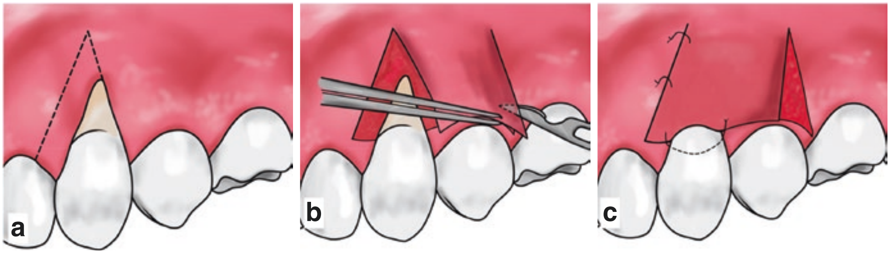

Fig. 11.2 Schematic illustration of the lateral sliding flap. (**a**) A V-shaped incision with a beveled wound edge is prepared on the recipient site (the tooth with the exposed root). (**b**) The donor site is prepared by making a vertical incision next to the recipient site at a distance approximately 1 1/4 to 1 1/2 times the mesial-distal width of the recipient tooth. It is important that the width of the flap must be sufficient to adequately cover the root dehiscence yet still place the flap margins on bone. Either a full-thickness or partial-thickness flap may be reflected and released to be laterally positioned without tension. (**c**) The flap is slid laterally to cover the recipient site and sutured

2. Following local anesthesia, prepare the recipient site (the tooth with the exposed root) by making a V-shaped incision and forming a beveled wound edge around the recipient site with a sharp scalpel blade (e.g., #15 or a #15c, Fig. 11.2a).
3. The incised tissue is then removed, and a smooth root surface is prepared with either hand or rotary instruments. Further preparation of the root can be performed chemically using an agent such as citric acid or EDTA. Please note: the use of etching agents may not be imperative to the success of the surgery [16]. A clean root surface, however, is a necessity.
4. Next, the donor site is prepared by making a vertical incision next to the recipient site at a distance of approximately 1 1/4 to 1 1/2 times the mesial-distal width of the recipient tooth (Fig. 11.2b). The flap will essentially include two papillae: the papilla of the recipient tooth and the closest papilla of the adjacent tooth (the donor tooth). The important part of this step is that the width of the flap must be sufficient to adequately cover the root dehiscence yet still place the flap margins on bone. It is also helpful if the vertical incision is angled slightly toward the recipient bed.
5. Once the vertical incision has been made, either a full-thickness or partial-thickness flap may be reflected. A combination of a full- and partial-thickness flap is also an option where the portion of the flap that will be placed over the exposed root is full thickness, but the portion of the flap that still covers the donor tooth is partial thickness. Partial-thickness flaps may protect the donor site from further recession and bone loss, especially in the event of an unforeseen fenestration or dehiscence.
6. After the flap is reflected, a periosteal releasing incision is made with a scalpel or scissors to adequately mobilize the flap to allow it to be laterally positioned without tension.
7. The flap is then slid laterally to cover the recipient site and sutured (Fig. 11.2c). The papillae are typically secured with a sling suture to help them properly adapt to their new positions while maintaining adequate flap height to fully

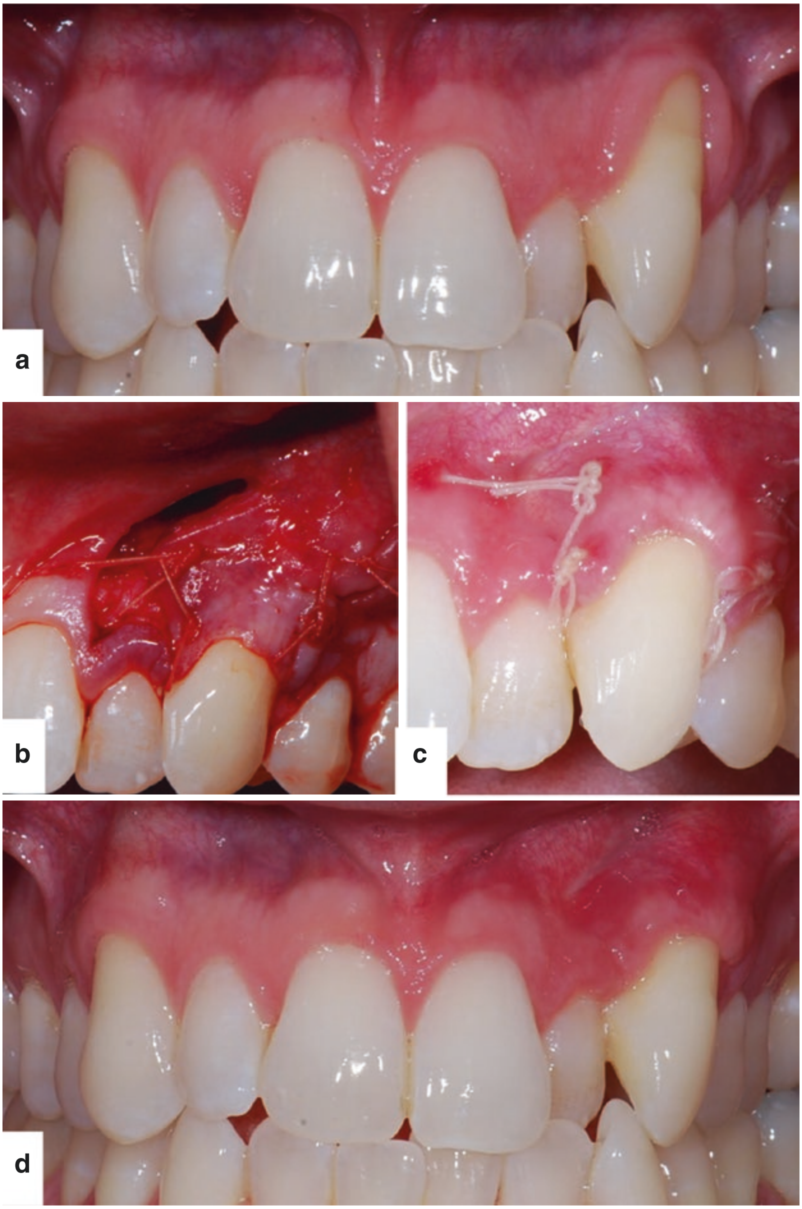

Fig. 11.3 The lateral sliding flap as a stand-alone surgery without the addition of graft materials. Prior to performing this procedure, the donor tooth is carefully examined to ensure that there is an abundance of keratinized gingiva (≥4 mm) present on the facial surface. When performed, care is taken to design the flap to minimize gingival recession of the donor tooth. Notice that a collar of marginal gingiva (≥2 mm) is left on the donor tooth. In addition, the periosteum is also left over the donor tissue in the event that there is an unanticipated root fenestration or dehiscence. By the time the sutures are removed at 2 weeks, complete wound closure is observed, and immature healthy tissue can be observed on the donor tooth. Root coverage on the recipient tooth is nearly 100% at 3 months

cover the root surface (Fig. 11.3b, c). The closure of the remaining incision may be performed with either interrupted or continuous sutures. A common suture size for closure is 5-0. Non-resorbable suture materials are recommended.

8. Finally, test for proper immobilization of the flap by manually manipulating the labial or buccal mucosa to ensure that the flap does not move.
9. Apply firm pressure to the flap for several minutes with a moist gauze pack to achieve further hemostasis while also encouraging close adaptation of the flap to the recipient site.
10. Place a periodontal dressing if desired.
11. Remove sutures at 14 days. The area should not be probed for 12 weeks. Postoperative visits should be as often as necessary to help maintain the area free from plaque and debris (Fig. 11.3d).

11.3 Complications and Treatment Modifications

Two primary concerns are typically expressed with the lateral sliding flap. First of all, flap necrosis is a potential complication due to the procedure typically involving only one tooth. With the flap design involving two vertical incisions over a denuded root surface, maintaining an adequate blood supply to the flap is imperative. Whenever possible, the base of the flap should be wider than the cervical portion. One flap design modification to address this potential issue is to widen the flap to include more than one tooth. In addition, it is important that the flap is mobilized enough with periosteal releasing incisions to ensure that the flap lays passively over the exposed root surface. Proper reapproximation of the wound edges and complete closure with sutures will also aid in the rapid healing of the recipient site (Fig. 11.3b, c).

The second complication associated with the lateral sliding flap procedure is the potential root exposure from gingival recession at the donor tooth. This complication is sometimes unpredictable and unavoidable since information about underlying dehiscences or fenestrations on the donor tooth is not necessarily available prior to elevating the flap. In a classic study that examined the changes that occur at both the donor and recipient teeth, it was discovered that about 1 mm of recession occurred at the donor tooth, which also lost approximately 1.25 mm of keratinized tissue, and the average root coverage was 69% [17]. There have been several changes and additions to the lateral sliding flap procedure to address these adverse events [18].

One way to minimize or even prevent gingival recession from occurring on the donor tooth is by designing the flap to leave approximately 2 mm of marginal gingiva on the facial surface of the donor tooth (Figs. 11.2b, c and 11.3b, c). While it is often debated how much keratinized gingiva is necessary for health, it is generally considered acceptable to leave both the donor and recipient teeth with 2 mm of keratinized gingiva, with 1 mm being attached gingiva [19]. Given this recommendation, an increased amount of keratinized gingiva (4 mm) on the donor tooth is necessary in order to consider a lateral sliding flap. This is important to avoid creating mucogingival deficiencies on the teeth. These criteria may eliminate many potential donor teeth from consideration for this procedure, if the lateral sliding flap is the sole root coverage strategy.

11.4 Soft-Tissue Grafts and the Lateral Sliding Flap

Thus far in this chapter, the basic indications and technique for the lateral sliding flap have been reviewed. Treatment modifications have also been introduced to reduce the adverse events that may occur at the donor tooth. Over the years, further additions to the technique have been employed in order to further accomplish the three goals of the lateral sliding flap mentioned in the introduction:

- Establish a sufficient band of keratinized and attached gingiva.
- Cover the exposed root surface.
- Establish a new gingival attachment to the previously denuded root surface.

Perhaps the most influential change to the success of the lateral sliding flap is the introduction of the subepithelial connective tissue graft (SECTG) (Fig. 11.4a–i). The SECTG was first described by Langer and Langer in 1985 as a root coverage procedure. Over the years, it has been proven as one of the more reliable techniques for gaining root coverage over recession defects while simultaneously thickening the band of keratinized and attached gingiva [20]. Moreover, the predictable formation of a new gingival attachment (versus a periodontal pocket) to the previously denuded root surface has been well-established [21, 22].

As a stand-alone procedure, the lateral sliding flap yields fair results with regard to the amount of root coverage achieved. The range of the amount of root coverage observed was 63% [23] in one report to 69% [17] and 74% [18] in two other papers. However, by combining this procedure with a subepithelial connective tissue graft, the amount of root coverage is generally increased. Utilizing a SECTG with a double-sliding papilla flap, Nelson reported a mean root coverage of 88% [24]. In a study where advanced recession defects with interproximal bone loss were treated with an SECTG and a laterally sliding flap, root coverage ranged from 60 to 95% depending on the degree of interproximal bone loss [25]. The greater the interproximal height of bone, the higher the degree of root coverage. These results relative to root coverage appear to be consistent to studies where similar recession defects were treated with a coronally advanced flap combined with an SECTG.

While SECTGs combined with either lateral sliding flaps or coronally advanced flaps are common treatment options, the next area of exploration, as far as lateral sliding flaps are concerned, appears to be their combined use with acellular dermal grafts (ADGs). ADGs have a practical advantage for patients since they are soft-tissue human allografts. Because they are devoid of any cellular components or proteins, they are biocompatible and widely considered safe. There is a wide amount of data regarding the effectiveness of ADGs for the treatment of gingival recession, and many compare favorably to SECTGs in regard to the amount of root coverage, the increased thickness of keratinized and attached gingiva, and the clinical attachment level gain [26–28]. ADGs also solve the problem of tissue quantity, as anatomical factors may often limit the amount of autogenous tissue that can be obtained. ADGs are an attractive choice for many clinicians and their patients largely due to being able to avoid using the palate or other intraoral donor site in order to obtain autogenous tissue. This, of course, is associated with decreased pain, morbidity, and other adverse events

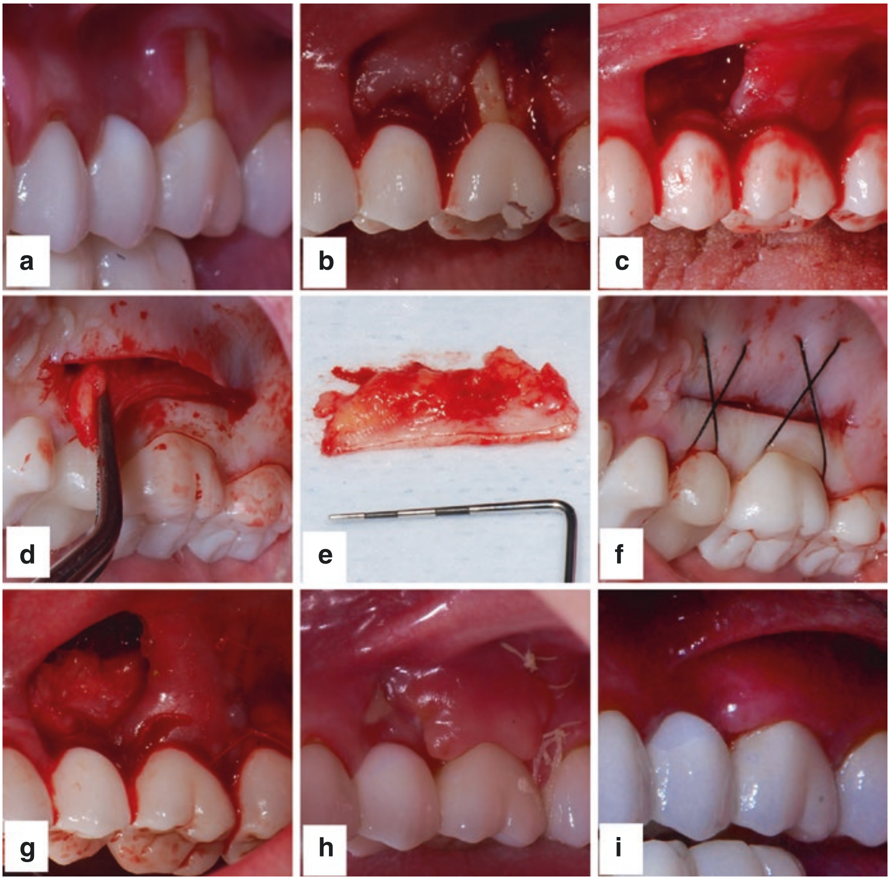

Fig. 11.4 In this procedure, a laterally sliding flap is performed with the addition of a subepithelial connective tissue graft (SECTG). In this situation, the pontic site makes an excellent donor site given the abundance of keratinized gingiva without the worry of underlying root anatomy. The SECTG is obtained from the palate and placed over the severely receded root of the molar prior to sliding the flap from the pontic site and suturing it to place. By utilizing an SECTG, the gingival tissues are augmented while also covering the severe recession on the upper molar

associated with a secondary surgical site. However, long-term data on ADGs is limited, and their use in combination with lateral sliding flaps has not been widely studied [29]. However, based on the data surrounding the use of ADGs and coronally advanced flaps, this leaves an area for further exploration with lateral sliding flaps.

11.5 The Role of Growth Factors

Blood-derived growth factors have been utilized in dental surgery for well over a decade. Their increase in surgical application is due to their ability to easily and practically introduce growth factors at wound and surgical sites to maximize healing while decreasing inflammation. They are relatively inexpensive and practical to use, and because the products come from the patient's own blood, they are safe. The can also be used in a variety of different forms such as a liquid, a membrane, or a plug. They are often used in a mixture or in combination with other regenerative materials such as bone replacement grafts. Generally speaking, they improve wound healing by accelerating the processes of hemostasis, inflammation, cell proliferation, and tissue remodeling. Most of their dental application has been in the area of regenerative surgery, specifically as it relates to bone regeneration. In its relatively recent history compared to periodontology and implantology, blood-derived growth factors have not been widely studied in periodontal plastic surgery. Nonetheless, a review of the various blood-derived products is offered, and potential for their use in root coverage surgery such as the lateral sliding flap will be reviewed.

11.5.1 Platelet-Rich Plasma (PRP)

Like all of the blood-derived growth factors, PRP requires the use of a centrifuge to procure its contents. What makes PRP "platelet-rich" is that the final product, which is a liquid or gel form, contains at least 1,000,000/1 L in a 5 mL volume of plasma. Normal platelet counts are 150,000/1 L to 350,000/1 L [30]. The growth factors associated with PRP are the following: Platelet-derived growth factor (PDGF), epidermal growth factor (EGF), transforming growth factor-beta (TGF-b), vascular endothelial growth factor (VEGF), and insulin-like growth factor I (IGF-1). Its gel form is derived by mixing PRP with thrombin and calcium chloride. Because of its liquid or gel form, it is not an ideal graft material for root coverage surgery. While it is not an ideal graft material, the growth factors released in its application have been associated with accelerated hard and soft tissue healing mediated through the formation of a fibrin clot [31].

PRP has been reviewed to a fair extent with mixed results in regard to periodontal regenerative therapy and oral surgery. Data in treating gingival recession is limited. In one study using PRP in combination with subepithelial connective tissue grafts on 40 patients and followed up to 48 weeks, the authors reported no benefit with the use of PRP [32].

In addition to the contradictory clinical benefits, the cost of application of PRP as well as the availability and practicality of using thrombin with the centrifuged blood makes it a less attractive product in root coverage surgery.

11.5.2 Platelet-Rich Fibrin (PRF)

Of all the blood-derived biologic modifiers, perhaps PRF has shown the most promise based on recent studies. While PRP is considered the first-generation platelet concentrate, PRF is considered the second generation. It differs from PRP in that its growth factors are released more slowly over time compared to a quick burst, and the levels of the growth factors remain higher over a period of 10 days [33]. There are several procedural differences in the preparations of PRP versus PRF, but in summary, PRF has a simpler and quicker preparation and less equipment and materials involved, and it is completely autologous. The primary difference that makes PRF more of an ideal graft material is that it is a three-dimensional fibrin scaffold that closely resembles the types of membranes and soft-tissue grafts used in periodontology.

The big question with PRF is whether or not it can act as a substitute for traditional graft materials such as the common subepithelial connective tissue graft (SECTG). Presently, a few studies have demonstrated similar root coverage results when comparing PRF grafts to the SECTG (Table 11.1). In reviewing this data, several key observations should be made. The longest follow-up period was 12 months. All of the recession defects that were studied were either Miller class I or class II defects. As far as root coverage is concerned, the PRF membranes performed statistically comparable (not superior) to the SECTGs.

There is some suggestion in other reports, however, that the keratinized tissue may be less stable after treatment with PRF compared to the palatal grafts (Fig. 11.5a–f). Therefore, it is recommended that when thin biotypes are present or more advanced recession defects such as Miller class III recessions are treated, that SECTGs are used in conjunction with PRF [30]. The primary reason for this recommendation is in understanding the differences in SECTGs and PRF as graft materials. SECTGs result in more keratinized tissue by genesis, where the graft transfers the genetic potential of the palatal tissue (the typical donor site) to the recipient bed and therefore influences the tissue phenotype of the surrounding tissue [39]. PRF, on the other hand, is a biological matrix of fibrin. It helps to cover exposed roots by promoting and inducing angiogenesis and new tissue at the site of the recession. Therefore, if the recipient site is keratinized, PRF will enhance this quality of the existing tissue; if it is nonkeratinized, the use of PRF will not result in its

Table 11.1 The results of PRF on root coverage gingival recession defects

Author	Study design	# of patients	Follow-up period	Treatments studied	Root coverage %	*P* value
Aleksic (2010) [34]	Split-Mouth; Miller Class 1 and II defects	19	12 months	Coronally advanced flap (CAF) + SECTG vs. CAF + PRF	88.6 79.9	N/S
Jankovic (2012) [35]	Split-Mouth; Miller Class 1 and II defects	15	6 months	CAF + SECTG vs. CAF + PRF	88.7 92	N/S
Eren (2014) [36]	Split-Mouth; Miller Class 1 and II defects	22	6 months	CAF + SECTG vs. CAF + PRF	94.2 92.7	N/S
Tunaliota (2015) [37]	Split-Mouth; Miller Class 1 and II defects	22	12 months	CAF + SECTG vs. CAF + PRF	77.4 76.6	N/S
Keceli (2015) [38]	Split-Mouth; Miller Class 1 and II defects	40	3 and 6 months	CAF + SECTG vs. CAF + SECTG + PRF	79.9 89.6	<0.05

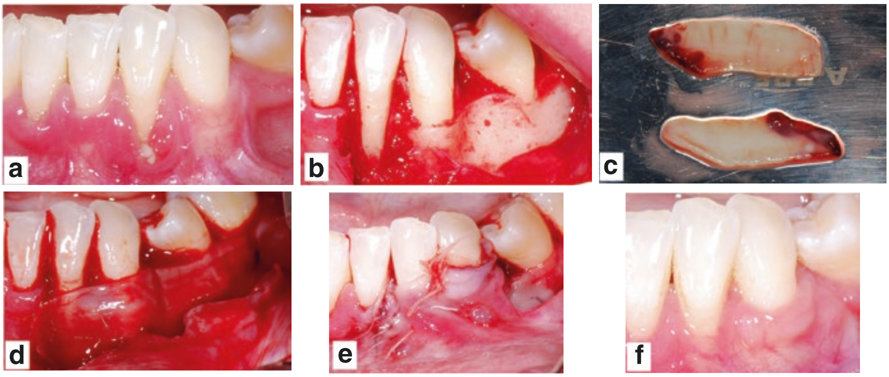

Fig. 11.5 When PRF was first introduced in root coverage surgery, it was used as shown here, like a traditional graft material. This case demonstrates a typical result when grafting with PRF in the absence of preestablished adequate keratinized gingiva in a Miller class III recession defect involving the loss of interproximal bone. Notice how root coverage is achieved, but the facial gingival tissues remain thin and nonkeratinized

keratinization. This is the rationale behind utilizing both a SECTG and PRF together when grafting Miller class III recessions or recessions where thin, nonkeratinized tissue is present.

