the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com
Volume 6 Number 1 February 15, 2005 Winter Issue

The Subepithelial Connective Tissue Graft: Part 1. Patient Selection and Surgical Techniques

Constance L. Sedon, DMD, MS; Lawrence G. Breault, DMD, MS;
Lemuel L. Covington, DMD; Barry G. Bishop, DDS

Abstract

Periodontal mucogingival techniques continually evolve. This provides the patient more treatment alternatives for common problems such as gingival recession. General practitioners should be familiar with these techniques in order to identify patients who might benefit from them. Currently, subepithelial connective tissue grafts (SCTG) remain the most reliable techniques used to cover denuded root surfaces. This paper reviews patient selection and the numerous surgical approaches for subepithelial connective tissue grafting.

Keywords: Connective tissue graft, root coverage, gingival recession, periodontal plastic surgery

Citation: Sedon CL, Breault LG, Covington LL, Bishop BG. The Subepithelial Connective Tissue Graft: Part I. Patient Selection and Surgical Techniques. J Contemp Dent Pract 2005 February;(6)1:146-162.

Introduction

As dental patients become more enlightened consumers, dentistry is challenged to develop improved techniques to meet the demands of this growing population. Specifically, periodontal defects such as root recession are becoming a greater concern for patients. Loss of gingival tissue can contribute to root sensitivity, unaesthetic appearance, unnatural restorative contours, cemental erosion, and possibly root caries. Fortunately for the progressive dental practice, periodontal plastic surgery techniques have evolved to predictably cover denuded root surfaces.

In 1963 Bjorn pioneered the free gingival graft (FGG), one of the first soft tissue techniques, in Europe.[1] The following year King and Pennel introduced it to the United States.[2] This technique was developed to augment attached keratinized tissue by transplanting a graft from the palate to the gingiva. Miller et al. expanded on the technique and successfully used FGGs for root coverage.[3, 4] However, the FGG is highly unpredictable for covering denuded roots[5], tends to produce unacceptable gingival color matches (Figure 1), and can heal with a "keloid" appearance.

Historically, a variety of pedicle flaps that use adjacent keratinized tissue to cover gingival defects have been developed. In 1956 Grupe and Warren introduced the lateral pedicle flap (LPF).[6] (Figures 2-4) Cohen and Ross proposed the double papilla flap in 1968.[7]

Unfortunately, if sufficient adjacent keratinized tissues do not exist, these techniques are unsuitable. In 1965 Harvey popularized the combination of a FGG, to increase the amount of attached tissue, followed by a coronally positioned flap (CPF).[8] However, this entails additional surgery, patient treatment time, and expense. Possible disadvantages of these techniques are recession and bone loss at the donor site and early graft retraction, resulting in partial root exposure.[9] Additionally, they have limited applications, working best for narrow defects only.

The advent of the subepithelial connective tissue graft (SCTG), as described by Langer and Langer with modification by others, predictably increased root coverage of Miller Class I and II recessions to more than 90%.[10, 11, 12, 13, 14] Due to superior

Figure 1. Poor gingival color match with classic Free Gingival Graft.

Figure 2. Lateral Pedicle Flap outline.

Figure 3. Flap sutured.

Figure 4. Four-week healing.

esthetics and the consistent results achieved with SCTG, the use of FGGs and pedicle flaps for root coverage has dramatically declined. The SCTG combines a connective tissue graft (CTG) with an overlying pedicle flap that provides the added blood supply needed to maintain the graft.[9]

In an attempt to reduce the morbidity associated with a donor site and produce true periodontal regeneration, Tinti and Vincenzi were the first to apply the principles of guided tissue regeneration (GTR) to root coverage.[15] (Figures 5 and 6) In theory, membranes placed over denuded root surfaces inhibit epithelial growth allowing bone, connective tissue, and cells of the periodontal ligament to preferentially proliferate on the root surface. Although very promising, with root coverage comparable to SCTGs, GTR is highly technique sensitive and time consuming. Additionally, the long-term stability of GTR induced root coverage has come into question.[16]

Figure 5. Resorbable GTR barrier utilized for root coverage.

Figure 6. Three-month healing.

The purpose of this paper is to review patient evaluation and preparation, as well as the surgical techniques of the subepithelial connective tissue graft, the most consistently predictable method of root coverage to date.