11.5.3 Fibrin-Assisted Soft-Tissue Promotion (FASTP) [40]

From Table 11.1, it is noted that various percentages of root coverage were achieved despite comparing only two treatment groups: SECTG vs. PRF. In addition, these results are also supported in a recent systematic review and meta-analysis [41]. As mentioned, PRF and conventional graft materials heal via two very different mechanisms. In order to maximize the volume and characteristics of gingival tissue using PRF for root coverage surgery, the FASTP technique was introduced.

FASTP for root coverage differs from the previously mentioned studies in two ways: First of all, the flap design used is not a conventional coronally advanced flap. Instead, it uses a papillae-sparing flap design that utilizes vertical incisions in the mucosa which provides the access for the PRF to be placed over the root surfaces. This flap design is very similar to that described for the vestibular incision subperiosteal technique access (VISTA) technique [42]. Second, rather than use PRF membranes in a conventional grafting manner where only one membrane/graft is placed over the teeth, the authors recommend using three to four membranes for every two teeth. Like typical grafting procedures, proper flap management, adequate release of the tissue, space maintenance, and tension-free passive closure are the keys to success for this procedure. Given the recent introduction of FASTP, lessons to learn from it for future study in lateral sliding flaps are to utilize more PRF membranes per tooth and realizing that they are not the same as conventional graft materials such as SECTGs. The use of more PRF membranes during root coverage surgery to capitalize on the increase in growth factors and leukocytes is an idea that will be observed and evaluated in the future.

11.6 Conclusion

Numerous root coverage surgeries are available to treat gingival recession. The large majority involve the use of graft materials in combination with either a coronally advanced flap or a lateral sliding flap. While originally introduced as a standalone surgery, the lateral sliding flap has undergone an evolution over the years. First came changes in flap design to maximize root coverage while minimizing damage to the recipient site. Next came the addition of autogenous tissue in order to further augment the gingival tissues and positively influence the gingival biotype. Other grafting materials such as acellular dermal grafts are worth considering in order to avoid the discomfort and morbidity of a secondary donor site; however, they have not been widely reported for use with lateral sliding flaps.

The addition of growth factors derived from the patient's whole blood is the next and newest area of exploration. The most widely studied blood-derived biologic modifier for root coverage surgery is PRF. While first investigated to determine if it can enhance existing grafting techniques, studies are now underway to see if they can be used as a solo grafting material. While very successful and predictable for more mild recession defects, PRF is less predictable in more severe sites, especially in sites where interproximal bone loss and thin, nonkeratinized tissue are present. Finally, the FASTP technique has been introduced to utilize PRF in a different manner than traditional graft materials. Elements of this technique may be explored in other flap designs such as the lateral sliding flap. Tissue engineering is the trend of the present and of the future to incorporate minimally invasive techniques to achieve excellent clinical results for the patient.

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Part V

Interdisciplinary Management of Periodontal Surgery

12 Crown Lengthening and Prosthodontic Considerations

E. Dwayne Karateew, Taylor Newman, and Farah Shakir

12.1 Introduction

Crown lengthening surgically increases the clinical crown in an incisal-apical dimension for either restorative or esthetic needs or a combination of both. The procedure may include apical repositioning of the gingival margin and osseous contouring. From a restorative standpoint, indications include insufficient clinical crowns for retention, subgingival caries, and subgingival fractures. Esthetically, short clinical crowns and cases of excess gingival display can also benefit from surgical crown lengthening [1, 2]. Case assessment prior to restorative treatment must take into consideration the biologic width and the mucogingival status (Fig. 12.1). Failure to do so can be detrimental to long-term periodontal health, resulting in subsequent inflammation, bone loss, and gingival recession [2, 3].

12.1.1 Biologic Width

Decay or placement of a restorative margin apical to the gingival sulcus risks impingement on the supracrestal fiber attachment and violation of the biologic width. The biologic width refers to the aspect of soft tissue, the dentogingival complex, that is attached to the tooth coronal to the alveolar bone. It is comprised of the connective tissue attachment, the epithelial attachment, and the gingival sulcus (Fig. 12.2) [3, 4]. Early work by Gargiulo et al. [5] on cadaver skulls found average measurements of 0.69 for the sulcus depth, 0.97 mm for the epithelial attachment, and 1.07 mm for the connective tissue attachment. A minimum of 3 mm from the alveolar bone to the restorative margin has been indicated to avoid infringement on

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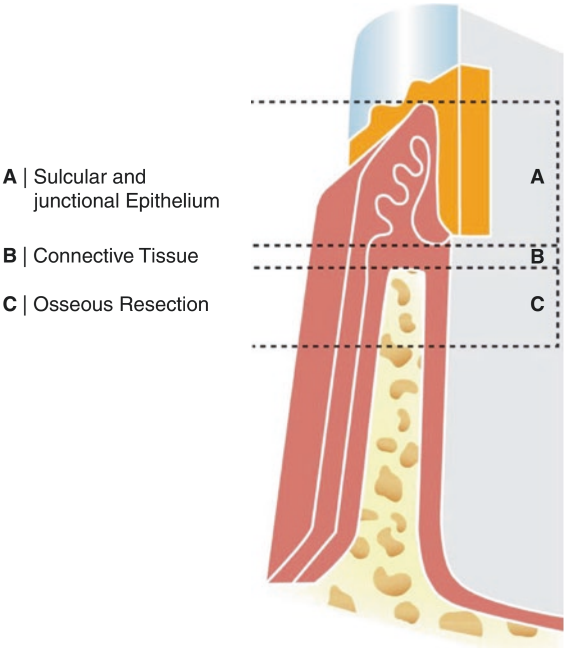

Fig. 12.1 Relationship of the sulcular and junctional epithelium, the connective tissue attachment, and the underlying alveolar crest. Biologic insult (golden-yellow) could include decay, external resorption, and restorative margin. This extends apically into Zone A and B causing an inflammatory response to the physical insult. Osseous resection, Zone C, must be conducted to surgically re-create the biologic width at a more apical position. Health can then be restored

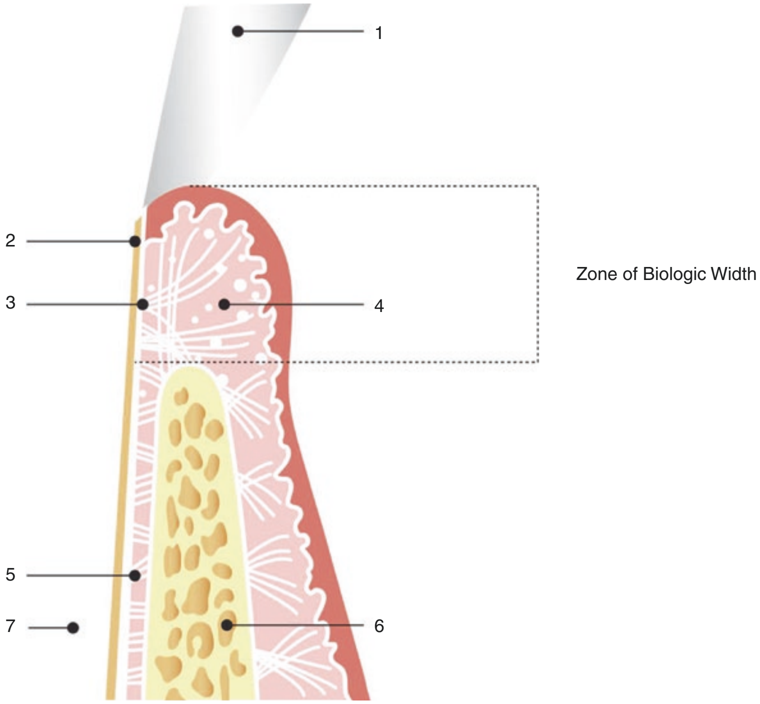

Fig. 12.2 Detail schematic of the periodontal structures. (1) Enamel of the clinical crown, (2) Cementum, (3) Gingival fibers, (4) Gingival connective tissue, (5) Periodontal ligament, (6) Alveolar bone, and (7) Dentin

the dentogingival complex and maintenance of the biologic width [6]. Kois [3] has expressed that the biologic width "averages" previously noted are quite variable between individuals and among the dentition of the same individual and therefore should be assessed on all included teeth prior to crown lengthening procedures. Additionally, it is more predictable to measure the entire dentogingival complex as a whole as opposed to individual components. This can be done by anesthetizing the patient for comfort and utilizing a periodontal probe to measure from the free gingival margin (FGM) to the osseous crest (so-called bone sounding). The resulting measurements can be categorized into normal, high, and low alveolar crests to further aid in determination of restorative margin location. A normal alveolar crest measures approximately 3 mm on the facial aspect and 3–4.5 mm on the interproximal surfaces. In this case, the restorative margin can safely be placed 0.5–1 mm apical to the FGM or 2–2.5 mm coronal to the osseous crest. In the case of a high alveolar crest, the total dentogingival complex measures less than 3 mm, and therefore the margin should be at, and no more than 0.5 apical to, the FGM. Alternatively, a measurement of greater than 3 mm for the total dentogingival complex is categorized as a low alveolar crest, in which case the margin can be placed more than 1 mm apical to the FGM. The relationship of the FGM to the alveolar crest should be measured prior to restorative preparation and surgical intervention, as well as after crown lengthening healing is completed.

Of critical importance is understanding the risks involved if the biologic width is violated. If crown lengthening is not performed when indicated, the oral tissues will aim to correct for this invasion in an unpredictable and uncontrolled manner. Chronic tissue inflammation can occur, as well as recession and bone resorption, possibly leading to intrabony defects [3].

12.1.2 Mucogingival Considerations

The term mucogingival condition refers to "deviations from the normal anatomic relationship between the gingival margin and the mucogingival junction (MGJ)." Examples include recession, absence or decreased keratinized tissue, and lack of attached tissue [7]. As discussed by Zadeh and Gil in this volume, the etiology of these mucogingival conditions is multifactorial. Factors can include tooth position, orthodontic treatment, gingival biotype, frenum position, vestibular depth, and mechanical insult. A thin gingival biotype is more likely to result in gingival recession versus a thick biotype. Buccally positioned dentition has been associated with thinner labial bone and gingiva and therefore at greater risk of gingival recession as well. Similarly, orthodontic movement in the buccal direction is more likely to cause mucogingival conditions versus that in a lingual direction [8]. Further evidence shows that some toothbrushing factors can be associated with gingival recession, especially in more prone sites (i.e., those with other contributable factors for mucogingival deformities) [8, 9].

Crown lengthening may include gingivectomy, and therefore it is important to understand the gingival condition prior to any surgical intervention. Additionally, the quality and quantity of tissue can contribute to the overall gingival health, especially around restorations.

The need for keratinized and/or attached gingiva for periodontal health is somewhat controversial in the literature. It is well-documented that areas of little to no keratinized tissue are able to be maintained and provide support over long periods of time. Nonetheless, this outcome is only possible with excellent oral hygiene and regular professional maintenance [8, 9]. This is highlighted in a split mouth long-term study [10]. Areas of little to no attached gingiva were either augmented with a free gingival autogenous graft or left alone, and not all of the patients received professional maintenance. Over time, patients who followed good oral hygiene and received maintenance showed adequate health in treated sites, as well as those that were not treated. In patients who did not follow maintenance protocols, the non-augmented sites resulted in increased inflammation and recession compared to augmented sites. Overall, the general consensus is that keratinized tissue deficiency predisposes to the development of gingival recession and inflammation [8]. It is suggested that 2 mm of keratinized gingiva, with 1 mm being attached, is needed for optimal health [9, 11]. Therefore, the keratinized and attached tissue should be assessed prior to crown lengthening procedures.

Furthermore, the role of tissue around restorative margins has been evaluated in the literature. Studies have compared two groups, one with a wide zone (greater than or equal to 2 mm) of keratinized gingiva and the other with a narrow zone (less than 2 mm) of keratinized gingiva [12, 13]. In the presence of subgingival restorations, the amount of inflammation was significantly increased in those with a narrow zone versus a wide zone of keratinized tissue. Another study was completed on dogs, where steel bands were placed subgingivally, and sites with adequate widths of keratinized gingiva were compared to those with inadequate keratinized gingiva [14]. Sites with inadequate keratinized tissue showed gingival inflammation in addition to loss of gingival tissue. Later work has confirmed that restorative margins placed subgingivally lead to early gingival recession and attachment loss, and recession is more likely in areas of narrow gingiva [15]. Systematic reviews and position papers have confirmed the negative impact on gingival health that intrasulcular margins can have, especially in the presence of minimal or no attached gingiva. Gingival augmentation is indicated in those sites planned for intrasulcular restorative margins [8, 10, 15, 16]. Some authors even advocate for a minimum of 5 mm of keratinized tissue (3 mm attached and 2 mm free) at those sites [17]. Therefore, prior to restorative treatment, the biologic width and the mucogingival state should be evaluated. As discussed, violation of biologic width has been shown to lead to unpredictable bone loss and recession. Crown lengthening procedures to provide restorative access should consider the biologic width of each tooth before and after surgery (Fig. 12.3). Additionally, the amount of keratinized and attached tissue, and the presence of mucogingival deformities, should be noted prior to surgical intervention and restoration placement. Thin gingival biotype and minimal attached gingiva can result in gingival inflammation and recession defects.

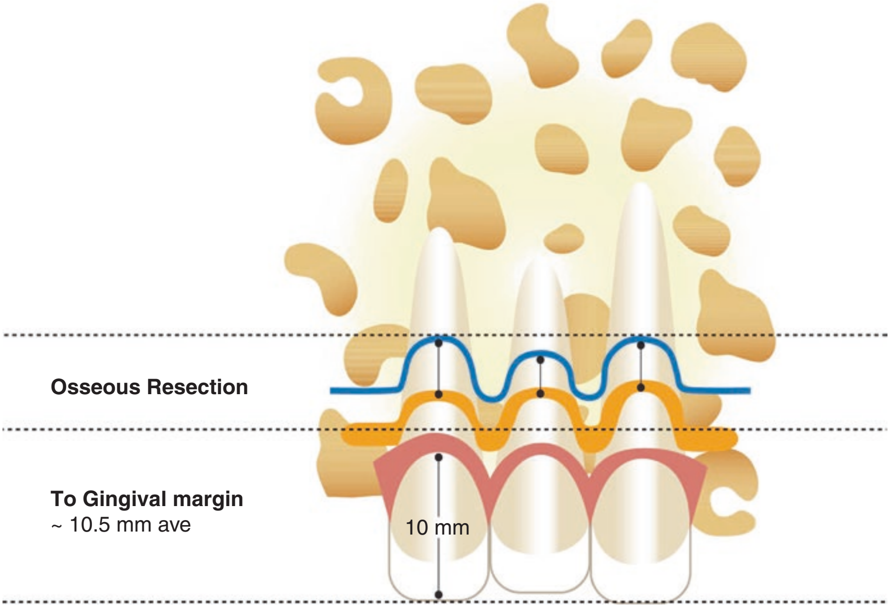

Fig. 12.3 Osseous recontouring for esthetic crown lengthening. Average distance from the incisal edge of a central incisor to the gingival margin is approximately 10.5 mm. Once the gingival tissues are surgically reflected and the existing osseous crest is identified (golden-yellow scalloped line), a new, apical osseous crest position (blue) can be created. This can be accomplished with piezoelectric, rotary, and/or hand instrumentation. This will allow for a new biologic width to become established at a more apical position

12.1.3 Functional Crown Lengthening

At its essence, functional crown lengthening is a resective procedure undertaken to so that sound tooth structure can be exposed to support a new restoration and to re-establish a biologic width at a more apical position than prior to the surgical intervention. Initially proposed by D.W. Cohen in 1962, current protocol involves judicious removal of surrounding hard and soft tissue structures, so that the resulting tooth exposure is approximately 4 mm superior to the osseous crest. This amount of tooth exposure is required to allow re-establishment of the biologic width and to facilitate the ideal preparation of the tooth, ferrule, and marginal seal [3, 18–20].

Rosenberg et al. [21] noted that there are several indications for functional crown lengthening in the dentoalveolar complex. These include:

(a) Tooth decay which compromises the gingival sulcus and connective tissue attachment and/or is invading the biologic width
(b) Tooth fracture which compromises the gingival sulcus and connective tissue attachment and/or is invading the biologic width, with adequate remaining tooth structure, periodontal attachment, and supporting alveolar bone

Fig. 12.4 Esthetic crown lengthening teeth #8/9 for management of APE. (**a**) Dental view: presurgery and 2 weeks postsurgery for treatment of altered passive eruption. (**b**) Facial view: pre-op and 10 weeks postsurgery for treatment of altered passive eruption

(c) Teeth with excessive retrograde wear where crown lengthening is required for adequate seating and retention of a full coverage restoration
(d) Teeth, due to super-eruption, which have insufficient interocclusal space for requisite restorative dentistry
(e) Altered passive eruption, where the gingival margin is coronal to the CEJ and the osseous crest is approximate to or at the CEJ (Fig. 12.4a, b)
(f) External root resorption involving the dental structures adjacent to the gingival margins and/or the osseous crest

An adjunctive or ancillary treatment modality to functional crown lengthening is the use of orthodontics for forced eruption. Orthodontic forces may be utilized to either slowly or rapidly erupt the tooth in an occlusal or incisal direction in an attempt to bring either the osseous crest and underlying periodontal structures more coronally [22] or to extrude the tooth from the dentoalveolar complex so that the fracture or caries is exposed. Subsequent surgical re-establishment in an apical direction of the periodontal complex may or may not be required. Further discussion of this treatment modality can be found in the chapter by Schmerman and Obando in this volume.

Contraindications to functional crown lengthening are well described. Jorgic-Srdjak et al. described several scenarios in which surgical crown lengthening is containdicated [23]. These include:

(a) Caries or dental fracture extending significantly apical to the osseous crest requiring excessing alveolar bone removal.
(b) Unesthetic outcomes projected as a result of surgery.

(c) Surgery will result in an unfavorable crown-to-root ratio.
(d) Non-restorable dentition.
(e) Short root trunk resulting in roof of furcation being close to the connective tissue attachment.
(f) Compromise of esthetics.
(g) Compromised periodontal support on adjacent dentition after surgery.

The clinical and radiographic evaluation of the proposed tooth are critical prior to surgical intervention. Position of the carious lesion or fracture relative to the osseous crest, sulcus depth, gingival status, root form and length, anticipated posttreatment crown-to-root ratio, anticipated position of the definitive restorative margin, and potential compromise to the adjacent teeth must all be evaluated. Furthermore, the advantages of retaining such an involved tooth must be weighed against the potential deleterious consequences to the periodontal-alveolar complex of the tooth inquisition and the adjacent structures. This consideration should extend to an analysis of number and complexity of procedures required to put the tooth back into function with an ideal restoration. There are times where extraction of the tooth, and replacement with either a removable or fixed restoration, or endosseous dental implant may be a better alternative.

Kois [18] proposed that a requirement of only 3 mm was needed to establish and maintain a healthy sulcus (1 mm), connective tissue, and epithelial attachment (2.04 mm). Kois proposed that probing the attachment levels and sounding the osseous crest through sulcus and connective tissue and epithelial attachment would produce an accurate representation of the location of the biologic width. Kois coined the terms normal crest, high crest, and low crest accordingly [3, 18]. Table 12.1 demonstrates the clinical and surgical implications of these three alveolar crestal positions.

It has been demonstrated that the establishment of the restorative margin 3 mm from the osseous crest has been stable for up to 6 months [24]. Postsurgical rebound of the soft tissues should be a consideration prior to establishment of the definitive restorative margins and delivery of the prosthesis [25]. Removal of sufficient osseous structure to allow for postsurgical rebound or proliferation of 3.2 ± 0.8 mm should be performed. This often requires the exposure of approximately 4 mm of tooth structure. Pontoriero and Carnevale were able to demonstrate that thick tissues rebounded significantly more than did a thin biotype [25]. Exposure of a greater amount of tooth structure should be considered when working with a thick biotype. Establishment of definitive restorative margin should be delayed until the biologic complex has had sufficient time to mature, a minimum of 6 months.

Table 11.1 Relative crestal positioning of Dentogingival complex as related to the CEJ

		Crestal position	
Location	Facial dentogingival complex (mm)	Interproximal dentogingival complex (mm)	Treatment required
Low	>3	>3–4.5	No
Normal	3	3–4.5	No
High	<3	<3–4.5	Yes

12.1.4 Protocol for Functional Crown Lengthening

1. Provisionalization of the tooth prior to surgery if possible. This will facilitate easier access for the surgeon to the interproximal areas, as well as convey where the ideal restorative margin will be placed.
2. Presurgical plaque control.
3. Adequate local anesthesia.
4. Presurgical bone sounding to determine the amount of tooth which will need to be exposed and to influence the position of the incisions.
5. Submarginal inverse bevel incision. Attention must be afforded to the amount of keratinized tissue which will be remaining postsurgery. Preservation of 4–5 mm of keratinized tissue is recommended. If this is not possible with a submarginal incision design, then a modification of the planned submarginal incision or sulcular inverse bevel incision design must be considered.
6. Incisions are minimally extended to one mesial and one tooth distal to the tooth in question. Greater extension may be considered if further relaxation of the surgical flap is required.
7. A full-thickness flap is refelcted to the mucogingivaljunction, then a partial-thickness flap is extended apically from this anatomical landmark.
8. Adequate degranulation of the area around the tooth. This will allow for greater visualization of the margins, decay, or fracture, facilitate a greater understanding of the surrounding osseous topography, and reduce intraoperative bleeding.
9. Ostectomy and osteoplasty to establish a minimum of 4 mm of sound tooth structure and provide a positive postsurgical architecture to the periodontium. This should be accomplished with high-speed drills and/or piezo ultrasonic instrumentation and copious irrigation. Hand instrumentation may be utilized to access those areas which the drills cannot reach.
10. Surgical flaps are approximated for a trial closure, any modifications to the soft tissues can be made, and then once satisfied, they can be sutured closed. Selection of a durable suture material and precise suturing technique is critical to avoid wound dehiscence and maintain the positioning of the flaps through the healing phase. Periodontal dressing may or may not be utilized, subject to the preferences of the surgeon. Sutures can be removed at 10–14 days or when deemed ready for removal.
11. It is recommended that definitive restorations should not be placed until a minimum of 6 months of healing has transpired [25]. This will allow for maturation of the new biologic width and any rebound which may occur.

As with any surgical procedure, there are potential complications. Improper tooth exposure, aggressive removal of interproximal soft tissues resulting in "black triangles," root hypersensitivity, iatrogenic damage to the root structure, and post-surgical temporary mobility of the dentition have all been reported.

12.1.5 Esthetic Crown Lengthening

Esthetic crown lengthening is a procedure aimed at increasing the clinical crown and improving the gingival contours in order to preserve the dentogingival complex. This often presents a challenge for dentists and perhaps for periodontists. This treatment usually involves diagnostic information, such as periodontal charting, radiographic assessment, diagnostic wax-ups, and a mock-up. It is imperative to understand the diagnosis prior to delivering treatment. Excessive gingival display can be unesthetic for patients and can influence confidence and self-esteem [26, 27].

Excessive gingival display can present due to passive eruption either altered or active, vertical maxillary excess, hypermobile lip, and perhaps a pseudopocket due to inflammation [28]. Altered active eruption refers to the emergence of a tooth into the oral active and is regulated by periodontal ligament, occlusal contact, and soft tissue like the tongue [29]. A comprehensive diagnosis must rule out vertical maxillary excess as a cause of excessive gingival display. Vertical maxillary excess can only be diagnosed with cephalometric imaging and be corrected via a LeFort I osteotomy with vertical impaction.

Altered passive eruption (APE) was first described by Gottlieb and Orban [30], referring to the soft tissue remaining incisal to the cementoenamel junction (CEJ). Tissue may remain on the enamel, cementum, or both. The etiology of APE remains elusive. However, theories that have been proposed include the interference of soft tissue migration, perhaps due to the thickness of the soft tissue impeding the normal eruption. This results in a short clinical crown that is often unesthetic. Coslet et al. [29] further classified these altered erruptive patterns into two categories depending on the location of the mucogingival junction in relation to the alveolar crest. Type I refers to normal relationship of CEJ and alveolar crest; however excessive tissue overlies the anatomical crown. Type 2 refers to the proximity of the CEJ to alveolar crest due to the failure of active tooth eruption [31]. Type 2 is classified into two subsets: (a) the distance between the CEJ and alveolar bone is 1.5–2.0 mm, allowing for normal connective tissue attachment and (b) the proximity of bone to the CEJ. Volchansky and Cleaton-Jones found the incidence of APE is 12.1% [31].

The treatment of altered active eruption and altered passive eruption involves careful evaluation and, possibly, a multidisciplinary approach. The smile line, tooth position and size, tissue thickness and amount of keratinized tissue should be evaluated. Smile lines were described by Peck et al. [32]. When the upper teeth are visible and displaying 1–2 mm of the gingiva, it is considered "normal" smile line. A "high" smile line is casually known as a "gummy smile." This is when one displays 2 mm or more of gingival tissue. Inversely, a "low" smile line is when the upper lip covers 25% of maxillary anterior teeth. Excessive gingival display can occur due to skeletal and/or dental abnormality. If it is skeletally related, orthodontic and orthognathic surgery should be considered to correct the "gummy smile" which in the clinical situation described is resultant of vertical maxillary excess, treatment of which is outside the scope of this discussion. Oftentimes, it is more related to dental reasons, which can be corrected through osseous and gingival recontouring.

Establishing a biological width and ferrule is an additional consideration important for maintaining a healthy periodontium. Bone sounding is critical to determine the level of the alveolar crest. It will guide the surgeon to understand thickness of the tissue, tooth morphology and anatomy, and how much resection is required. The gingival tissues should be symmetrical and balanced. They provide a backdrop for esthetic restoration [33]. Additionally, ideal maxillary incisor dimensional relationships should follow the "golden proportions." The mesial-distal relationship between the dentition of the maxillary anterior group should be central incisor 1.6, lateral incisor 1, and mesial third of cuspid 0.6 [34]. Furthermore, Lee [35] proposed a classification for esthetic crown lengthening depending on the relationship of the alveolar crest and anticipated gingival margin.

Type I esthetic crown lengthening is categorized by the appropriate position of the alveolar crest, however an excess of gingival tissue. In this situation, it would simply require gingival recontouring or gingivectomy, preferably using a scalpel or a laser. Submarginal incisions are usually made at this point guided by a surgical stent.

Type II allows for gingival recontouring with additional need for ostectomy in order to re-establish biological width (Fig. 12.5a–h). These images presented in Fig. 12.5a–h represent a sequential study in the approach of contemporary crown lengthening

Fig. 12.5 Sequencing the treatment of a Type II case. (**a**) Pre-treatment condition of the dentition showing significant retrograde wear. (**b**) Diagnostic wax-up and silicon index. (**c**) Presurgical provisionals on prepared teeth. (**d**) Surgical soft tissue scalloping. (**e**) Hard tissue scalloping and creation of the biologic width dimension on the root surface. (**f**) Provisional restorations 3 months after crown lengthening surgery. (**g**) Finalized case lateral view. (**h**) Final smile

procedures in the anterior esthetic zone. This approach may involve a two-stage procedure. Once the initial presentation is recorded, a diagnostic wax-up is completed with approximate final teeth preparation and dimensions. Gingivectomy could be completed with provisional restoration invading biological width. This is temporary and is completed to allow for soft tissue healing and establishment of zenith positions imitating the golden proportions. In the subsequent surgery, the gingival margins are established and can be utilized to guide the periodontist for alveolar recontouring; sulcular incisions are made with possible papilla preservation. This will serve to maintain soft tissue thickness and avoid the likelihood for recession and open embrasures. New provisional restorations are fitted and cemented into place for 6 months to allow for ideal establishment and maturation of the soft tissues overlying the new recontoured osseous structures. Once stable, the final restorations may be fabricated and inserted.

Type III refers to situations in which the gingival excision is completed to the desired clinical crown length, which exposes the alveolar crest. This may be a result of a lack of communication with the interdisciplinary team. Therefore, flaps should be positioned coronally, rather than apically, in these clinical situations, and a staged approach might provide better results.

Type IV is reserved for situations where gingival excision will leave a band of inadequate amount of attached tissue, perhaps utilizing apically repositioned flap regardless of osseous recontouring. This will require a longer period of healing and less of an immediate result. As previously discussed, Kois [3, 18] coined the terms “high crest” and “low crest.” This refers to the gingival margin in relation to the alveolar crest. A “high crest” is one where the bone is close to the gingival margin, which is at risk for violating the biological width. In the latter, the total complex is greater than 3 mm, which results in a more apical positioning of the free gingival margin without subsequently violating the biological width.

Conventional healing is typically between 4 and 6 weeks. However, in the esthetic zone, it is important to allow for soft tissue to mature at least 3 months, and if bony resection is completed, an additional 6 months of healing is necessary. Bragger [24] found the recession of 2-4 mm postoperatively occuring between 6 weeks and 6 months. Recession can occur, and it is therefore imperative to defer final restoration until tissue has completely healed, especially in the esthetic zone. The amount of tissue rebound seems to be correlated to the distance from flap margin to alveolar crest at suturing [11].

There is a symbiotic effect between the location and precision of the definitive restorative margin and the health of the periodontium. Violation of the biologic width is a common sequelae of poorly planned restorations. The requirement for crown lengthening, whether functional or esthetic, involves an in-depth knowledge of periodontal anatomy, restorative requirements, and surgical techniques. The desired outcome is a functional and healthy periodontium situated immediately to a restoration.

Success is also directly related to level of plaque control which the patient is able to maintain. This is influenced by the maintenance of physiologically healthy periodontal probing depths, provision of sound tooth structure, anatomically suitable restorative contours, and creation of an environment in which the patient and dental team members can adequately maintain.

12.2 Conclusion

Although there are no significant changes in the procedures involved with contemporary crown lengthening, there have been significant improvements with the introduction of digital workflows. Core concepts still remain essential, as are the diagnosis and execution of the prescribed treatment plan. Differentiation between vertical maxillary excess, altered passive eruption, altered active eruption, and crestal position is essential prior to putting scalpel to tissue.

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13 The Adjunctive Relationship Between Orthodontics and Periodontics

Michael Schmerman and Julio Obando

13.1 Introduction

The adjunctive relationship between orthodontics and periodontics is both complex and symbiotic. Both specialties rely on each other's principals and expertise to accomplish their respective goals. Advances in material science and technical developments have changed the outlook on how we treat patients and what is clinically possible. The interactions of the two have led to a series of proposed goals and guidelines that can be realized [1]. They include:

1. Improved cleansability by reduction of crowding
2. Vertical positioning changes to reduce osseous resective needs
3. Alignment of maxillary gingival margins to avoid surgery
4. Forced eruption for traumatic fractures
5. Embrasure change to regain papillary form
6. Improved spacing for dental implants

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13.2 Patient Evaluation

Of paramount importance, prior to performing any procedure, is the formulation of a proper diagnosis. The medical and dental histories must be carefully reviewed for any needed precautions or contraindications that may influence treatment planning. Diagnosis should be based on clinical findings and confirmed radiographically. Marked technological improvements in radiography have had a significant impact on the accuracy of analysis. Most procedures require simple imaging techniques. These include roentgenograms and orthopantomograms. For more complex procedures such as exposure of impacted teeth, the use of cone beam computed tomography (CBCT) is essential [2]. This affords the clinician the ability to accurately determine the position of the impaction in three dimensions. Until the advent of this tool, the guesswork of periapical radiographs using Clark's rule (tube-shift technique or SLOB rule) was always present [3]. Intraoperatively, procedural progress in many areas may be determined by either periapical or CBCT analysis, depending on the situation.

13.3 Exposures of Impacted Teeth

Of historical interest is the evolution of exposures of impacted teeth. Until the development of direct bonding of orthodontic devices, practitioners were limited in their abilities to move impacted teeth. An example of this was the use of wire ligation [4, 5]. The ligature was placed around the cervical neck of the tooth and then attached to the orthodontic appliance. Control of mechanics was haphazard. The use of dental adhesives beginning in the mid-twentieth century changed that dramatically [6]. Multiple generations and advances in etching and adhesive materials have improved our abilities to accurately bond teeth. As a result, mechanics have been made more predictable. A variety of devices are now available for bonding to an impacted tooth. These include buttons, cleats, chains (single and double) in a multiplicity of varieties, and direct bond brackets. The most prevalent impacted tooth, aside from third molars, is the maxillary canine. A number of theories have been proposed as to the cause of impactions. These may be localized or generalized and range from tooth size to arch discrepancies or even idiopathic in nature, etc. Specific causes include endocrine and febrile diseases and irradiation. Buccal impactions are usually attributed to inadequate arch space or vertical developmental position. Palatals, according to the guidance theory, are caused by local predisposing factors which interfere with the path of eruption. Genetics is also a significant cause [7]. These have been cited in the literature as occurring in about 1–5% of cases [8, 9]. They are more prevalent in the Caucasian population and occur in the palate about 85% of the time [10]. The female predilection of occurrence is about 2:1 with bilateral incidence occurring in 8% of individuals [7, 11].

13.3.1 Canine Exposures

Because of differences in accessibility, buccal and palatal exposures must be approached differently. Though canines located on the buccal would seemingly be easier to expose, careful diagnosis of their relative position is essential. For those located close to the bony crest and having little cortical plate, a simple gingivectomy, removal of the thin plate of the bone and follicle, may suffice. This is provided that there is adequate keratinized tissue and a bracket can be placed. Important in management of these and all related procedures is the sufficient exposure of the crown of the tooth. Incumbent on the surgeon is the knowledge of intended mechanics to bring the tooth into proper alignment. For those teeth located coronal to or at the mucogingival junction, a pedicle flap with apical positioning is indicated. This is provided that there is adequate vestibular depth (Fig. 13.1). Both of these scenarios require a single intervention. The gingival flap is positioned apical to the bracket. Ligation can be done directly with the orthodontic appliance. In cases where the impaction in question is located beyond the possibility of apical flap positioning, a two-step approach is required. The crown of the tooth is bonded to a chain, a wire (attached to the chain) is extended through the edge of the incision, and the tooth is brought into position through the flap. Subsequently, keratinized tissue may be augmented to the cervical area of the previously impacted tooth if necessary. The patient must be informed of this possibility at the initial stage of planning.

Palatal impactions should be approached using a full-thickness mucoperiosteal flap (Figs. 13.2 and 13.3) with adequate extension for access and hemostasis. This is particularly critical with impactions that are extensively covered by bone. It is imperative that a dry field be obtained in order to effect a proper bond of a chain to

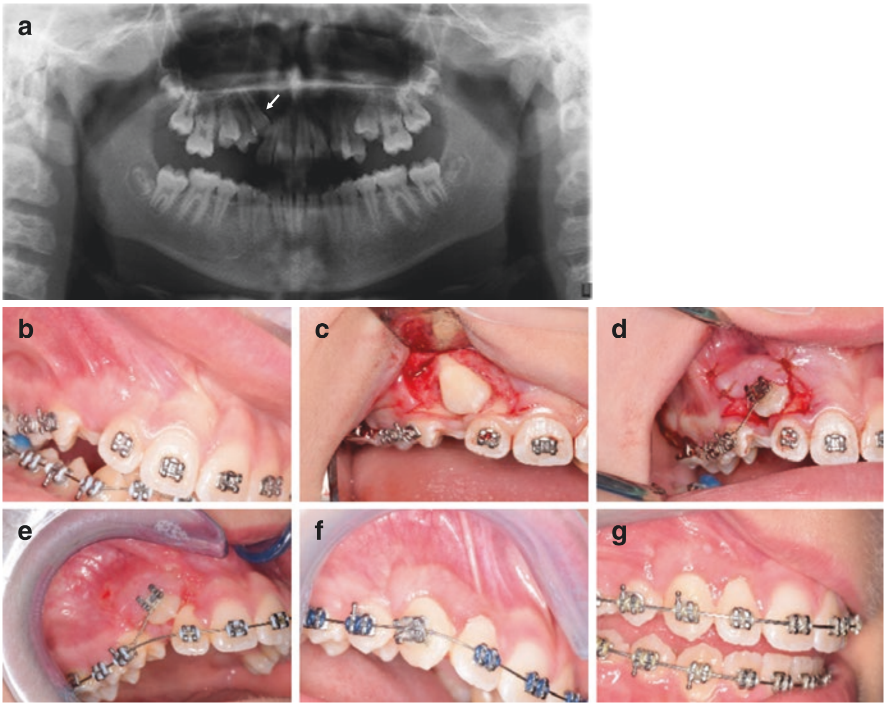

Fig. 13.1 (**a**) Pre-op panoramic image. (**b**) Preoperative photo. (**c**) Full-thickness flap reflection. (**d**) Flap positioned above bracket. (**e**) Two-week post-op. (**f**) Three-month post-op. (**g**) Six-month post-op. Images courtesy Dr. E. Kaminsky

the tooth. Local anesthetics with a vasoconstrictor, hemostatic agents, and careful handling of the flap are normally adequate. If untoward position of the tooth makes adhesion of a bond unfeasible on either the buccal or lingual of the crown, lateral aspects must be used until the eruptive sequence allows bonding in a more appropriate area. The crown is gently manipulated with an elevator, or similar instrument, to

Fig. 13.2 (**a**) Preoperative photo. (**b**) Full-thickness mucoperiosteal flaps. (**c**) Brackets placed after uncoveries

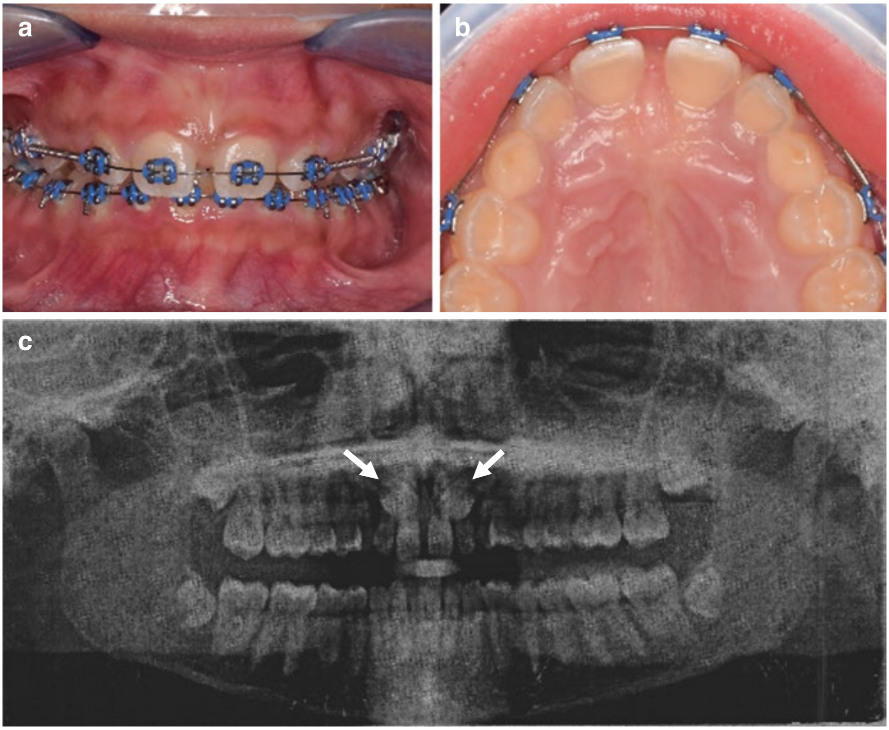

Fig. 13.3 (**a**) Preoperative (buccal view). (**b**) Preoperative (palatal view). (**c**) Panoramic radiograph—note positions of impactions (arrows). (**d**) CT scan showing exact locations in various dimensions. (**e**) Full-thickness flap. (**f**) Chains bonded to impacted canines. (**g**) Flap replaced with tissue and deciduous teeth removed to facilitate movement. (**h**) Three-week post-op with teeth canines exposed. (**i**) Six-month post-op with tooth progression to desired position. Images courtesy Dr. E. Kaminsky

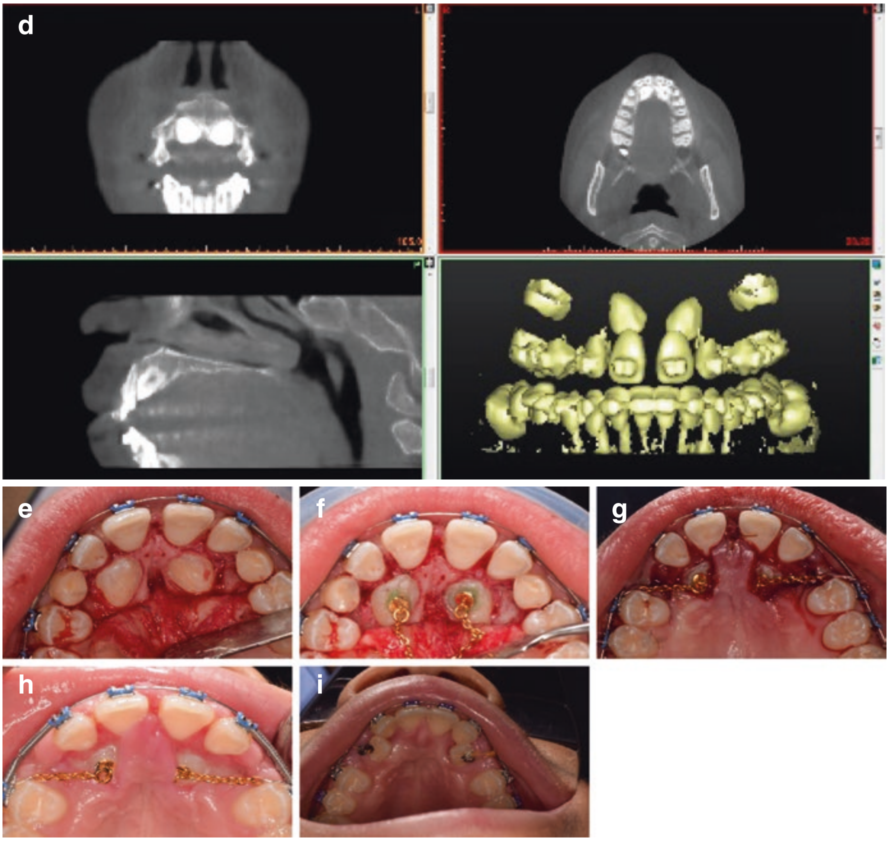

Fig. 13.3 (continued)

evaluate patency of the periodontal ligament. The entire occlusal aspect must be free of bony encumbrance to insure its ability to be moved. Studies have not shown a difference in outcomes between open and closed techniques in which the crown is either exposed or unexposed postoperatively [12]. If the operator chooses the former, exposure will be determined by the position of the crown in relation to the edge of the reflected flap. That distance dictates either removal of marginal tissue or creation of a stoma in the tissue for exit of the chain attachment to the appliance.

13.3.2 Other Impaction Exposures

Impactions of other teeth may occur individually or coincidental with others (Fig. 13.4). Similar principles apply to their exposure as well. On occasion, teeth close to the surface of the gingiva with an unimpeded exit path may erupt with the simple removal of occlusal tissue. Many times, trauma to an area may prevent eruption of a succedaneous tooth, and the simple removal of tissue is the only procedure needed (Fig. 13.5).

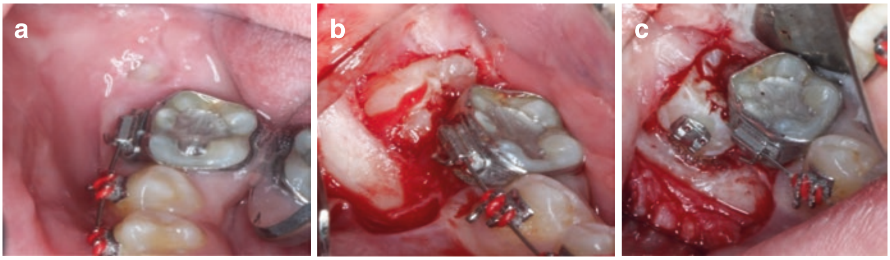

Fig. 13.4 (**a**) Preoperative impacted second molar. (**b**) Split thickness dissection to aid tissue positioning. (**c**) Bracket placed and tissue positioned to maintain keratinized gingiva

Fig. 13.5 (**a**) Preoperative image of impacted premolar. (**b**) One-week post-gingivectomy to aid eruption. (**c**) One-month postoperative image

Complications including postoperative bleeding and infection should be managed appropriately and expeditiously. Careful surgical and bonding techniques reduce the potential for debonding of either a bracket or chain. When it does happen, further procedures are indicated. Patients need to be informed of the potential problems prior to intervention, not after the fact.