Patient Evaluation and Preparation

Evaluation of a gingival defect prior to surgery is critical to accurately inform the patient regarding the expected outcome. Assessing the amount of root coverage that can be achieved requires evaluation of the height of the interproximal tissues, the Miller's classification of the recession, and width of the defect.

It is beneficial to classify the interproximal papilla using the system developed by Nordland and Tarnow because root coverage is highly dependent on these tissues. The classification is as follows:

- Normal: Papilla fills the entire gingival embrasure. Complete root coverage is anticipated.
- Class I: The crest of the papilla is located between the contact point and the most coronal extent of the interproximal cementoenamel junction (CEJ). Complete to partial root coverage is anticipated.
- Class II: The crest of the papilla is at or apical to the interproximal CEJ but coronal to the facial CEJ. Only partial root coverage is anticipated.
- Class III: Crest of the papilla is at or apical to the facial CEJ. No root coverage is anticipated.[17] If the interproximal tissues are adequate, the next consideration is the Miller's classification of the recession.

Although the Miller's classification is a predictor for root coverage when FGGs are the treatment modality, it is also useful for CTGs. The classification is as follows:

- Class I: Marginal tissue recession that does not extend to the mucogingival junction. The interproximal bone and soft tissues are unaffected. Complete root coverage is anticipated.
- Class II: Marginal tissue recession extends to or beyond the mucogingival junction. The interproximal bone and soft tissues are unaffected. Complete root coverage is anticipated.
- Class III: Marginal tissue recession extends to or beyond the mucogingival junction. Bone or soft tissue is lost interproximally or teeth are malpositioned. Only partial root coverage is anticipated.
- Class IV: Marginal tissue recession extends to or beyond the mucogingival junction. Bone or soft tissue loss interproximally and/or malpositioning of the teeth is so severe, no root coverage is anticipated.[18]

Another consideration is the width of the defect. Allen found that width is inversely proportional to the amount of root coverage that can be achieved.[19] Thus, there is a higher probability of complete root coverage if the denuded area is narrow.

If autogenous connective tissue is to be used, the palatal dimensions must also be assessed. Adequate palatal donor tissue exists if bone sounding reveals a depth of at least 3 mm.[20] Additionally, the height of the palatal vault should be considered. Generally, the widest grafts can be taken from the patient with a large U-shaped vault because the clinician can easily avoid the greater and lesser palatine nerves and vessels.

Patient preparation is minimal. Aberrant frenal attachments in the area of the recession should be eliminated 4-6 weeks prior to grafting. Otherwise, incisions made during the frenectomy could compromise blood flow to the flap and, thus, the graft success.[21] Langer and Langer also suggest removing cervical restorations to allow thorough scaling and root planing during the procedure.[22]

Recipient Site Preparation

Graft survival depends heavily on the maintenance of blood supply. Preparation of the recipient site must maximize blood supply to prevent graft necrosis, while minimizing mobility to prevent tearing of the delicate blood vessels that invade the graft during healing. In an attempt to improve blood supply to the graft, various bilaminar techniques have been developed. Langer and Calagna were the first to propose a SCTG for ridge augmentation. By combining a connective tissue graft, much like the FGG, and a pedicle flap, the SCTG takes advantage of the blood supply from the connective tissue, periosteum, as well as the overlying flap.[23] Langer and Langer later modified this technique for root coverage, especially for use in areas with multiple recessions, such as those in the maxilla where coverage is most difficult. The authors advocated a partial thickness flap with vertical releasing incisions 1⁄2 to 1 tooth wider than the recession, preserving the interproximal papilla. The flap is dissected below the mucogingival junction so it can be positioned coronally to cover the entire graft. (Figures 7-10)

Figure 7. Langer flap design.

Figure 8. Clinical outline.

Figure 9. CTG sutured.

Figure 10. Six-month healing.

Figure 11. Bruno flap design.

Figure 12. Flap prepared, root etched with TCN.

Figure 13. CTG placed.

Figure 14. Three-month healing.