13.4 Mucogingival Therapy in Orthodontics

Tooth eruption activity dictates a significant portion of the gingival biotype. The position of teeth with regard to the dentoalveolar process also plays an important role in the dimension of that phenotype [13]. The effect of orthodontic movement on the periodontium is controversial [14]. Several authors state that well-aligned teeth with optimal occlusal relations will provide a physiologic process of auto-cleansing. This allows for plaque removal with well-managed plaque control when there are closed contacts [15, 16]. Current bias concerns itself with augmentation of soft tissue in thin biotypes. The rationale is that of prevention of future mucogingival recession [15, 17, 18]. Accordingly, a wide and thick keratinized attachment apparatus is therefore critical to resist orthodontic forces, especially in arch expansion. In addition, it resists functional and physiologic trauma. A more conservative approach is one of careful observation and monitoring on the part of the orthodontist and general practitioner for signs of change. Should they occur, action to remedy the problem should be considered. These include inflammation of the gingival marginal tissue as well as progressive recession. A significant number of procedures are available to augment soft tissue. Location and anatomy of the site should be given consideration as to the appropriate modality. Soft tissue augmentation is discussed in the chapters by Chambrone et al., Zadeh et al., and Wong in this volume.

13.4.1 Free Soft Tissue Autografts

Current assumptions state the need for 2 mm of keratinized tissue in individual with thin phenotypes [15, 19, 20]. Tooth movements to the facial (expansion) and extrusion are most likely to incur negative alterations in the mucogingival complex, thus increasing the risk of dehiscence or recession [13, 21–24]. Soft tissue autografts are believed to be the gold standard as a surgical option by which thin areas devoid of keratinized tissue can be augmented. This is the most reliable option for tissue gain [22, 25–28]. A recipient site is prepared, and donor tissue is usually taken from the surface of the hard palate. This tissue is typically characterized by a superficial layer of epithelium with the underlying layer being connective tissue in nature. Widths range from.8 mm to 1.6 mm in dimension [29]. Although active tooth movement may proceed during surgical intervention, if the need for grafting is advisable prior to therapy, grafting should be considered beforehand to avoid exacerbation of the condition [15]. The decision to graft is based not only on the amount of keratinized tissue present but also the frenum and vestibular position. Expected outcomes of this therapy include a thickened band of keratinized tissue, able to resist abrasion, reduction of frenum pull, if present, and increased vestibular depth (Fig. 13.6). This

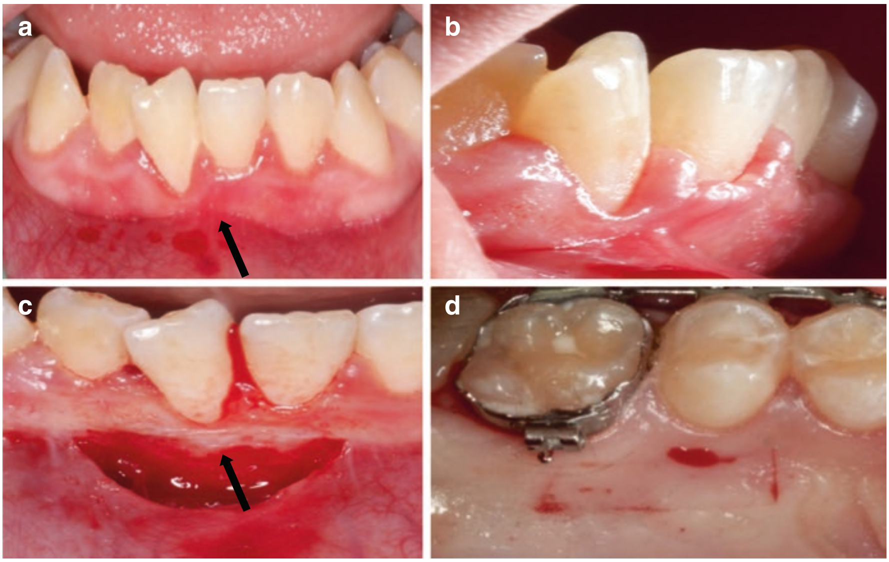

Fig. 13.6 (**a**) Preoperative image taken prior to application of orthodontic appliance. Note position of mucogingival junction (arrow). (**b**) Lateral view showing inflammation and hyperplastic tissue. (**c**) Split dissection at mucogingival junction of recipient site. (**d**) Palatal donor site outline. (**e**) Free Soft tissue autograft in place. (**f**) Donor site sutured for hemostasis. (**g**) Three-month post-op. (**h**) Six-month post-op with orthodontic appliance in place

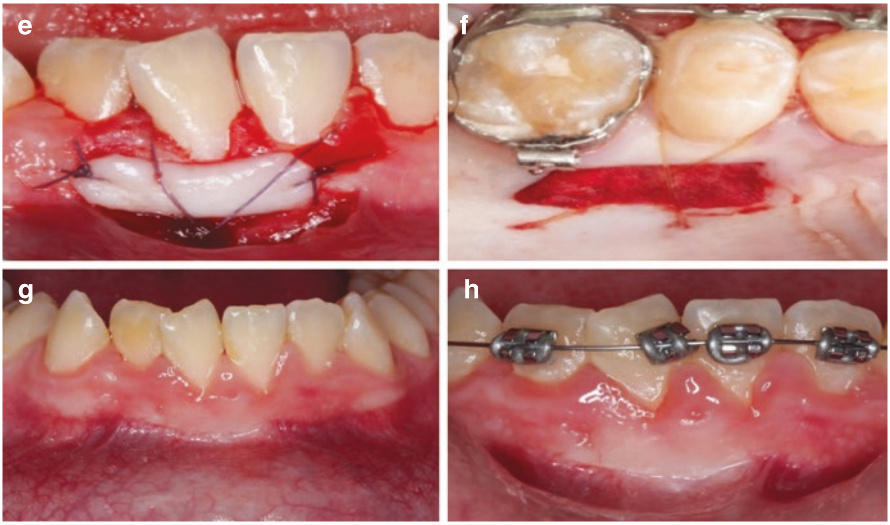

Fig. 13.6 (continued)

provides the patient better auto-cleansing and better access for personal oral hygiene. Alternative materials can be substituted for autografts and include allografts, xenografts, and synthetic materials. These may be used in conjunction with biologics to produce similar outcomes in regard to the gain in keratinized tissue. They afford the benefit of the elimination of a donor site, thus decreasing morbidity and surgical donor time [30, 31]. Randomized controlled trials and clinical control for long-term findings are needed to provide proof of greater efficacy of one technique over another.

13.4.2 Connective Tissue Grafts

The subepithelial connective tissue graft is another viable option to increase the mucogingival apparatus [32, 33] (see chapter by Zadeh in this volume). Among the advantages of this surgical method are better tissue color match, faster healing, and less invasion at the donor site [34, 35]. More technique sensitive than the free soft tissue graft, the connective tissue graft can be obtained in several ways as can the recipient site. The dissection from the donor site should contain lamina propria with a small amount of submucosa and should be about 1.5 mm in thickness [36]. Contained in the lamina propria are elastic fibers and collagen [36]. The submucosa consists of fibrous connective tissue and the presence of thicker adipose tissue, vessels, nerves, and glands [37, 38]. As a general rule, it is preferred that more lamina be contained in the graft to provide better handling and less shrinkage. This allows for more root coverage and better color match [38]. Because there is less exposure at the donor site, morbidity is reduced. Because expansion in the maxilla may cause changes in the esthetic zone during active appliance therapy, connective tissue is the preferred treatment for augmentation. These procedures should precede orthodontics if recession is present or becomes evident during treatment.

13.4.3 Pedicle Grafts and Coronal Advancements

Contiguous blood supply and a single surgical wound site offer an advantage over augmentations requiring autogenous donor sites or allograft/xenograft materials. The same criteria of indications either prior to or during orthodontic therapy apply. The requirement of the ability to mobilize a suitable amount of tissue to augment an area without significantly altering the anatomy is critical. If a contiguous graft is planned, it should not reduce vestibular depth and change the accessibility for oral hygiene. Further, tissue moved from one area to another should not alter the area from which it was obtained. Significant crowding may require a combination of procedures (Fig. 13.7). These may include augmentation followed by pedicles or flap advancement (see chapter by Wong in this volume).

As material science has changed the manner in which orthodontic treatment is rendered, so too have scientific advances in allografts, xenografts, and biologic tissue engineering created new possibilities for favorable outcomes in periodontal therapy [39, 40]. The rationale that the underlying connective tissue genetically predisposes epithelial expression is applicable to procedures using these materials to increase the zone of functional keratinized tissue [41].

13.4.4 Gingivectomy and Gingivoplasty

Gingival enlargement, both hypertrophic and hyperplastic, often accompanies active orthodontic appliance therapy. Poor plaque control and the retention of plaque biofilm are contributory to the problem. Gram-positive facultative bacterial species are replaced in population by an increase in several *Prevotella* species (*ninogenica* and *intermedia*) [42]. Researchers have also found increased populations of *Aggregatibacter actinomycetemcomitans* [43].

Counseling in meticulous plaque control as well as active professional hygiene measures should be instituted prior to active therapy. In those cases where overgrowth has taken place, consideration must be given to its effect on treatment. Should the need arise, gingivectomy and gingivoplasty are indicated in those areas where active tooth movement cannot proceed. This should be limited to those areas where necessity dictates.

Fig. 13.7 (**a**) Preoperative image of mucogingival defect with frenum pull at margin. (**b**) Lateral pedicle graft suture in place. (**c**) Three-month postoperative image taken prior to placement of orthodontic appliance

Once active treatment is completed and the retention phase starts, an appropriate period of time is necessary to reassess the need for surgical intervention. Allowing at least 6 months insures that the overgrowth has abated.

Any hyperplastic tissue still present can be managed accordingly, whether it be for functional or cosmetic reasons. By following this course of action, surgical intervention can be minimized, and its utilization can have maximal value.

13.5 Forced Eruption

The understanding of the biologic interactions of teeth and the importance in maintenance of the dentoalveolar complex as long as possible continues to gain credence. Surgical and interdisciplinary techniques are being developed with the main objective of trying to preserve the dentition. The implementation of dental implants into the stomatological realm has created a high demand for these replacements. This blurs the real importance of our profession, to preserve, maintain, and prolong the health of the human dentition. This demand has created a significant number of over-prognostications that deem teeth hopeless when in fact they can be treated, maintained, and are functional. This easy solution substitutes an artificial replacement for a healthy tooth.

The process by which a tooth is orthodontically extruded into a more coronal position to expose more dental surfaces is defined as forced eruption [44, 45]. On the contrary, a tooth moved apically through the process is referred to as orthodontic intrusion [46].

13.5.1 Retention of Teeth with Crown Lengthening

Depending on the force applied, a tooth can be moved coronally with or without the alveolar housing and gingival tissue. When light force is applied, moving the entire unit will result in uneven gingival margins at the zenith. In order to alleviate this problem, surgical crown lengthening is necessary to recreate an even smile line in the esthetic zone. This usually involves ostectomy, osteoplasty via flap access, and possible removal of gingival tissue to recreate biologic width. This is discussed in detail in the chapter by Karateew et al. in this volume.

13.5.2 Retention of Teeth Without Crown Lengthening

Orthodontic extrusion provides the opportunity to restore teeth that could not have otherwise been retained. This provides the dental surface area necessary to restore function [45, 47]. During normal orthodontic tooth movement, two basic physiologic processes occur—tension and compression [48]. The application of slow light forces allows for biologic recovery of the treated site. This will afford the entire process to move without loss of the attachment apparatus [45]. Heavy forces, which facilitate rapid movement, will move the tooth but not shift the dentoalveolar complex coronally [48–51]. The result is that more tooth will be exposed without change in the position of the periodontal attachment. This simplifies the course of treatment by eliminating the need for ostectomy, osteoplasty, or gingival recontouring [52]. Biologic shaping of the teeth is discussed in the chapter by Melker et al., in this volume. The time needed for retention may, however, be altered. Fixation is highly recommended for a period of time to allow for bony reapposition to take place [45, 52, 53]. A possible cause of relapse is the elongation of collagen fibers [54]. This theory describes the movement of teeth to the baseline position followed by a return of the stretched fibers to a relaxed position [54]. However, even if a retention process has been maintained for a prolonged period of time, the reorganization of the fibers may not occur and relapse can take place [55]. The circumferential supracrestal fiberotomy has been shown to reduce the posttreatment reversion to the initial position. The procedure consists of severing the supracrestal fibers in order to minimize stress on soft tissue. This allows time for reattachment of collagen fibers to the final tooth position [55, 56].

13.6 Tooth Movement to Enhance the Prognosis of Bone Augmentation

The regeneration of the periodontium has been a goal of periodontal treatment for generations. Multiple types of orthodontic tooth movements have been used to improve this architecture. They include extrusion, intrusion, lateral, and tipping movements.

Extrusion may be used to manage both single wall and two-wall bony defects after completion of initial periodontal therapy to minimize periodontal inflammation. In addition, soft tissue enhancement has been shown to occur. Several authors suggest the stretching of the periodontal ligament fibers may affect apposition of the bone at the alveolar crest [54]. This is in keeping with findings noted during normal eruption.

Intrusion has been used in a number of situations to improve periodontal outcomes. Both hard and soft tissues may be affected. Marked changes in occlusal relationships may be corrected with intrusion. These types of problems may include flared incisors that have drifted as a result of severe bone loss. Deep overbites where trauma to the soft tissue exists may also warrant this procedure. Consideration must be given to the use of light orthodontic forces to reduce the possibility of root resorption. Careful monitoring of plaque control to minimize inflammation and proper maintenance during active therapy are essential. Supra-erupted posterior teeth that would have been deemed hopeless, can also be intruded for periodontal management in addition to use as restorative abutments or crowned restorations.

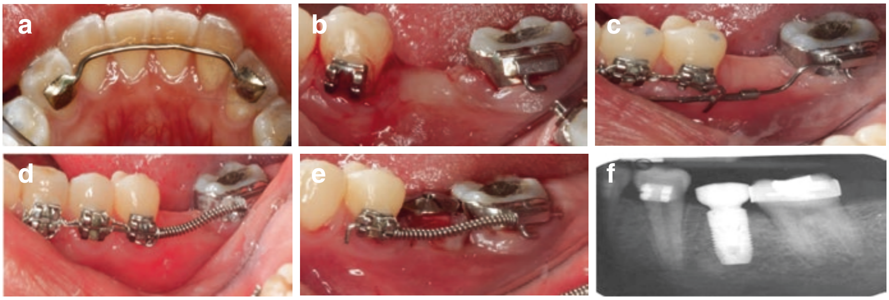

Fig. 13.8 (**a**) Lingual holding arch placed for molar uprighting. (**b**) Band on molar with hyperplastic tissue on mesial aspect of tooth. (**c**) Uprighting appliance activated with Forestadent spring in place. (**d**) Open coil spring placed to complete distalization. (**e**) Single-stage implant placed. (**f**) Radiograph of appliance in place to maintain space until prosthesis is fabricated

Lateral tooth movements may be employed to change the morphology of infrabony defects of various configurations. This is done to narrow the size of these defects to improve the results of grafting. By doing so, the vascular supply to the area may be enriched. The success of augmentation is improved if the defect volume is minimized. The uprighting of a tooth that may have shifted because of adjacent tooth loss may accomplish the elimination of both hard and soft tissue discrepancies and aid the patient in access to cleansing (Fig. 13.8).

13.6.1 Implant Site Development

Significant changes in our abilities to provide predictable restorative results in both the anterior and posterior areas have emerged because of auto-, allo-, and xenografting materials and techniques. These procedures, designed to augment the bone, have enhanced dental implant placement in deficient sites, both horizontal and vertical. The limitations of vertical augmentation, particularly in the esthetic zone have given rise to a novel approach to site development—the use of forced eruption of otherwise hopeless teeth. The concept of forced eruption is not a new one. It has been applied to retention of fractured as well as periodontally involved teeth for decades. The use of the procedure for site development is more recent. The intent is to erupt the entire gingival and osseous complex vertically to enhance esthetics of the emergence profile. Parameters of feasibility include the need for 1/2 to 1/3 of the original bony housing to be present. Light orthodontic forces should be applied over a 3–6-month period of time to allow for eruption of the dentogingival complex. On occasion, prophylactic endodontic therapy may be necessary as occlusal adjustment dictates reduction of tooth structure. Bone apposition and maturation are also required. The resultant changes may eliminate the need for bony augmentation by surgical means or reduce the amount needed (Fig. 13.9). As stated previously, some proponents recommend the inclusion of supracrestal fiberotomy [55, 56]. The significance of the benefit is still open to question.

Fig. 13.9 (**a**) Pre-treatment image with gingival and incisal levels noted (dashed line). (**b**) Slow extrusion of central and lateral incisors. (**c**) Slow extrusion of left central incisor to enhance tissue position for eventual implant placement Note differences in incisal position (dashed line)

13.7 Conclusion

By following evidence-based principles in adjunctive procedures to aid periodontic and orthodontic needs, successful outcomes can be obtained. Violation of sound scientific philosophies will result in unwanted complications, resultant failures, and disappointment. Simple attention to detail is of utmost importance in obtaining quality interdisciplinary endings.

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Surgically Facilitated Orthodontic Therapy

14

George A. Mandelaris and Bradley S. DeGroot

14.1 Introduction

It is widely accepted that diseases of the oral cavity have effects which reach past the head and neck area and may significantly impact the general health of the patient. Whether it is malocclusion, caries, attrition, erosion, periodontitis, deficient dentoalveolar bone volume, mucogingival discrepancies, or the impairment of craniofacial structural integrity, patients often find themselves at risk for systemic comorbidities. Increasingly, the underdeveloped or compromised airway and the myriad health impairments this may cause have become an emerging focus of dentistry. Deficiencies in dentoalveolar bone volume (relative to the dentition) and discrepancies in skeletal

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relationships can reduce oral cavity and oropharyngeal airway volume. Dentoalveolar volume deficiencies are manifesting with increasing prevalence as dental crowding, inappropriately compensated arch forms, and malocclusion.

Surgically facilitated orthodontic therapy (SFOT) uses corticotomies and decortication within the dentoalveolar and alveoloskeletal bone complex to stimulate the regional acceleratory phenomenon (RAP) [1–6] and upregulate bone remodeling in order to facilitate tooth movement as a part of orthodontic decompensation measures. It also generally includes efforts consistent with guided periodontal tissue regeneration (where fenestrations or dehiscence's are present) and/or dentoalveolar bone augmentation. This treatment modality is based on addressing the etiology of the core problem and is aimed at achieving a physiologically sound and homeostatic resolution. The harmonization of tooth-to-tooth, tooth-to-jaw, jaw-to-jaw, and jaws-to-face relationships, when implemented appropriately, can provide the patient with stable, sustainable esthetics and function.

SFOT is emerging as a pivotal component of interdisciplinary dentofacial therapy (IDT) for the improvement of overall health. However, SFOT is demanding for both patient and treating clinician. It requires a high level of training, focus, attention, and communication by and among all members of the interdisciplinary team as well as thorough communication with the patient about the realistic expectations and outcomes from the therapy.

This chapter discusses SFOT as an integral component of contemporary IDT to establish, enhance, or recreate the underlying homeostatic physiology in order to enhance and facilitate more predictable and sustainable dentofacial outcomes.

14.2 Developmental Impact of Human Evolution and Culture on the Cranio-dentofacial Complex

Over thousands of years, evolutionary changes have contributed to the current prevalence of the phenomenon of "facial recession" [7]. This progressively retrognathic maxillary and mandibular positioning is the result of the evolutionary and cultural demands to develop a more pronounced frontal lobe of the brain (i.e., klinorhynchy) (Fig. 14.1). The prevalence of an ideal dentofacial condition may be decreasing currently among some populations [8]. In parallel, tooth crowding, retrognathia, deficient DA bone, and other maxillary and mandibular dentofacial abnormalities have become widespread [9, 10].

Dental compensations result from a skeletal disharmony and are commonly seen whenever anterior-posterior or transverse maxillo-mandibular discrepancies are present [11, 12]. The positions of teeth within the mouth represent a homeostatic relationship between the opposing forces of the lips, tongue, oral musculature, and alveolar bone. Dental crowding generally results from a deficiency in dentoalveolar bone volume and associated arch-length deficiency.

Importantly, an increasing prevalence of such abnormalities should not be deemed a variation of normal. Case-type patterns of common dentofacial disharmony malocclusions have been described by Mandelaris et al. (Table 14.1) [13, 14] and can help identify situations in which SFOT may be indicated.