The exposed root is planed and flattened, if necessary. Langer and Langer suggested root conditioners such as citric acid and tetracycline on endodontically treated teeth or roots with a glass-like finish. The connective tissue graft is then sutured to the recipient site followed by the overlying flap.[9, 22] Bruno modified this technique by eliminating the vertical incisions and introducing sulcular incisions on adjacent teeth.[24] (Figures 11-14)

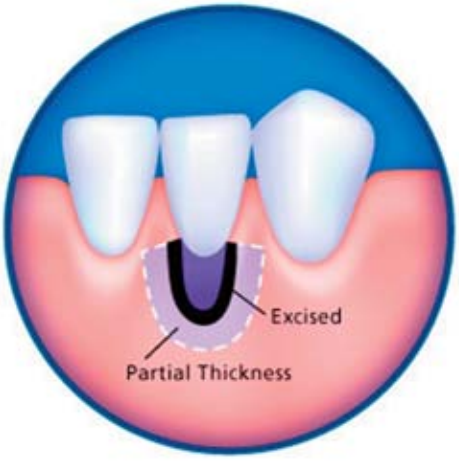

Figure 15. Raetzke flap design.

Figure 16. CTG placed.

Figure 17. Three-month healing.

Raetzke suggested an "envelope" technique for isolated root coverage. The sulcular epithelium of the affected tooth is removed and the exposed root is thoroughly scaled and planed followed by treatment with citric acid. A partial thickness envelope is created in the tissues surrounding the recession. (Figures 15-17) A graft twice the width of the area of recession is placed into the envelope, completely covering the exposed root. Finger pressure is then applied to stabilize the graft until hemostasis is achieved. Tissue adhesive is used to keep the graft in place rather than sutures.[25]

The key to the envelope flap is that it preserves the lateral and apical blood supply of the flap by eliminating vertical release incisions. Although traditionally employed in soft tissue grafting procedures, the effect of vertical incisions on graft survival is mixed. Mormann and colleagues demonstrated that the gingival tissues receive the majority of their blood supply from an apical direction.[26] Therefore, vertical releasing incisions should not compromise this blood supply. However, Tarnow demonstrated the lateral blood supply was more significant than previously assumed when tissues survived after severing the apicocoronal blood supply.[27] This suggests vertical releases may compromise the lateral blood supply. Thus, the advantage of the envelope flap is preservation of the lateral blood supply.

Caffessee et al. studied the healing of FGG when placed on bone or periosteum and found resorption of the denuded bone delayed vascular proliferation.[28] Assuming the same would be true for a SCTG, partial thickness flaps had always been advocated unless the tissue was thin and friable. Nelson, however, successfully included full thickness flaps in his preparations. He developed a grafting procedure to completely cover the portion of the graft placed over the exposed root. Full thickness pedicle flaps are elevated on either side of the defective area with care not to jeopardize the interdental papilla or periodontal coverage of adjacent teeth. Two vertical incisions are made from the distal crest of the bordering interdental papillas to the base of the vestibule. Horizontal incisions then connect the vertical incisions to sulcular incisions made on the exposed root. (Figures 18-20) The pedicle flaps are then sutured together and used to cover the CTG with a sling suture.[10]

Allen presented the supraperiosteal envelope for use in multiple adjacent areas of recession. This technique allows conservation of the existing gingiva. A partial-thickness supraperiosteal

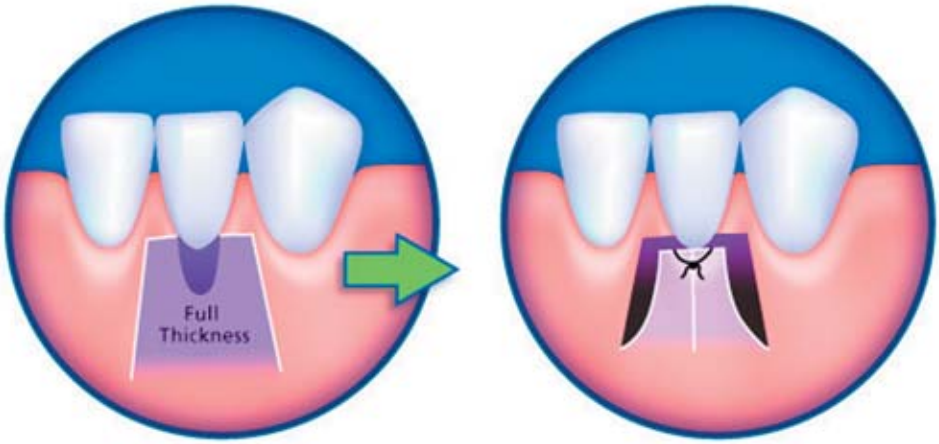

Figure 18. Nelson flap design.

Figure 19. Flap sutured.