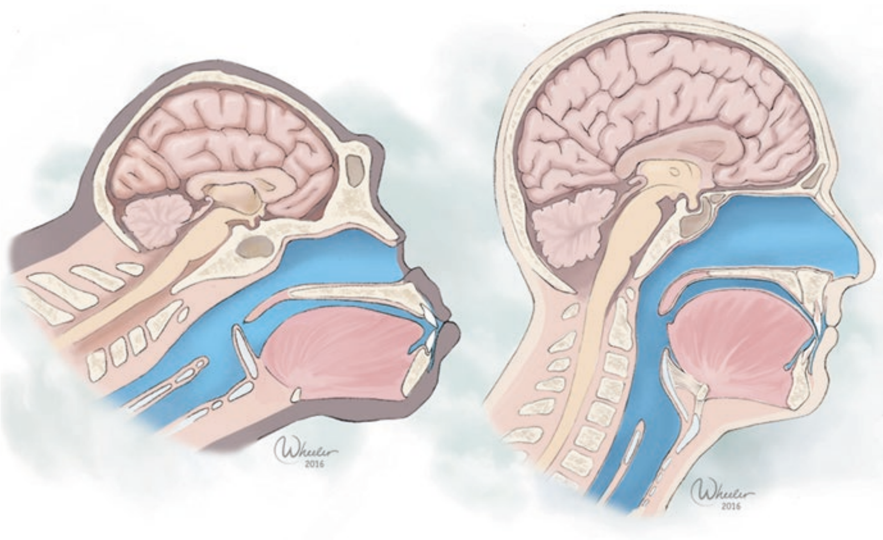

Fig. 14.1 Facial recession, or klinorhynchy, demonstrating progressive retrognathism of the craniofacial complex secondary to brain growth/development of the frontal lobe

Table 14.1 Patterns of facial disharmony/skeletal malocclusion and benefit from periodontal-orthodontic therapy involving corticotomy and dentoalveolar bone augmentation (i.e., SFOT/PAOO®)

Malocclusion anatomic description	Defining characteristics	Treatment planning challenges and opportunities	Treatment options using SFOT prior to OGS
Transverse maxillary deficiency	Highly prevalent malocclusion case type Usually presents with excess curve of Wilson Typical correction involves SARPE, which decreases buccal alveolar bone	SFOT/PAOO® allows more optimal decompensation and correction of excess curve of Wilson as well as idealizes axial inclination of teeth by augmenting buccal alveolar bone Skeletal movement needed with OGS may become purely expansion with improved decompensation (if possible)	SFOT/PAOO® to expand and increase buccal alveolar boundary conditions (i.e., orthodontic walls) laterally, allowing decompensation to occur through buccal root torque LeFort I osteotomy OGS may reduce the need for tipping to optimize posterior articulation

(continued)

Table 14.1 (continued)

Malocclusion anatomic description	Defining characteristics	Treatment planning challenges and opportunities	Treatment options using SFOT prior to OGS
Skeletal Class II, division 2 dentofacial disharmony malocclusion with severely upright or retroclined maxillary incisors	Notoriously difficult cases to decompensate due to thick crestal bone May require 20° of torque, exceeding orthodontic capabilities	The use of SFOT/PAOO® induces RAP, which can help achieve more ideal decompensation for the orthodontist because the teeth move in a demineralized bone matrix, which facilitates movement, may improve the predictability of tooth movement, and decreases treatment time	SFOT/PAOO® to induce RAP and allow decompensation to occur in a demineralized bone matrix while augmenting the dentoalveolar bone complex OGS thereafter to align skeletal discrepancies once decompensation is corrected and inter/intra-arch dimensions are aligned for such correction
Skeletal Class II or III dentofacial disharmony malocclusion with maxillary incisor proclination requiring labial root torque	Crown is in a relatively good position Root position is unfavorable and requires movement Dentoalveolar bone volume is limited to accomplish ideal decompensation	Proclination requires labial root torque while holding incisor crown position Risk is pushing roots out of the alveolar bone and exceeding the alveolar boundary conditions (i.e., orthodontic walls) Conventional correction may include extraction and/or skeletal anchorage for maximum space closure Conventional correction necessitates increasing a negative overjet and a larger skeletal correction If OGS is needed, one-jaw surgery may now become a double-jaw procedure	SFOT/PAOO® to develop dentoalveolar bone and augment/enhance alveolar boundary conditions (i.e., orthodontic walls), facilitating tooth movement and expanding tooth movement capabilities
Skeletal Class III den-tofacial disharmony malocclusion cases with protrusive and retroclined mandibular incisors	Very limited alveolar bone to move teeth safely "Teeth on a pedestal" presentation on CBCT cross section/sagittal view	Decompensation of mandibular incisor position is impossible with labial crown torque as it can create dehiscences and periodontal problems Conventional OGS therapy includes antero-posterior reduction genioplasty, which may not look favorable and does not correct the dentoalveolar bone deficiency/volume etiologic problem	SFOT/PAOO® to provide dentoalveolar bone and alveoloskeletal bone augmentation and to allow proclination of mandibular incisors to occur

Table 14.1 (continued)

Skeletal Class II den-tofacial disharmony malocclusions with mandibular incisor proclination needing labial root torque	Severely proclined mandibular incisors requiring decompensation for future OGS Limited dentoalveolar bone to accomplish labial root torque movement while allowing roots of teeth to be placed in bone	Typical plan: extract and decompensate for OGS Not an ideal plan when patient has an ideal Holdaway ratio or no additional overjet is needed for desired skeletal correction If the patient has obstructive sleep apnea, this condition might become worse before becoming better	SFOT/PAOO® to enhance orthodontic decompensation and apply labial root torque and place roots in bone for decompensation OGS thereafter to correct skeletal discrepancy

An escalating prevalence of malocclusions over the last 250 years [15, 16] correlates with increased consumption of highly processed foods [17], decreased breastfeeding [18–20], and a uniformly soft diet fed to infants and toddlers. This is theorized to result in a failure to develop forward tongue and lip muscular habits, which perpetuates a reduced oral cavity volume (OCV). Impaired development of craniofacial-respiratory structures may manifest as deficient dentoalveolar bone [21, 22] as well as impaired development of the maxilla and mandible (i.e., hypoplasia and/or retrognathia).

The teeth develop independently of the soft tissue structures and require a specific bone volume for proper alignment within the dental arch. When there are discrepancies between the available dentoalveolar bone volume and the size of the teeth, intraoral forces may move teeth into abnormal positions to compensate (i.e., dental compensations) for the skeletal imbalance, and dental crowding and malocclusions can occur [23]. Crowding may also be accompanied by alveolar dehiscences and fenestrations [24]. Deficiencies in dentoalveolar bone volume and discrepancies in the relationship between the alveolus and skeletal base may limit the extent to which teeth can be safely "decompensated." These deficiencies and discrepancies narrow the "orthodontic walls" or reduce the orthodontic boundary conditions within which teeth can be safely moved without iatrogenic harm to the periodontium [13, 14].

The impact on oropharyngeal airway volume is an emerging focus of contemporary IDT. The most common manifestation of a suboptimal airway space is sleep-disordered breathing conditions and obstructive sleep apnea (OSA), which has reached epidemic proportions in both adults [25, 26] and children [27, 28]. Intuitively, a larger oral cavity volume should make it easier for air to pass through the upper respiratory track and improve a patient's ability to breathe. However, the evidence about how directly oral cavity volume may impact these diseases is somewhat equivocal and inconclusive. An increased tongue-to-oral cavity volume has been found to predispose patients to sleep-disordered breathing [29]. Other research suggests that the extraction of four bicuspids does not influence sleep apnea conditions or esthetic perceptions of changes in facial profile, though it would seem to decrease the oral cavity volume [30, 31]. More directed and definitive research is needed in order to more decisively discern the relationship between oral cavity volume and breathing disorders.

14.2.1 Embryogenesis of the Craniofacial Skeleton

A thorough understanding of embryologic and developmental processes leading to craniofacial anatomic development is essential to appreciate—and therapeutically reestablish—the homeostatic balance essential for sustainable craniofacial stability and esthetics. This is particularly true if one is to be successful at sustainable bone regeneration or augmentation/construction efforts.

Unfortunately, it is not possible to discuss the details of embryogenesis of the craniofacial skeleton nor the impact of epigenetic processes influencing individual response to SFOT surgery in this chapter, but rather to indeed acknowledge its vital role in surgical planning. As such, the reader is encouraged to consider the indicated references for further background and study [32–48].

14.2.2 Biology of Corticotomy-Assisted Orthodontic Tooth Movement

The regional acceleratory phenomenon (RAP) was first described by Harold Frost in 1983 in response to bone injury (specifically, fracture healing) [6]. The four key events include osteopenia, vasculoneogenesis leading to bone resorption and formation, activation of normal biologic processes from chemical signals sent by inflammatory cells, and a duration of 6–12 weeks during which RAP is present. In the context of SFOT, corticotomy and dentoalveolar bone decortication surgery has been shown to result in a coupled demineralization-remineralization of bone through which teeth are moved [1–6]. Zimmo et al. published a systematic review summarizing the history and research supporting the safety of SFOT, its efficacy in the IDT setting, and the pivotal role of the RAP in accelerating tooth movement and alveolar augmentation [49]. The implications of combined therapy (surgery and tooth movement) include (1) a bypass of the lag phase (rate-limiting step in orthodontia) whereby the osteoblastogenesis-osteoclastogenesis coupling mechanism occurs earlier, (2) there is a reduction in the risk of hyalinization of the periodontal ligament, and (3) a reversible osteopenia occurs with no pathologic loss of bone density, mass, or volume [49].

14.2.3 Facially Prioritized Interdisciplinary Workflow

Contemporary goals of facially prioritized IDT contribute to a global/comprehensive treatment approach with a restoratively driven and airway-centric context and can be compartmentalized into four relationships. These include Tooth-to-tooth, tooth-to-jaw, jaw-to-jaw, and jaws-to-face [13].

Tooth-to-tooth planning is critical to (re)establish and maintain a homeostatic intermaxillary relationship, which includes anterior protected articulation schemes, an absence of fremitus, optimized arch forms, and interdental relationships. These relationships are critical to the success of restorative dentistry and dental implant therapy.

Teeth-to-jaw/s planning is most effective when cases are envisioned in terms of reproducible case-type patterns, as described by Mandelaris et al. [13] and shown in Table 14.1. A key overall objective of this phase is to increase dentoalveolar bone availability so that teeth can be decompensated and arch forms expanded, thus increasing oral cavity volume and optimizing airway conditions.

Facial bone is often very thin,: most often 1 mm or less [49]. This lack of buccal bone has been described as the "human problem." Orthodontic boundary conditions/orthodontic walls are limited and unable to accommodate more advanced tooth movement, as the modulus of elasticity of alveolar bone (in vivo, in humans) has yet to be determined [14, 49]. A key part of SFOT treatment planning involves CBCT imaging to establish pretreatment risk to the periodontium and determine realistic tooth movement possibilities without iatrogenic harm (i.e., bone loss). Care must be taken to evaluate the regional anatomical characteristics of the individual patient. Pretreatment orthodontic simulation software systems, such as SureSmile®, provide a distinct advantage compared to conventional 2D planning or even 3D planning that does not account for the changes in the dentoalveolar compartment (but only displays the tooth-to-tooth relationship).

When planning with contemporary CBCT imaging, Mandelaris et al. have published a classification system of dentoalveolar bone phenotypes by compartmentalizing the crestal and radicular dentoalveolar bone and classifying it based on pretreatment bone volume thickness [14, 49, 50] (Fig. 14.2). This classification establishes pretreatment risk of the periodontium and allows for alternative approaches to tooth movement, such as SFOT, when appropriate [14, 49, 50].

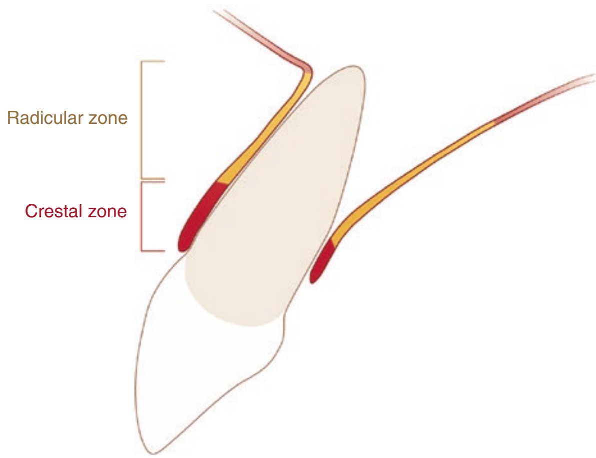

Fig. 14.2 Crestal and radicular zones in classifying dentoalveolar bone phenotypes. Reprinted with permission from Mandelaris GA, Vence BS, Rosenfeld AL, Forbes DS. A Classification System for Crestal and Radicular Dentoalveolar Bone Phenotypes. *Int J Perio Rest Dent 2013; 33(3): 289–296*

The critical benefits of SFOT in teeth-to-jaws planning and harmonization are apparent in pre- and posttreatment cephalograms of a Class III dentofacial disharmony patient with protrusive and retroclined lower incisors. To correct such malocclusions, the mandibular incisors need to be decompensated using labial crown torque which may be impossible without creating dehiscence's or serious periodontal/dentoalveolar bone compromise. Further, conventional orthognathic surgery (OGS) correction may involve an anterior-posterior reduction genioplasty which may not look favorable and does not correct the etiologic factor of inadequate dentoalveolar bone [14]. Figures 14.3, 14.4, 14.5, 14.6, 14.7, and 14.8 demonstrate a Class III dentofacial disharmony patient with protrusive and retroclined lower incisors, a high angle mandible and significant dentoalveolar bone deficiencies, alveoloskeletal discrepancies, and skeletal disharmony. Decompensation was facilitated by SFOT surgery in conjunction with management of dentoalveolar bone deficiencies and recession-based attachment loss problems (gingival recession with or without mucogingival deficiencies).

Fig. 14.3 Class III dentofacial disharmony malocclusion with retroclined and protrusive lower incisors. Dentoalveolar deficiencies abound and have manifested as recession-based attachment loss (i.e., gingival recession). The patient presents with dentoalveolar bone volume deficiencies and alveoloskeletal and skeletal bone discrepancies. Reprinted with permission from Mandelaris GA, Neiva R, Chambrone L. American Academy of Periodontology Best Evidence Consensus on Cone Beam Computed Tomography and Interdisciplinary Dentofacial Therapy. A Systematic Review Focusing On Risk Assessment of the Dentoalveolar Bone Changes Influenced By Tooth Movement. *J Periodontol* 2017; 88(10): 960–977

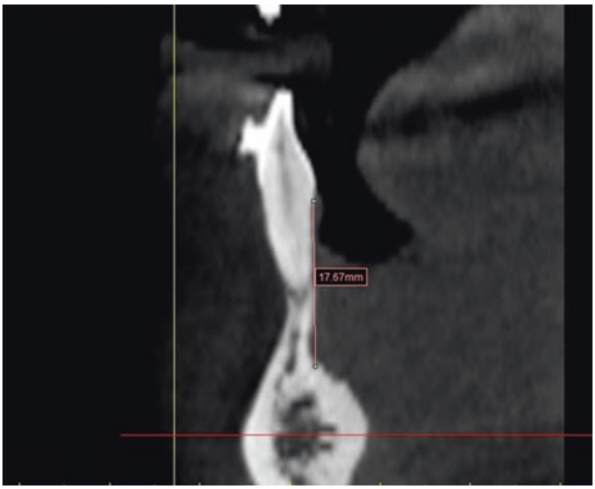

Fig. 14.4 Cross-sectional view from CBCT imaging demonstrating "teeth on a pedestal" appearance. Deficiencies in dentoalveolar bone volume are apparent as is a discrepancy in the alveoloskeletal relationship. The orthodontic boundary conditions are limited, and tooth movement is ill-advised without augmentation of the dentoalveolar/alveoloskeletal bone complex otherwise risking iatrogenic compromise to the periodontium

Fig. 14.5 Intrasurgical photos from SFOT surgery. Corticotomies and dentoalveolar bone decortication (where possible) have been made. Dentoalveolar bone deficiencies present surgically as dehiscences throughout. Note the discrepancy between the alveolar compartment and the skeletal base (i.e., alveoloskeletal discrepancy). Reprinted with permission from Mandelaris GA, Neiva R, Chambrone L. American Academy of Periodontology Best Evidence Consensus on Cone Beam Computed Tomography and Interdisciplinary Dentofacial Therapy. A Systematic Review Focusing On Risk Assessment of the Dentoalveolar Bone Changes Influenced By Tooth Movement. *J Periodontol* 2017; 88(10): 960–977

Fig. 14.6 Bone grafting performed for purposes of (1) guided periodontal tissue regeneration and (2) bone augmentation to convert the "at-risk" dentoalveolar bone phenotype to tooth movement. Bone augmentation performed using a layered approach via cancellous allograft, corticocancellous allograft, followed by an organic bovine bone and a collagen membrane. Reprinted with permission from Mandelaris GA, Neiva R, Chambrone L. American Academy of Periodontology Best Evidence Consensus on Cone Beam Computed Tomography and Interdisciplinary Dentofacial Therapy. A Systematic Review Focusing On Risk Assessment of the Dentoalveolar Bone Changes Influenced By Tooth Movement. *J Periodontol* 2017; 88(10): 960–977

Jaw-to-jaw planning involves aligning the maxilla to the mandible and is, in general, addressed with orthognathic surgery. However, this treatment generally involves orthodontic decompensation measures that may increase the risk of adverse iatrogenic sequela to the teeth. This is especially true if the patient is beginning with deficient dentoalveolar and/or alveoloskeletal bone. While SFOT may camouflage mild orthognathic-related issues, OGS can be a necessary and prudent step in correcting dentofacial disharmony.

In cases where mild skeletal discrepancies are noted, SFOT may be able to sufficiently camouflage the case by dentoalveolar and alveoloskeletal bone

Fig. 14.7 Pre (top row)- and post (bottom row)-outcome at 1 year. Orthodontics by Dr Howard Spector (Chicago, IL, USA). Patient declined orthognathic surgery to correct the remaining right-side crossbite/transverse maxillary deficiency via surgically assisted rapid palatal expansion. However, if elected, SFOT has now simplified orthognathic surgery measures (unilateral SARPE vs. bilateral SARPE requirements), produced a more stable orthodontic result, and remarkably converted an "at-risk" periodontal phenotype to one with substantially less risk to recession-based attachment loss problems secondary to dentoalveolar and alveoloskeletal bone gain

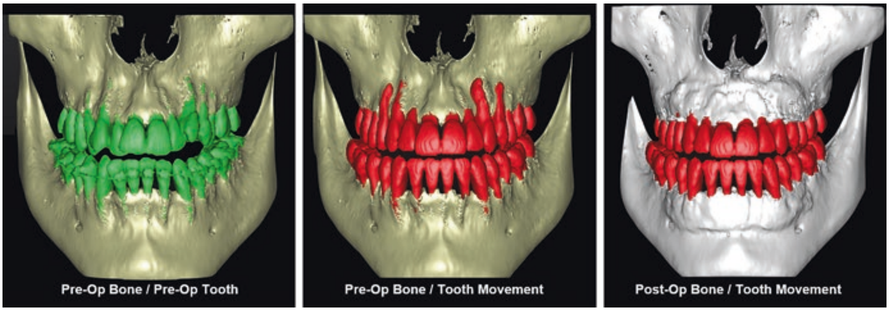

Fig. 14.8 Before and after CBCT imaging and 3D reconstruction. 3D image on the left demonstrates initial regional anatomy phenotype prior to SFOT intervention. 3D image in the center demonstrates projected bone loss patterns if teeth were to be moved without consideration to the dentoalveolar complex. 3D image on the right demonstrates actual outcome post-SFOT treatment (1 year) from CBCT imaging after treatment. Dentoalveolar bone phenotype has been converted from thin crestal, thin radicular to thick crestal, thick radicular dentoalveolar bone phenotype via SFOT. Reprinted with permission from Mandelaris GA, Neiva R, Chambrone L. American Academy of Periodontology Best Evidence Consensus on Cone Beam Computed Tomography and Interdisciplinary Dentofacial Therapy. A Systematic Review Focusing On Risk Assessment of the Dentoalveolar Bone Changes Influenced By Tooth Movement. *J Periodontol* 2017; 88(10): 960–977

augmentation measures. Such surgery will increase hard tissue A and B point and allow for orthodontic expansion to occur subsequent to the increased orthodontic boundary conditions established by SFOT surgery. Decompensation efforts to optimize anterior protected articulation/coupling by means of labial root torque may be available to the orthodontist secondary to the bone augmentation.

Figures 14.9, 14.10, and 14.11 demonstrate a patient with a mild Class III dentofacial disharmony including a transverse maxillary deficiency that was managed safely with SFOT rather than OGS. This is an example of a *jaw-to-jaw* discrepancy that was correctable through dentoalveolar bone regeneration and augmentation surgery efforts alone.

Jaws-to-face planning involves a harmonization of overall facial presentation in order to establish an appropriate physiologic and homeostatic craniofacial balance. Proper assessment of the patient will be necessary to determine the overall extent of surgery needed to address pertinent skeletal anatomic features. Discrepancies in the *jaws-to-face* relationship are addressed with an orthognathic surgical approach to manage dentofacial disharmony problems and improve airway volume.

14.2.4 Jaws-to-Face Planning: The Orthodontic, Periodontal, Surgical, and Restorative Team

It is imperative that the interdisciplinary team arrives at the correct diagnosis at the onset of treatment planning. This requires either an "inside out" or "outside in" approach. The "outside" can be defined as the jaws-to-face relationship, and the "inside" can be defined as the tooth-to-tooth relationship. Without a thorough understanding of all components by all team members concurrently, there is the risk of isolated perception, incorrect diagnosis, and compromised results.

Fig. 14.9 Mild Class III dentofacial disharmony malocclusion patient with transverse maxillary deficiency and notable gingival recession at #6 and #11. Thin crestal and radicular dentoalveolar bone phenotypes noted in both arches, anterior and posterior

Fig. 14.10 Post-SFOT outcome at 1 year. SFOT surgery was performed in the maxillary and mandibular arches followed by expansion in both arches. Note the improved anterior coupling and resolution of posterior cross bites with a subsequent improvement in the periodontal phenotype. Dentoalveolar bone phenotype has been converted from thin crestal, thin radicular to thick crestal, thick radicular dentoalveolar bone phenotype. Interproximal black triangles resulting from expansion can be predictably managed, if required, by conservative bonding approaches. Orthodontics by Dr. David Forbes (West Dundee, IL, USA)

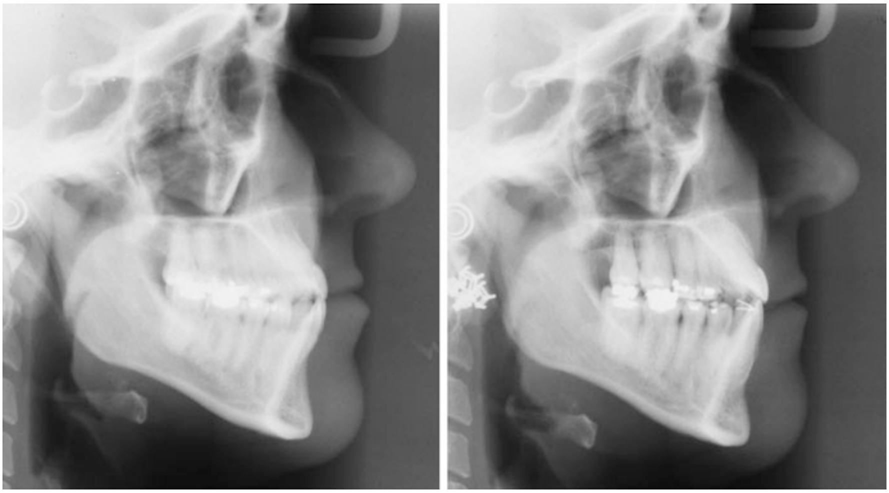

Fig. 14.11 Pre- and post-cephalometric head plates. Note the increased labial bone plate with upright mandibular central incisors. Labial root torque has been used to accomplish the orthodontic result, a movement that would not have been possible without dentoalveolar bone augmentation. Also, note the subtle change in soft tissue B point resulting from the bone augmentation in the mandibular anterior. Hard tissue A and B points have both been augmented providing sufficient change for this malocclusion to be managed by dentoalveolar surgery efforts (SFOT) rather than orthognathic surgery

As an example of isolated treatment approach, imagine the management of a Class II dentofacial disharmony malocclusion with mandibular incisor proclination. The restorative dentist may be focused on an increased overjet with flared spaced maxillary incisors and a traumatic deep bite. The periodontist sees recession and thin fenestrated bone around the mandibular anterior teeth as a result of compensated, proclined incisors. The orthodontist sees Class II molars and canines with the associated sagittal and vertical problems, and the oral and maxillofacial surgeon sees a convex profile, decreased lower face height, weak chin, the illusion of a large nose, and a small airway.

While each practitioner need not extend his or her specialty to every other discipline, the crucial goal is to get all of these disciplines to diagnose comprehensively and understand all of these diagnostic observations at the initial consult. If not, “tunnel vision” and “patchwork” treatment planning may ensue with a final outcome likely to be esthetically flawed, prone to relapse, and potentially detrimental to the patient. Each team member’s existing training already puts him or her in a position to easily understand patterns and key findings that are critical in a complete interdisciplinary diagnosis.

SFOT as an Adjunct to Orthognathic Surgery

While it is possible to decompensate the tooth-to-tooth relationship, full correction may not be possible without some kind of surgery. When orthodontically setting up a case in the context of orthognathic surgery, SFOT can be utilized for pre-surgical orthodontic decompensation to move teeth more quickly while optimizing

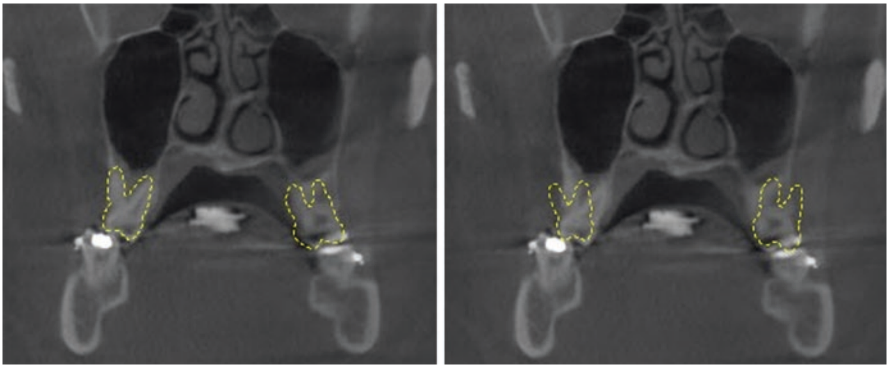

Fig. 14.12 Transverse maxillary deficiency malocclusion. Note the decompensation efforts needed to optimize conditions to prepare for the skeletal surgery required to manage this disharmony. Severe adverse changes to the periodontium are likely to result in the buccal alveolar bone complex with decompensation movements planned. Reprinted with permission from Mandelaris GA, Neiva R, Chambrone L. American Academy of Periodontology Best Evidence Consensus on Cone Beam Computed Tomography and Interdisciplinary Dentofacial Therapy. A Systematic Review Focusing On Risk Assessment of the Dentoalveolar Bone Changes Influenced By Tooth Movement. *J Periodontol* 2017; 88(10): 960–977

physiologic health by maintaining the roots in a robust volume of bone and soft tissue. This contributes to greater long-term stability with reduced chance of relapse. It also may decrease the required surgical movements in the case of transverse maxillary deficiency (Fig. 14.12) [14]. This diagnosis carries the potential for surgical and dental relapse that may be mitigated with SFOT. Because relapse is related to the total amount of expansion required, if a 10 mm discrepancy can be decreased to 6 mm, stability will likely improve.

Another benefit of SFOT-assisted decompensation is that it could potentially accelerate orthodontic treatment and allow an OSA patient to get to life-altering orthognathic surgery in a more timely manner.

If orthognathic surgery is ultimately envisioned, establishing beneficial tooth-to-tooth and tooth-to-jaw corrections with SFOT may expedite and minimize orthognathic surgical correction. Further, the risk of long-term relapse could be reduced in the presence of the more robust dentoalveolar bone volume established through SFOT [49].

14.2.5 Restorative Leadership

Figures 14.13 and 14.14 demonstrate the SFOT IDT workflow and associated treatment synthesis used in contemporary IDT, respectively. The collaborative flow of the IDT approach always involves the primary restorative dentist and/or prosthodontist, periodontist, orthodontist, oral and maxillofacial surgeon, and endodontist. In many cases the involvement of the otolaryngologist/ear-nose-throat (ENT) specialist and sleep physician may be necessary in order to make the correct diagnoses, establish prognoses, and develop a personalized treatment plan. Another

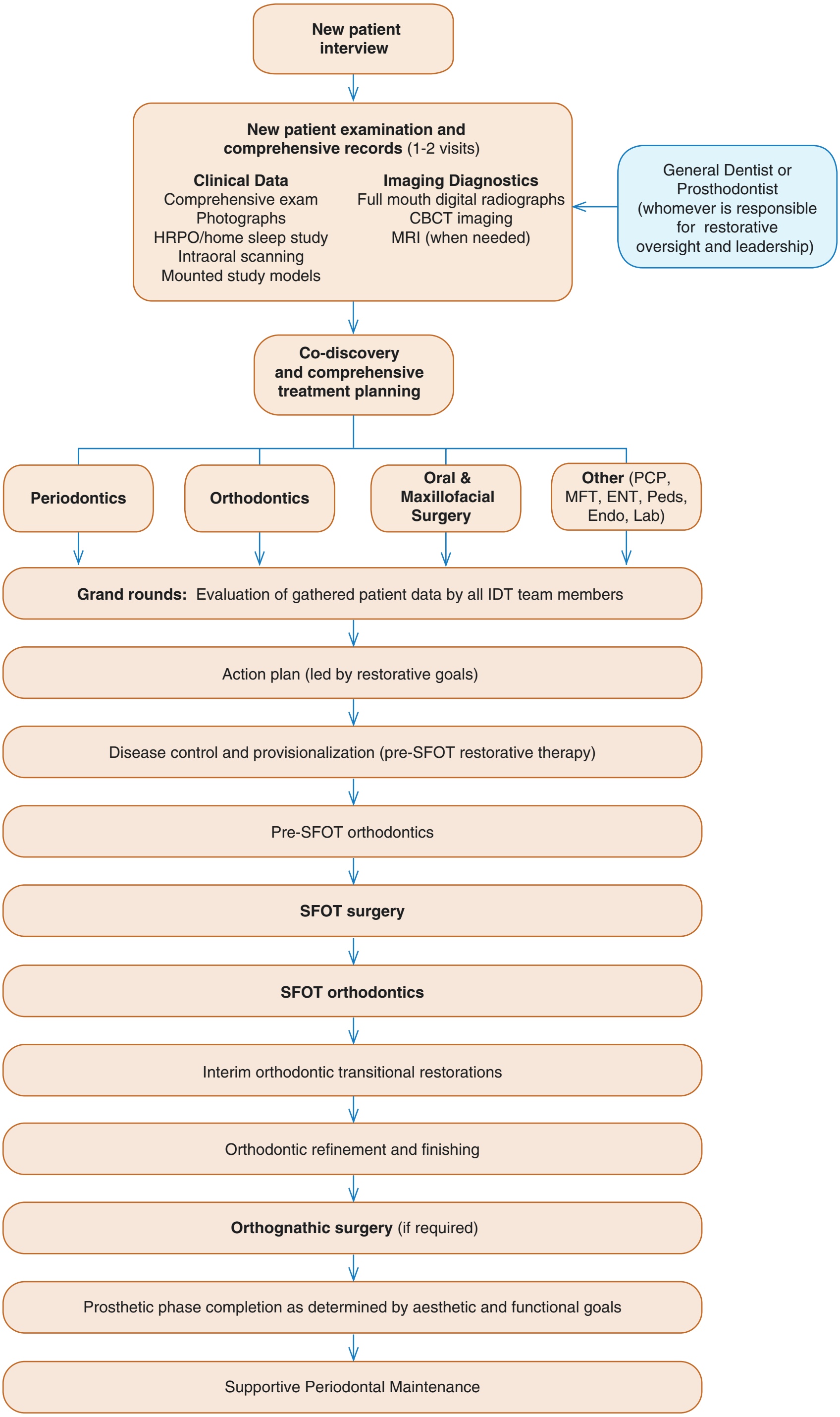

Fig. 14.13 The surgically facilitated orthodontic therapy interdisciplinary dentofacial therapy workflow

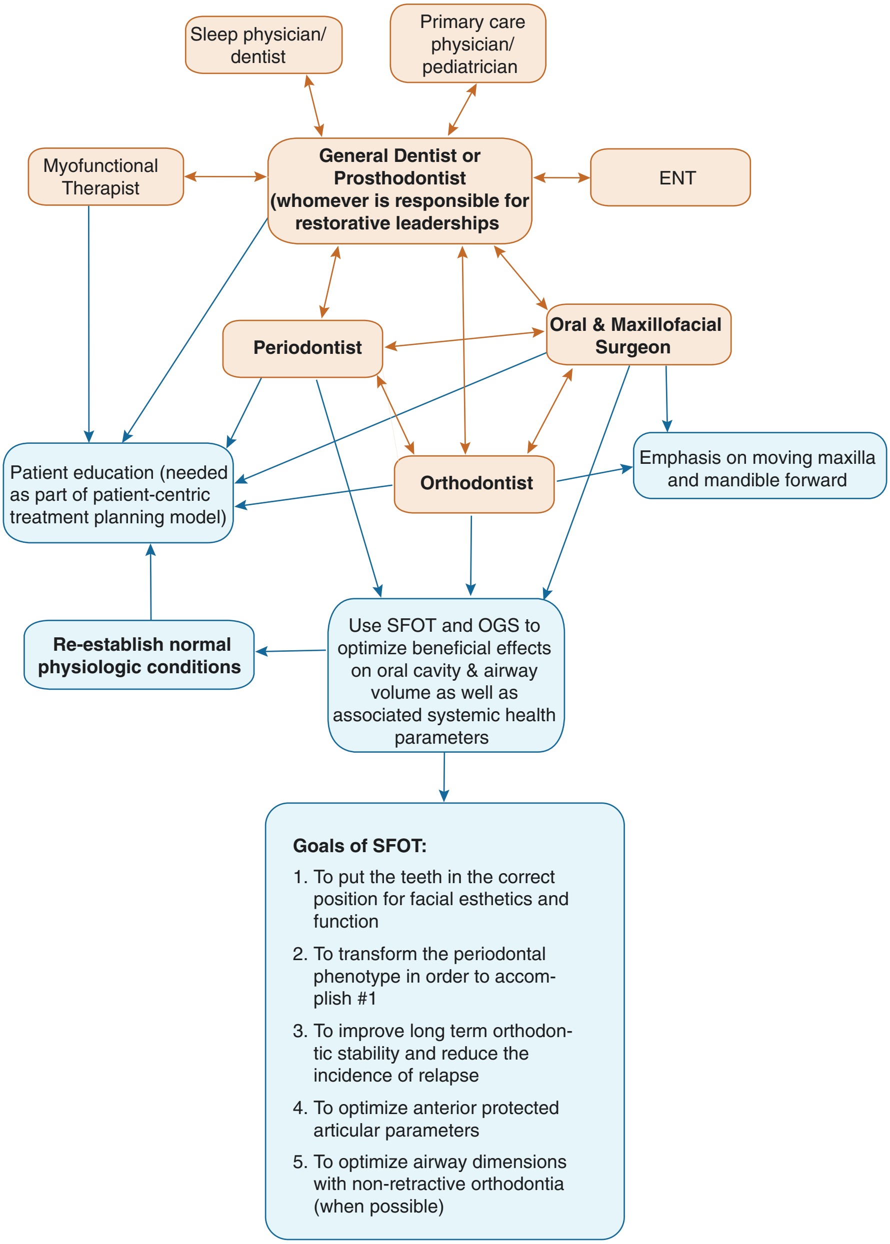

Fig. 14.14 Synthesizing interdisciplinary dentofacial therapy workflow involving SFOT

pivotal component of such a plan involves treatment by the orofacial myofunctional therapist (OMT/MFT) to reestablish homeostatic balance of the tongue, palate, orofacial musculature, and airway and effectively eliminate parafunctional habits.

The importance of the coordination and primary oversight role of the restorative dentist [51] cannot be overemphasized during the entire IDT treatment sequence: from initial craniofacial observation of the face and dentofacial case-type pattern through the most aggressive intervention, such as orthognathic surgery. The restorative dentist must cultivate the ability to envision a structural and esthetic outcome with the teeth and dentoalveolar complex in a far different position from that at the outset. Once the case has been correctly diagnosed, the restorative dentist must maintain collaborative communication with IDT members throughout the IDT treatment workflow. While this is sometimes forgotten, it is critical to a successful outcome.

This emerging scope of collaborative coordination by the restorative dental practice should emphasize early (and accurate) diagnosis and prevention. From a dental perspective, the outcome goal of airway management can be envisioned in terms of expanding oral cavity volume in conjunction with hard tissue space appropriation to allow for ideal functional and esthetic prosthodontics.

Frequently, aberrant tooth position and structural compromise of the dentition (from attrition and erosion) make ideal dentistry impossible. In these cases, orthodontic treatment is necessary to reappropriate space in order to facilitate anatomically correct prosthetic dentistry. However, the benefits of idealizing tooth form and position are not limited to the restorative outcomes. In the contemporary IDT paradigm, recognizing airway problems (frequently accompanied by retrognathia [52, 53]) as a component of dental-related treatment planning is of paramount importance.

Alternative orthodontic approaches, such as rapid palatal expansion prior to the midpalatal suture fusing, can achieve skeletal growth modification and mitigate the need for expansion at the dentoalveolar level (such as SFOT) but may also be detrimental to the periodontium or increase the incidence of relapse, especially if tooth-borne expanders are used [14, 54]. Emerging nonsurgical orthodontic approaches for maxillary skeletal expansion, such as micro-implant assisted rapid palatal expansion (MARPE), are exciting possibilities that are technique sensitive and depend on the ability to separate the midpalatal suture (which may be age dependent) through bone-anchored expanders [55]. Clearly, the earlier expansive intervention can take place, the greater the homeostatic balance that can be achieved, thus minimizing or obviating the need for traumatic intervention in a compromised adult dentition.

Importance of 3D Imaging in the Restorative/Surgical Workflow

The 3D cone-beam computed tomography (CBCT) imaging component of these planning software programs is a paradigm shift in IDT [14, 56]. Two recent best-evidence consensus statements from the American Academy of Periodontology acknowledge an accumulating mass of evidence to support the use of CBCT in accelerated tooth movement in the IDT setting [14, 56].

Specifically, CBCT was found to enhance the diagnostic acumen and proactive risk assessment in cases where alveolar bone augmentation was contemplated [14].

This is especially true for cases where buccal expansion is implemented such as orthodontic repositioning in the anterior mandible or in maxillary premolars [14].

Incorporating 3D regional anatomy into virtual planning allows a biologic conscience to guide the clinician during dental and orthodontic planning [14]. If the facially prioritized treatment plan calls for the tooth position outside of the dentoalveolar bone volume limits, alternative approaches to orthodontic tooth movement *must* be considered and offered to the patient.

Treatment such as SFOT may allow the IDT team accomplish outcome goals and avoid iatrogenic complications associated with tooth movement. Collaborative treatment planning on the part of a cohesive IDT team must be done prior to embarking on a restorative rehabilitation or orthodontic treatment that may exceed the boundaries of the “orthodontic walls” [57]. Failure to respect these boundaries could lead to unstable and potentially harmful results.

The ever-important, but often deficient, facial bone thickness (especially in the anterior sextant) must be considered during treatment planning [58, 59]. CBCT is a critical method to assess dentoalveolar, alveoloskeletal, and skeletal relationships (as well as the anatomic structures of the temporomandibular joint) in the comprehensive treatment planning process [50].

Importantly, sleep-disordered breathing conditions are not unlike other systemic health problems: if they are diagnosed and treated earlier, there are fewer negative sequelae and more favorable outcomes.

Even milder forms such as upper airway resistance syndrome (UARS) or respiratory effort-related arousals (RERAs) can be addressed before they begin to harm the patient if they are detected early. This underscores the need for the restorative dentist to be conversant with airway assessment, especially by CBCT. Because of the ability to influence growth in skeletally immature patients, early orthodontic and dentofacial intervention can be instrumental in idealizing space appropriation and increasing the oral cavity volume.

14.2.6 SFOT Surgery

The pre-surgery patient work-up in a potential SFOT case involves all members of the IDT, under the primary direction of the restorative dentist, periodontist, and orthodontist. In addition, an ENT consultation is often prudent in order to assess and understand physical airway conditions, rule out potential oral or nasal obstructions (including deviated septa), review the anatomy of the respiratory tree, and assess tonsillar size, Mallampati score, and oral cavity volume.

Advantages of using a hospital operating room versus performing in-office SFOT surgery are best assessed on a case-by-case basis and dependent on the medical work-up of the patient. In most instances involving at least one jaw of surgery, operating conditions should be performed under intravenous (IV) moderate or deep conscious sedation combined with profound local anesthesia to maximize patient comfort. Collaboration with a dental anesthesiologist may, in many cases, alleviate the stress of patient management and allow the surgeon to focus solely on a very demanding surgery. In-office intubated general anesthesia in collaboration with a dental anesthesiologist requires the most complete pre-surgical work-up, allows the airway to be protected, and helps maximize the surgeon's skill set while maintaining comfort for the patient during complex dentoalveolar bone surgery. This is especially important if the patient has been previously diagnosed with OSA. Because some operations involve double jaw SFOT surgery, with or without placement of skeletal anchorage devices, securing the airway and maximizing patient comfort for a 4–5 h operation is prudent.

SFOT Corticotomy Procedure

The SFOT surgery itself involves broad, full-thickness mucoperiosteal flap reflection with deep (i.e., 2–5 mm cuts into the medullary bone) interdental corticotomies through the alveolar cortical plate that extend and circumscribe at least 5 mm beyond the apex of each individual tooth. Decortication is completed using uniformly spaced "injury" of the facial plate using rotary or piezoelectric instrumentation. Palatal or lingual corticotomies may also be utilized, depending on the orthodontic plan. Following flap reflection, the first step of surgery is to ensure that the dentogingival complex is in the correct position. This may require correction of crestal bone positioning by ostectomy/osteoplasty for esthetic crown enhancement so that the full clinical crown length of the teeth will be displayed after healing. Placement of corticotomies and dentoalveolar bone decortication is then performed to achieve a demineralized dentoalveolar bone environment which will facilitate tooth movement. The positioning of corticotomies (buccal, lingual, or both) is dependent upon the planned tooth movement and need for bone augmentation to accommodate orthodontic requirements. In general, the more the injury (i.e., corticotomy + dentoalveolar bone decortication) to the dentoalveolar/alveoloskeletal bone complex that surrounds the tooth/teeth, the more profound will be the RAP produced from surgery [14, 49]. Table 14.2 highlights the key phases and features of SFOT.

Table 14.2 Key phases and features throughout the life cycle of the regional acceleratory phenomenon (RAP) associated with corticotomy surgery (SFOT)

Key procedures and processes		Metabolic processes	Published observations
Timing	Beginning of orthodontic therapy	• Demineralized bone matrix	Yaffe et al. document the RAP in the mandible following mucoperiosteal flap surgery
	Selective corticotomies as needed throughout therapy	• Transient alveolar osteopenia	Wilcko et al. describe the accelerated orthodontic process as a result of coupled demineralization-remineralization phenomena
Surgery	Corticotomies, decortication	• Vasculoneogenesis leading to bone resorption and formation	• "Bone matrix transportation" occurs with tooth movement, not a "bony block" movement

Table 14.2 (continued)

Method of Accelerated Movement/Alveolar Bone Development	Regional Acceleratory Phenomenon (RAP)	• Coupled osteoclastic and osteoblastic activity in response to alveolar decortication	Sebaoun et al. demonstrate the histologic wound healing (modeling of trabecular bone following selective decortication in rats), including:
	Bone matrix transposition	**Historical Timeline for Clinical Use of RAP**	• Less calcified spongiosa bone context (×2)
	Bone grafting (allow 2–4 weeks after surgery before initial activation to allow greatest effect)	1893: Cunningham (interalveolar osteotomy introduced) 1921: Cohn-Stock (3 basic strategies to correct malocclusion) 1931: Bichlmayr (Palatal corticotomies to facilitate correction of maxillary protrusion) 1959: Köle (Labial and palatal corticotomies, with orthodontic “bony block movement”) 1968: Schallhorn (Autogenous hip marrow for bone-graft management of bony crater defects around natural teeth) 1969: Bell (Wound healing of interalveolar osteotomies in rhesus monkeys with intact mucoperiosteum, collateral circulation, and vascular anastomoses preserve bone/pulp blood supply) 1983: Frost (Introduces the RAP concept in fracture healing)	• Greater PDL surface (increase twofold)
Location of corticotomy or DA bone decortication	Buccal and lingual (current)		• Catabolic and Anabolic activity = 3× greater
	Based on individual needs of the patient and overall goals of team and expertise of orthodontist and periodontist		• Significant increase in tissue turnover × 3 weeks
Additional adjunctive	Functional or esthetic crown lengthening		Baloul et al. publish the first study providing scientific evidence for the role of coupled osteoclastic and osteoblastic activity in response to alveolar decortication through which the orthodontic tooth movement is enhanced
Procedures	Connective tissue grafting		
	Anchorage plates and/or TADs		
	Extractions		
	Guided periodontal/bone regeneration		
	Implant site development for edentulous areas		
Minimum orthodontic activation intervals	Biweekly		
Types of movement	Dentoalveolar RAP-driven acceleration through demineralized bone matrix, with tipping followed by uprighting		
Indication	Accelerated tooth movement		
	Shorter treatment time		
	Supercharging dentoalveolar changes		
	Minor skeletal discrepancies		
	Mild-to-moderate crowding or arch development		
	Extraction site closure		

PDL periodontal ligament, *RAP* regional acceleratory phenomenon, *SFOT* surgically facilitated orthodontic therapy, *TAD* temporary anchorage device

Adherence to the basic principles of periodontal regeneration includes managing dentoalveolar deficiencies such as dehiscences and fenestrations, to achieve true periodontal regeneration (PDL, cementum, alveolar bone) and encase each tooth in dentoalveolar bone that has a functional matrix with a true periodontal organ system produced, including the vascularized bone. This is a large part of the surgical outcome goals with SFOT surgery.

In addition, the principles of bone construction and regeneration are utilized in SFOT increase bone volume to allow tooth movement into a biologically sound environment. A critical objective here is to achieve a functional matrix for the periodontal organ system but in a displaced position so that the tooth can settle into that new position. Bone substitutes and other materials chosen for SFOT surgery should support principles of periodontal regeneration and guided bone augmentation for short- and long-term outcome goals. These may or may not involve growth factor-mediated approaches to optimize results. Given that SFOT is often performed in a partially edentulous patient requiring future implant therapy, site development surgery can also be combined with SFOT for future implant placement purposes.

Reconstructive and constructive surgery were reviewed earlier in this chapter. Given the goal of an individual SFOT surgery, the clinician must understand and apply the principles of embryogenesis to treatment planning for the creation or recreation of a dentoalveolar apparatus. This will ensure that treatment outcomes will function with stable, long-term implant osseointegration or tooth support. The Harvold principles for optimal and predictable embryologic bone formation remain true today for constructive or reconstructive periodontal surgery, such as for SFOT [33]. Those requirements were described as a stabilized environment, a source of cells, a source of neuromuscular input, and an absence of pathology. Similar requirements have been published for predictable periodontal regeneration and guided bone regeneration efforts and have become known as the PASS principles [60]. The PASS acronym stands for primary wound closure, angiogenesis, space maintenance, and stability of the wound. These principles are critical to follow for predictable SFOT surgery outcomes.

In the context of IDT, SFOT can be utilized to enable orthodontic treatment more safely, predictably, and expeditiously in order to accomplish the goals laid out by the IDT team. This can include the restorative goals of reestablishing natural tooth proportions and optimizing tooth positioning with a non-extraction mantra (whenever possible). It can encompass the periodontal goals of regenerating lost periodontal support and ensuring that teeth remain surrounded by their appropriate dentoalveolar complex. It can be a part of the orthognathic surgical goals of jaw expansion or decompensation.

The four aspects of IDT treatment planning (tooth-to-tooth, tooth-to-jaw, jaw-to-jaw, jaws-to-face) are the main components of piecing together the puzzle of complex interdisciplinary treatment. SFOT is a treatment modality which can be prudently applied as a part of interdisciplinary care to expand the possibilities and minimize some of the risks and limitations of orthodontic and orthognathic therapy. Continued mindfulness of the restorative leadership perspective is critical for the final functional and esthetic outcome envisioned during initial planning.

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Management of Endodontic-Periodontic Lesions

15

Bradford R. Johnson

15.1 Introduction

Although endodontology and periodontology are often viewed as two separate areas of oral science and clinical practice, the intimate association between diseases of the pulp and diseases of the periodontium creates areas of significant overlap. The relationship between the pulp and periodontium has embryologic origins and continues as a functional relationship in the mature dentition [1]. Oxygen saturation was found to be lower in pulps of teeth with periodontal attachment loss and recession, and there is a negative correlation between markers of periodontal disease and pulp oxygen saturation [2]. Diagnosis and management of endodontic-periodontic (endo-perio) lesions often involves interdisciplinary consultation and shared treatment planning. The purpose of this chapter is to provide a brief overview of endodontic-periodontic lesions, with a primary focus on endodontic considerations in diagnosis and treatment planning.

15.2 Pathways Connecting the Pulp and Periodontium

There are three primary paths of communication between the pulp and periodontium. First, the largest opening in an intact permanent tooth is the apical foramen, typically measuring between 0.2 and 0.4 mm [3]. The spread of inflammatory by-products and microorganisms from the pulp to the periodontium via the apical foramen is a well-documented sequelae of infection of the root canal space. The resulting apical periodontitis may range in degree from completely asymptomatic to acute pain and swelling. Nonsurgical root canal therapy is usually the treatment of first choice for apical periodontitis in a restorable tooth with adequate periodontal support. Alternatives include no treatment and extraction, and, for teeth that have already

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received initial root canal therapy, revision of initial therapy and/or endodontic microsurgery should be considered. Spread of infection from the periodontium to the pulp via the apical foramen is believed to occur only when attachment loss reaches the foramen. The second pathway of potential communication between the pulp and periodontium is lateral or accessory canals (Fig. 15.1a), which are most common in the apical third of the root but can also be found in the middle and cervical third, as well as the furcation of molars (Fig. 15.1b) [4]. Finally, exposed dentinal tubules in an area of the root with no cementum layer can also allow for communication between the pulp and periodontium. Dentinal tubules extend from the pulp to the external root surface, with a mean diameter of approximately 2.5 μ at the pulp-dentin interface and narrowing to a mean diameter of 0.9 μ at the root surface [5]. Since most oral bacteria are smaller in diameter than 0.9 μ, penetration into the tubules and eventually the pulp is possible if the protective cementum layer on the root surface is absent. The predominant microorganisms found in infected root canals, *Porphyromonas* sp. (13.9%), *Filifactor* sp. (12.5%), and *Parvimonas* sp. (11.1%), are similar to those identified in periodontal pockets, suggesting the periodontal pocket could be a source of infection in the root canal space, and vice versa [6].

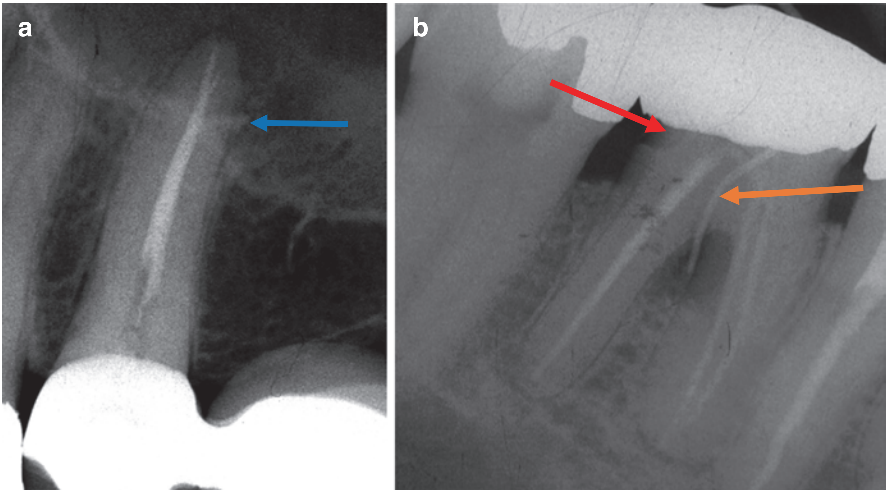

Fig. 15.1 Accessory canals and periodontal defects. (**a**) The blue arrow demonstrates sealer in an accessory canal. This accessory canal, a fairly common finding in the apical third of many roots, is large enough to allow spread of bacteria and bacterial by-products from the pulp to periodontium and vice versa. (**b**) A buccal sinus tract was present and traced with gutta-percha (orange arrow) to the furcation of #30. The location of the lesion is suggestive of a primary perio lesion, but this is actually a primary endo lesion (previously treated with chronic periradicular abscess) due to coronal microleakage secondary to recurrent caries at the distal crown margin (red arrow). Since accessory canals are not uncommon in the furcation area of molars, bone destruction can occasionally appear first in the furcation area rather than the more common presentation at the root apices

15.3 Classification and Diagnosis

A practical way to classify endo-perio lesions for treatment planning purposes is to separate into three broad categories: (1) primary endodontic, (2) primary periodontal, and (3) combined endo-perio lesion [7]. The combined endo-perio lesion category can be further subdivided into primary endodontic with secondary periodontal disease, primary periodontal with secondary endodontic disease, and true combined endo-perio lesions. Proper classification will help guide treatment sequence and determine prognosis.

15.4 Primary Endodontic Lesion (Fig. 15.2)

- Pain is often absent (drainage may occur through the sulcus and/or sinus tract; sinus tracts should be traced with gutta-percha although this is not always a reliable test [Fig. 15.3a]).
- No response to pulp sensibility testing (thermal and electric pulp test).
- Periodontal probings within normal limits (WNL) except one isolated defect that may probe to the apex.
- Response to percussion and palpation is variable.
- Treatment: prognosis is favorable with RCT (root canal therapy) only (nonsurgical or surgical).

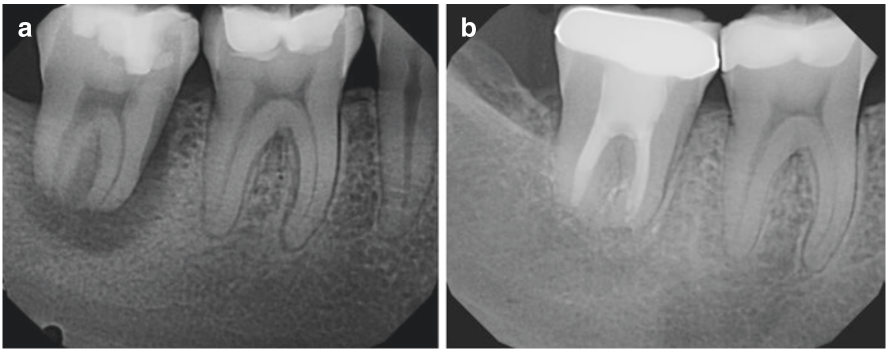

Fig. 15.2 Lesions of primary endodontic origin periodontal status. (**a**) Preoperative radiograph of tooth #31. The tooth was nonresponsive to pulp sensibility testing and exhibited grade 2 mobility. Although probing depths ranged from 3.0 to 5.0 mm, the cervical periodontal attachment appeared to be intact circumferentially. A draining buccal sinus tract was present. The diagnosis was primary endo lesion (pulp necrosis with chronic apical abscess) with an unfavorable prognosis. The patient was highly motivated to try to save the tooth, and initial response to pulp debridement and placement of interim calcium hydroxide paste was favorable. RCT was completed in two appointments. (**b**) Good healing and bone regeneration are apparent at the 18-month posttreatment evaluation (Case courtesy of Dr. Cristina Olarov). (**c**) Heavily restored tooth #30 was nonresponsive to pulp sensibility testing. The tooth was slightly sensitive to percussion, palpation, and biting. Mobility was WNL. A periodontal probe could be inserted to full length of probe in a single, isolated mid-buccal defect. The diagnosis was primary endo lesion (pulp necrosis and chronic apical abscess). (**d**) Favorable initial healing was observed at the 1-year posttreatment evaluation and all probing depths are now WNL

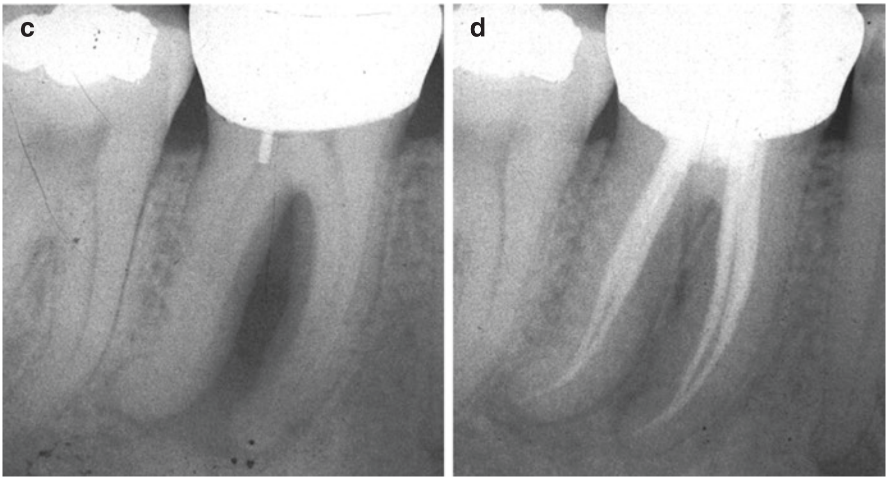

Fig. 15.2 (continued)

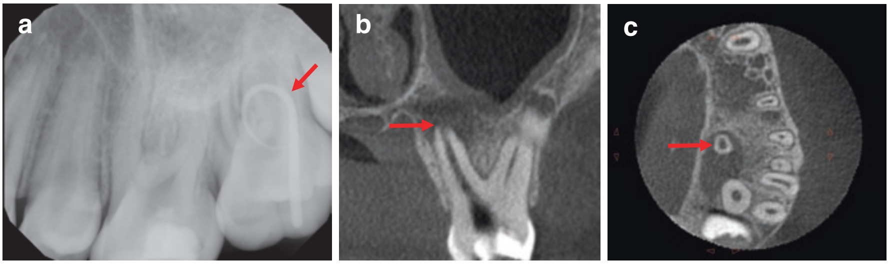

Fig. 15.3 Palatal sinus tract. A palatal sinus tract adjacent to tooth #15 was traced with gutta-percha (arrow) and suggested a primary endo lesion associated with recently erupted #15 (**a**). Teeth #13, 14, and 15 all responded positively to cold testing. A limited field of view CBCT of the area (without gutta-percha in the sinus tract) demonstrated a distinct periapical lesion associated with the P root of #14 (**b** and **c**; arrows pointing to the P root apex, in coronal and axial views, respectively). On endodontic access of #14, some vital tissue was found in the MB and DB roots (explaining the positive response to cold), and the P root was completely necrotic. The sinus tract resolved after initial canal space debridement and placement of calcium hydroxide paste as an interim intra-appointment medication in tooth #14

15.5 Primary Periodontal Lesion (Fig. 15.4)

- Usually evidence of advanced periodontal disease.
- May observe widened PDL secondary to occlusal trauma (can be confused with lesion of primary endo origin).
- Normal response to pulp sensibility testing (thermal and electric pulp test).
- Plaque and calculus present on root surfaces.

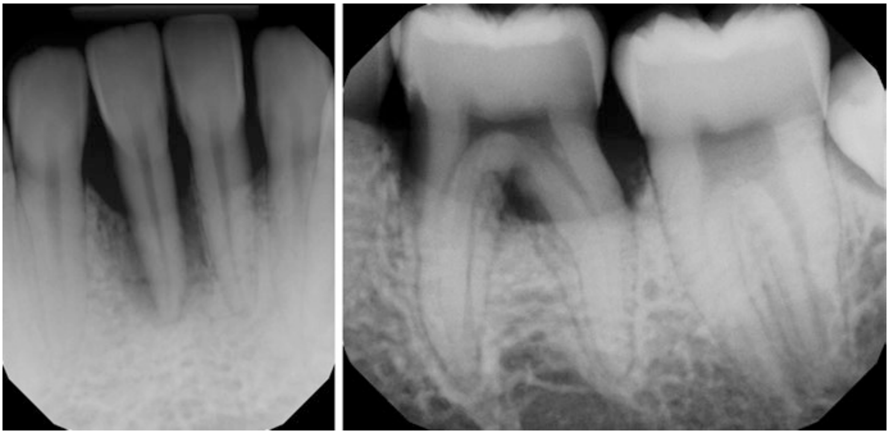

Fig. 15.4 Primary periodontal lesions. Two periapical images from an 18-year-old female referred to an endodontist for evaluation. All teeth responded WNL to pulp sensibility testing. The diagnosis was localized aggressive periodontitis, and prognosis depends entirely on ability to manage periodontal disease

- Treatment: prognosis depends completely on ability to manage periodontal disease; RCT may be indicated if periodontal therapy could lead to devitalization of the pulp or pulp status is uncertain.

15.6 Combined Endodontic-Periodontal Lesion

- In early stages, endo and perio lesions are separate and may later connect.
- Non-vital pulp and periapical lesion of endodontic origin.
- Crestal bone and attachment loss; deep periodontal probings; plaque and calculus.
- Need to rule out vertical root fracture (hopeless prognosis) (Fig. 15.5).
- Treatment: Periodontal consult, if periodontal condition is manageable, then RCT, followed by periodontal therapy; prognosis is typically questionable.

Radiographic imaging is an essential first step although, as can be seen by numerous examples presented in this chapter, radiographs alone do not provide a defintive diagnosis. The recent introduction of cone beam computed tomography (CBCT) has greatly enhanced diagnosis and treatment planning in all areas of dentistry and gained rapid acceptance in endodontics [8–10]. Of the commonly used pulp sensibility tests for establishing pulp vitality, cold is generally the most useful and accurate [11, 12]. Electric pulp testing (EPT) may be useful for teeth with calcified and/or receded canals since these teeth often do not respond to cold but will respond to EPT. Heat testing is not as commonly used but can be very helpful when the chief complaint is sensitivity to hot foods or liquids. Laser Doppler flowmetry (LDF) and pulse oximetry (PO) have been proposed as alternative pulp sensibility tests and have the advantage

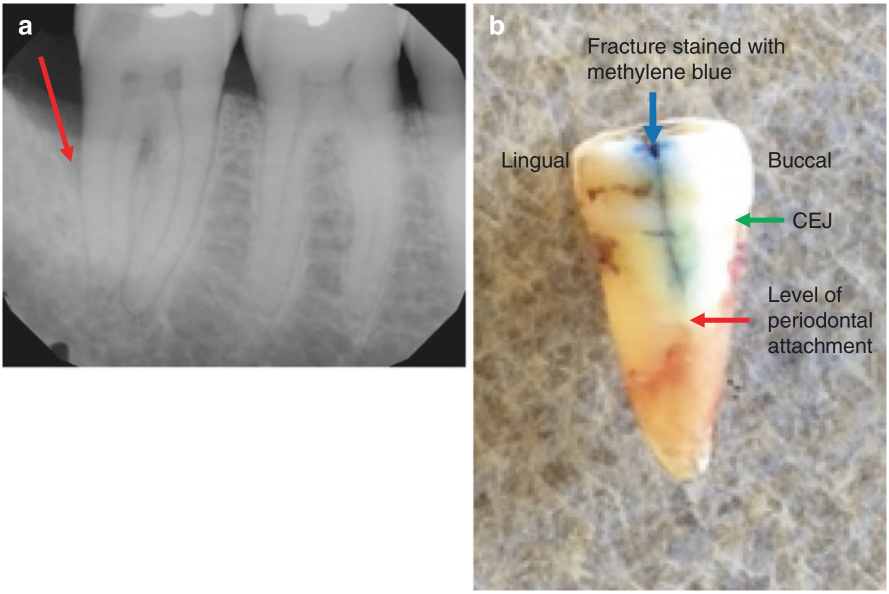

Fig. 15.5 Vertical root fracture. (**a**) Tooth #31 was nonresponsive to pulp sensibility tests and sensitive to percussion and biting. A 10+ mm periodontal probing depth was noted on the distal aspect (red arrow). Transillumination with a light source and visual examination revealed an incomplete vertical root fracture. This is an example of a true combined endo-perio lesion, and the tooth was extracted due to unfavorable prognosis (**b**)

of being able to measure pulp blood flow [13–15]. However, even though these tests perform very well in limited benchtop and clinical experimental models, currently there are no commercially available and practical devices for this type of pulp testing. A small test cavity is considered to be highly accurate for determining pulp vitality but is invasive (albeit, minimally) and not routinely used.

Percussion is useful for generic identification of a tooth with inflammation in the periodontal ligament and especially apical tissues, but is not specific to endodontic vs. periodontic pathosis. Likewise, palpation sensitivity may help localize a problem but is not particularly useful for differential diagnosis of endo-perio lesions. Complete periodontal pocket depth probings are an essential part of any endo-perio diagnostic process and can help distinguish generalized periodontal attachment loss (suggestive of a primary perio lesion) from a single isolated deep probing pocket, which is more suggestive of a primary endo lesion.

15.7 Root Resorption

Pathologic root resorption can be broadly classified into two categories—internal and external. Internal resorption is primarily an endodontic only problem with unknown etiology and, in the early stages, requires the presence of active clastic cells in a vital pulp. The presence of an incomplete vertical root fracture or herpesvirus outbreak along a branch of the trigeminal nerve serving the affected tooth or teeth have both been suggested as possible causes of internal resorption [16, 17]. A possible genetic component has also been proposed and requires further investigation [18]. Regardless of etiology, root canal therapy is usually recommended when internal resorption is first diagnosed since progression of the disease process is unpredictable and the condition may remain inactive for years before a sudden increase in resorptive activity, leading to extensive loss of root dentin and often tooth loss. An example of internal resorption and management with nonsurgical root canal treatment is shown in Fig. 15.6. In this more advanced case, the pulp became necrotic and an endo-perio lesion developed.

External root resorption is most commonly referred to as invasive cervical resorption (ICR). ICR is a challenging condition to predictably manage and may require multidisciplinary collaboration. Predisposing factors for ICR include history of trauma, orthodontic treatment, and intracoronal bleaching, although the majority of cases are idiopathic in nature [19, 20]. Other potential causes of ICR include exposure to feline herpesvirus type 1 (FeHV-1) through contact with domestic or wild cats and playing wind instruments (presumably due to excessive pressure placed on anterior teeth) [21, 22]. Classification of ICR lesions is important to help guide treatment and determine prognosis. A commonly used classification system developed by Heithersay [19] is presented in Fig. 15.7. The advantage of treating these lesions in the early stages (Class 1 or 2) is apparent since the prognosis for tooth retention approaches 100%, defined as no evidence of continued or recurrent resorption and absence of periapical or periodontal pathosis [23]. However, the prognosis decreases significantly as the ICR lesion progresses to Class 3 and 4, with reported success of 78% and 12.5%, respectively. A common treatment protocol typically includes surgical exposure of the lesion, curettage of granulation tissue, chemical cautery with trichloroacetic acid (TCA), and restoration with a resin-modified glass ionomer material [23] (Fig. 15.8). Orthodontic extrusion may also be an option to move the ICR root defect to a more coronal position for nonsurgical management. Limited field of view CBCT has recently gained widespread acceptance in endodontics and

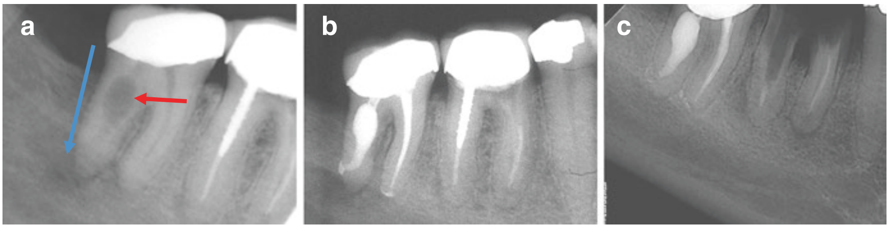

Fig. 15.6 Example of internal root resorption with endo-perio lesion, tooth #31, managed with nonsurgical root canal treatment. (**a**) The resorptive defect is visualized (red arrow), and distal periodontal attachment loss extended to the apex of the distal root (blue arrow). (**b**) The immediate post-fill radiograph. (**c**) 18-month posttreatment evaluation radiograph. Note excellent healing of the distal endo-perio lesion associated with #31, although #30 is now non-restorable for unrelated reasons

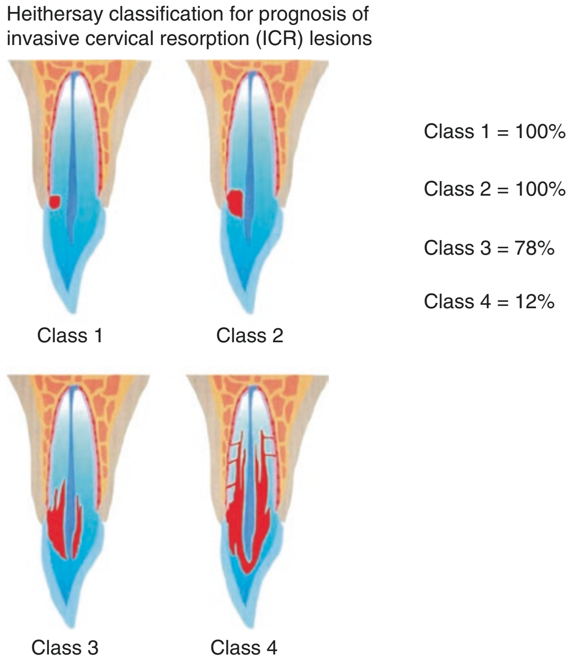

Fig. 15.7 Heithersay's classification system for prognosis of ICR lesions (from: Heithersay GS. Quintessence Int 1999;30(2):96–110)

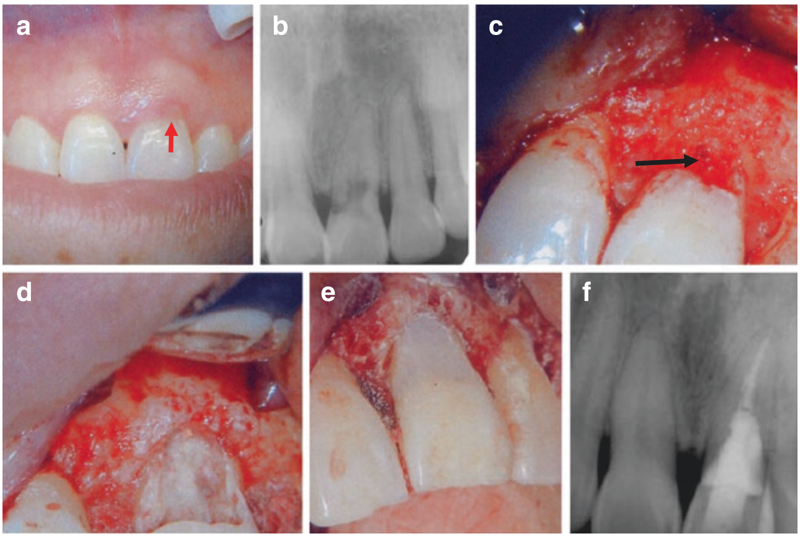

Fig. 15.8 External root resorption and surgical treatment. (**a**) Image taken when the patient, a 25-year-old healthy female, presented for initial evaluation. Her only complaint was slight soreness to touch and mild bleeding when brushing associated with the maxillary left central incisor (red arrow points to inflamed gingiva). (**b**) Radiograph that demonstrates a moderately extensive ICR lesion (Heithersay Class 3). (**c**) A flap was reflected, exposing the inflamed granulation tissue in the facial defect (arrow). The granulation tissue was curetted and the tooth was treated with TCA (**d**). The defect was restored with a resin-modified glass ionomer material (**e**). (**f**) Is a radiograph of the restored tooth. The long-term prognosis is questionable

has proven to be an excellent tool to assess the location and extent of ICR (Fig. 15.9). Heithersay Class 1 and 2 ICR lesions can sometimes be managed without root canal therapy, since in many cases the external defect has not yet reached the pulp. If symptoms are present or the tooth is nonresponsive to pulp sensibility testing, root canal treatment is usually performed before surgical repair of the ICR lesion.

Whether to treat or observe small ICR lesions is often a judgment call, and it is important to fully inform the patient of benefits and risks of each option. It is not possible with current technology to predict which ICR lesions will remain dormant

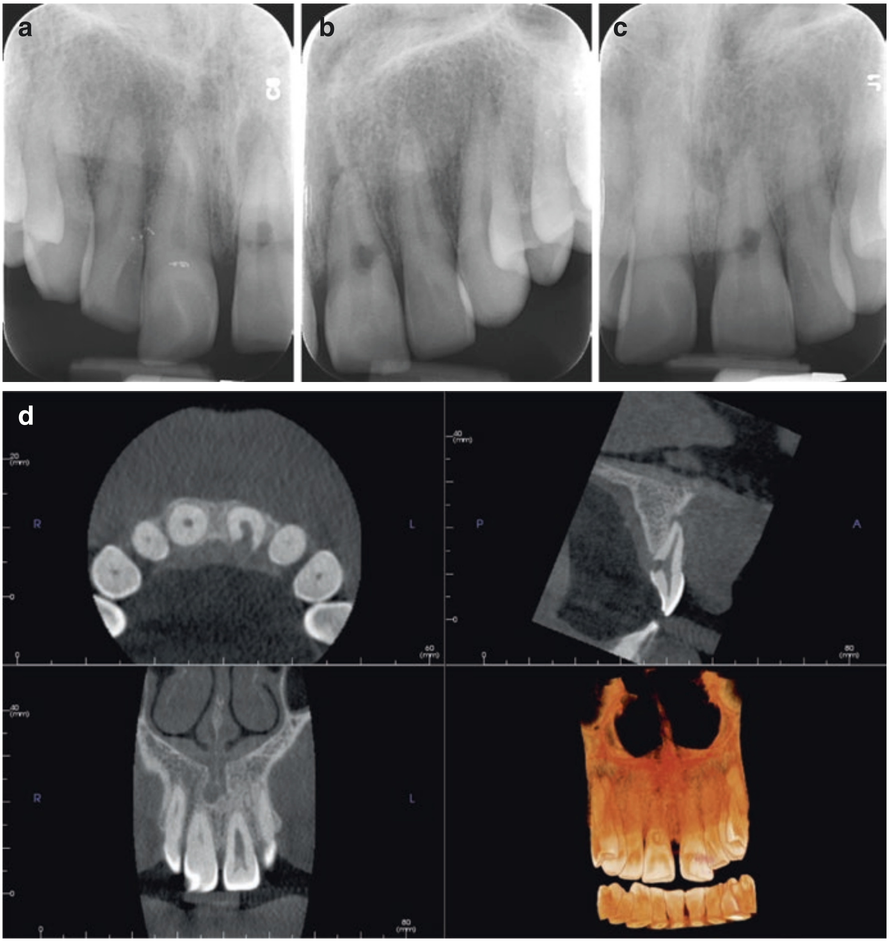

Fig. 15.9 An asymptomatic 44-year-old male presented on referral from his general dentist for evaluation of suspect internal resorption in the maxillary left central incisor. Several angled radiographs were obtained but the true nature and extent of the lesion was uncertain (**a**–**c**). The tooth was nonresponsive to pulp sensibility testing and the pulpal diagnosis was necrosis. A CBCT was then obtained (**d**), and the location and extent of the lesion is now apparent, with presumed initial origin as an external ICR-type lesion that progressed to the pulp. The treatment plan was combined nonsurgical root canal therapy and surgical flap reflection and repair of the palatal defect. Minor orthodontic extrusion of teeth like this is not usually necessary but may be indicated to gain better access for repair

for years and which will rapidly progress from the early stages (Heithersay Class 1 and 2) to more advanced (Class 3 or 4) lesions, which can be much more challenging to manage and have a poorer prognosis. While it may be tempting to recommend observation for relatively small ICR lesions in asymptomatic teeth, the downside risk is potential rapid progression to the point where extraction becomes the best option. The more “conservative” option may often be surgical intervention and restoration of the defect, while the ICR lesion is still small and easier to manage.

15.8 Influence of Periodontal Disease on Endodontic Outcomes

Modern endodontic microsurgery involves use of the dental operating microscope, near perpendicular root-end resection, use of ultrasonics for root-end preparation, and bioceramic root-end filling materials. With careful case selection, the expected prognosis is approximately 90%, a dramatic improvement compared to traditional endodontic surgery [24–26]. Kim and Solomon demonstrated that endodontic microsurgery was generally the most cost-effective option for management of failure of initial root canal therapy in a molar tooth when compared to various combinations of nonsurgical treatment revision and restoration, as well as extraction and a single-tooth implant-supported crown [27].

However, the presence of concurrent periodontal disease has a significant negative effect on the prognosis of endodontic microsurgery and often requires concurrent bone graft and/or guided tissue regeneration [28]. In a classification system developed by Kim and Kratchman (Fig. 15.10), Classes A, B, and C should respond predictably to endodontic microsurgery only, while Classes D, E, and F demonstrate progressive levels of periodontal involvement and are likely to require additional periodontal therapy in conjunction with endodontic microsurgery [28]. The prognosis for teeth in Classes D, E, and F is questionable and the treatment outcome depends more on periodontal therapy than endodontic treatment. One study reported the prognosis for a successful outcome for teeth with a combined endo-perio lesion was about 78%, compared to a success rate of greater than 90% if there was only an isolated endo lesion [29]. This is another example of a situation where multidisciplinary treatment planning expertise should lead to a more predictable outcome.

A vertical root fracture should always be suspected in teeth with no other obvious etiology for pulpal pathosis, especially mandibular molars and posterior teeth with a steep cusp-fossa relationship as well as teeth that have had previous RCT (Fig. 15.11) and/or patients with parafunctional occlusal habits (Fig. 15.12).

When one root of a multi-rooted maxillary molar is severely compromised (e.g., vertical root fracture, significant loss of periodontal attachment isolated to only one root, large strip perforation, failure to heal following nonsurgical and/or surgical root canal therapy), root amputation may be an option. Anecdotal evidence suggests that this procedure is not nearly as common as it was two or three decades ago prior to the widespread emergence of dental implants, although this may still be a

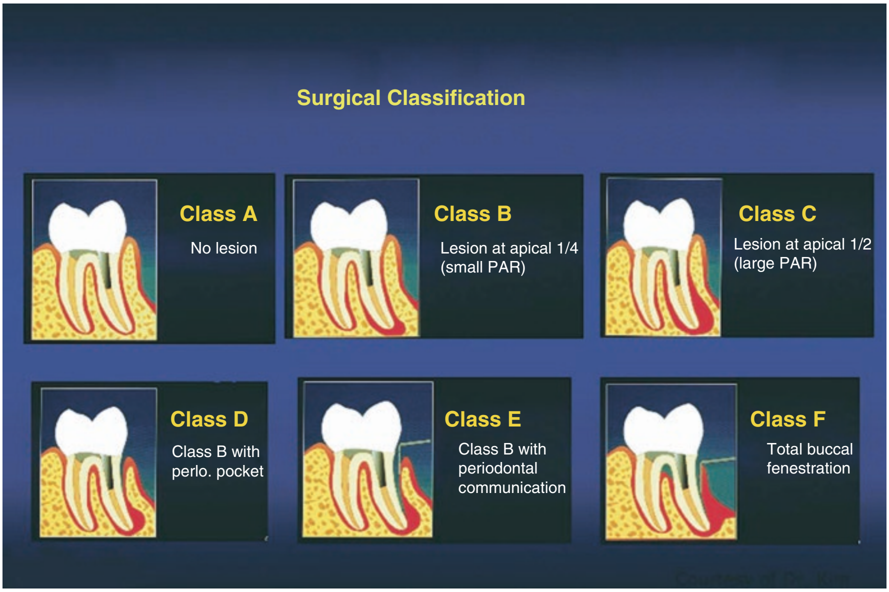

Fig. 15.10 Classification system to help predict prognosis for endodontic microsurgery in teeth with uncomplicated endo only lesions compared to teeth with varying degrees of concurrent periodontal involvement. This classification approach is also useful in determining which teeth will benefit from grafting and/or GTR. Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. J Endod 2006;32:601–23

reasonable option for some patients, especially if location of the sinus would require a sinus lift graft.

15.9 Conclusions

When a combined endo-perio lesion is identified, the treatment plan and sequence of treatment require careful consideration and can often benefit from a multidisciplinary approach. Generally, a periodontal consultation is recommended to establish prognosis from a periodontal standpoint. That is, assuming root canal treatment can be predictably performed and the tooth is deemed restorable, will the remaining periodontal issues be manageable? If the answer is no, then extraction is the best option. Assuming the periodontal prognosis is favorable, then nonsurgical root canal treatment or endodontic microsurgery is typically the first step, in conjunction with or followed by definitive periodontal therapy as needed [7, 30]. Elimination of microorganisms from the root canal system and properly sealing of the canal space prior to periodontal therapy (including scaling, root planning, and bone graft/guided tissue regeneration) is important to help ensure a favorable periodontal outcome. Following initial endodontic therapy, treatment results should be evaluated in 2–3 months to determine if additional periodontal treatment will be required [7].

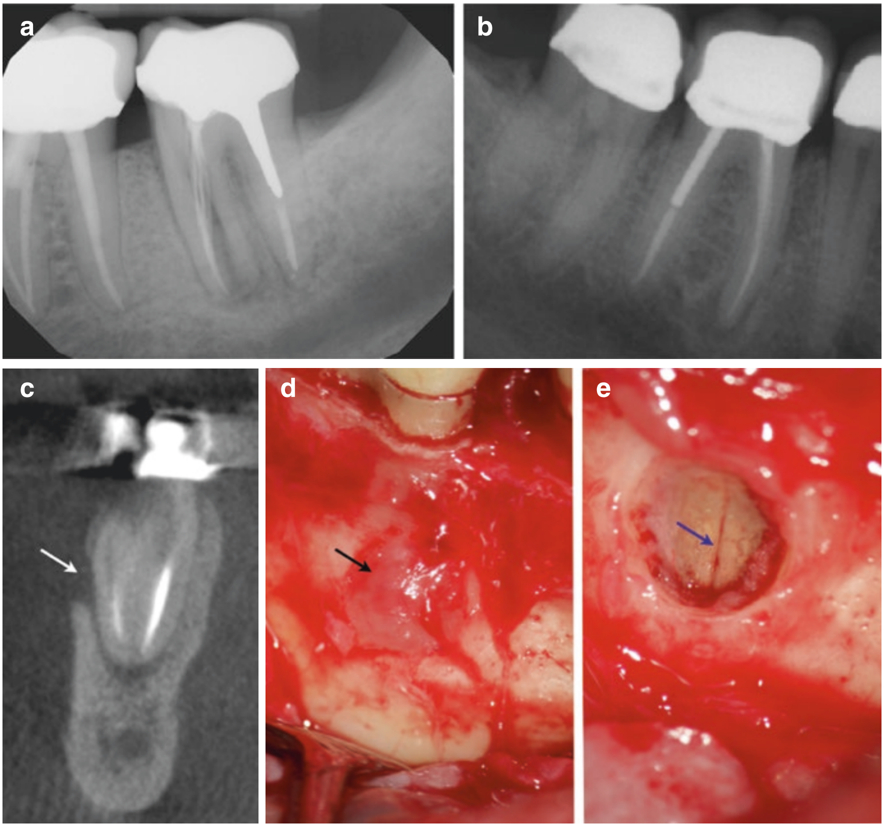

Fig. 15.11 (**a**) Image demonstrating an obvious example of a vertical root fracture in the mesial root of previously treated tooth #18. In the early stages of incomplete root fracture, the appearance is not as obvious and can often present a diagnostic challenge. (**b**) Example of an endodontically treated #30 that developed a mid-root vertical fracture in the mesial root approximately 7 years after apparently adequate initial RCT. Although all periodontal probings were WNL, the coronal CBCT view of the mesial root shows a buccal bony dehiscence (**c**—white arrow). After surgical flap elevation, granulation tissue over the mid-root buccal surface of the mesial root was identified and curetted (**d**—black arrow). The vertical root fracture was then directly visualized (**e**—blue arrow). Extraction was the treatment option of choice for both of these teeth although it should be noted that hemisection would also have been an option (Reference [9], Fayad MI, Johnson BR. 2016)

Although complete healing of an endo-perio defect typically takes much longer than 3 months, there should be evidence of initial healing at 3 months (e.g., resolution of a sinus tract or deep isolated periodontal pocket).

Multidisciplinary consultation and collaboration among dental specialists is particularly relevant in view of the finding that dental specialty status may have a significant influence on the recommended treatment plan [31]. When presented with the same clinical scenario, there was a wide divergence of opinion regarding the ideal treatment plan among different dental specialists. Even for teeth with a

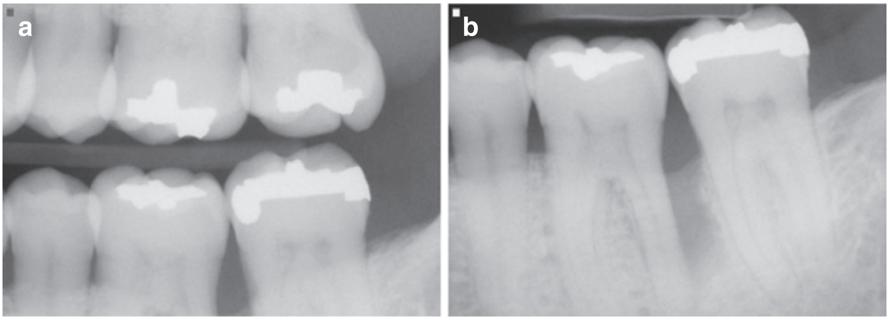

Fig. 15.12 Tooth #19 is an example of a minimally restored tooth with no obvious explanation for a diagnosis of pulp necrosis and deep vertical periodontal defect on the distal. (**a**) The patient acknowledged bruxism and a long history of intermittent biting stress sensitivity on the mandibular left side. Approximately 2 years prior to these radiographs, the problem was initially diagnosed as an isolated periodontal defect and treated with surgical pocket debridement, deep scaling, and bone graft/GTR. (**b**) Since the true source of the lesion was pulp necrosis secondary to incomplete vertical root fracture, the lesion recurred. Note also the appearance of diffuse calcifications in the pulp chamber, which is suggestive of long-term low grade chronic inflammation occurring prior to pulp necrosis

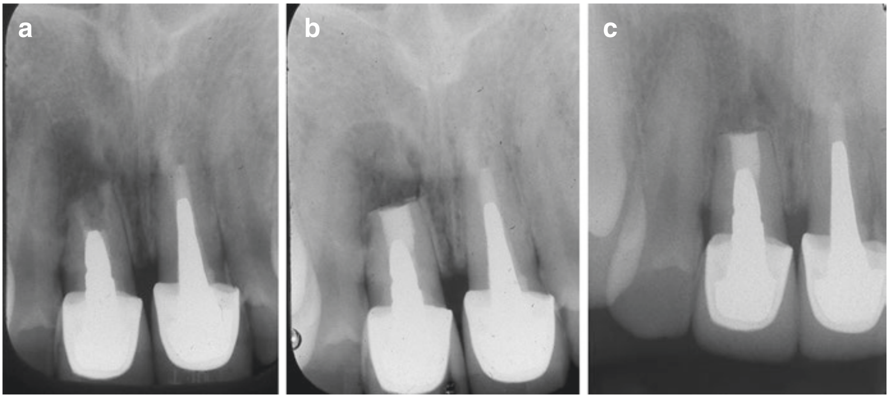

Fig. 15.13 A healthy 23-year-old male presented with a draining sinus tract associated with tooth #8 (**a**). Periodontal probings were WNL and the tooth exhibited class 2 mobility. The radiographic appearance is suggestive of previous surgical treatment but no evidence of a root-end filling material. Extraction and implant placement was recommended, but financial concerns prevented the patient from accepting this treatment option. An alternative option of endodontic microsurgery, with questionable prognosis, was presented and accepted. Endodontic microsurgery with minimal root-end resection and mineral trioxide aggregate (MTA) root-end filling was performed (**b**). (**c**) 6-month posttreatment evaluation radiograph and demonstrates good initial healing and bone regeneration. Mobility was reduced to class 1 (Case courtesy of Dr. Shawn Velez)

questionable long-term prognosis, nonsurgical or surgical endodontic therapy may allow for regeneration of bone and ultimately an improved site for a future implant (Figs. 15.13 and 15.14) [32]. Giannobile and Lang remind us of dentistry's long history of success in tooth maintenance and suggest that an unfortunate trend

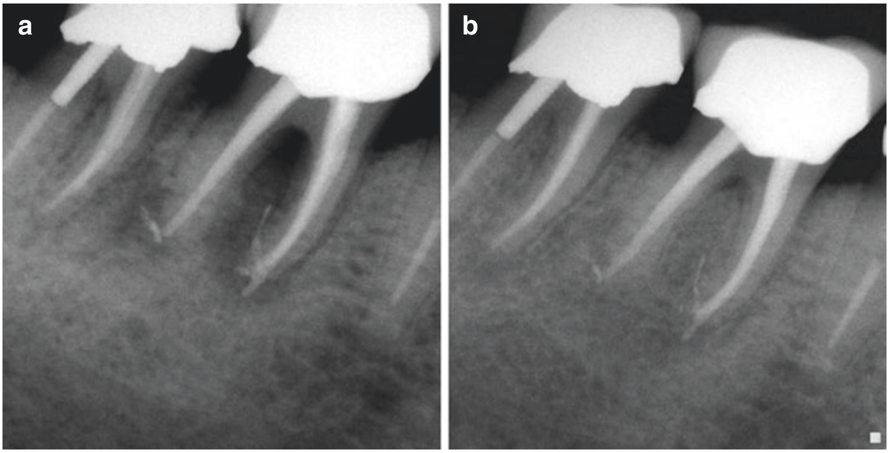

Fig. 15.14 (**a**) Immediate post-RCT radiograph of tooth #30. Prognosis was questionable due to extensive bone loss and class 2 mobility. (**b**) 12-month posttreatment evaluation radiograph demonstrating good initial healing. Mobility was reduced and periodontal probings were WNL

observed in the past two decades has been the reduced emphasis on preservation of the natural dentition, even though periodontally compromised teeth may still have a longevity that surpasses that of the average implant [33].

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