Figure 20. Two-month healing.

envelope is created 3-5 mm laterally and apically to multiple adjacent defects. A tunnel is created apical to the papilla, which keeps the graft in tight contact with the denuded root. The ends of the graft are beveled and a suture is placed in one end to help guide the graft through the tunnel. Mattress sutures secure the graft in place.[21]

Blanes and Allen combined a tunnel with lateral pedicle flaps to treat adjacent areas of recession. Double split thickness lateral pedicle flaps are elevated at the level of the CEJ at the proximal extent of the recession and extended apically 10-12 mm. A tunnel is created under the tissue remaining between the two pedicle flaps. The graft is placed through the tunnel and sutured in place. The pedicle flaps are then sutured to the tunnel.[29] (Figures 21-24)

Santarelli and colleagues modified the envelope preparation to include a vertical incision made from the distal corner of the base of the papilla to beyond the mucogingival junction. This incision simply aids in placement of the graft.[30]

In 2003 Tözüm altered Allen's technique by creating a partial thickness envelope lateral to the recession and a full thickness envelope apical to the recession. (Figure 25) The author suggests full thickness flaps maintain the integrity of critical gingival blood vessels by securing them within the flap.[31] Ultimately, the type of surgical technique utilized must be based on patient variables and clinician skill.

Root Treatments

Citric acid, tetracycline, and Enamel Matrix Derivative (EMD) are applied to root surfaces in an attempt to improve soft tissue attachment. Studies reporting on the effectiveness of these conditioners are conflicting and their value is still unproven. Citric acid applied to the root is intended to remove

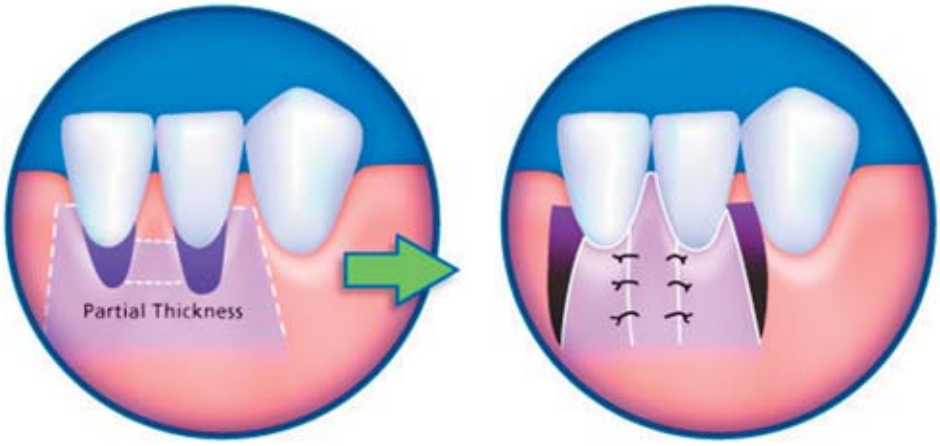

Figure 21. Blanes and Allen tunnel flap design.

Figure 22. Modified tunnel preparation.

Figure 23. CTG placed.

Figure 24. Six-month healing.

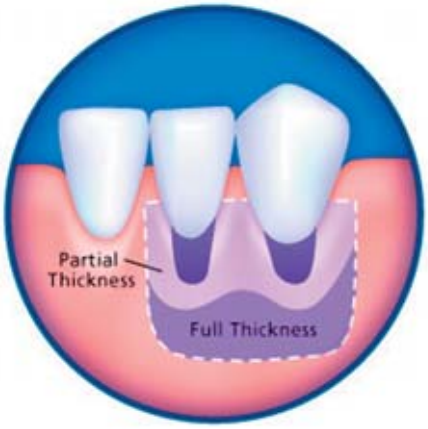

Figure 25. Full/partial thickness flap design.

microbes, their by-products, and the smear layer while exposing the collagen matrix and biologically active proteins and growth factors on the root.[32] (Figure 26) Register demonstrated citric acid accelerated soft tissue attachment to the root.[33] Several other histological studies showed citric acid treatment favors development of connective tissue attachment as apposed to long junctional epithelium.[34, 35]

Conversely, other studies indicate citric acid does not have any affect on the graft. Histologic studies on 3 beagle dogs by Gottlow and colleagues revealed new attachment formed with or without citric acid treatment.[36] Caffesse et al. and Bouchard et al. found it had no effect on root coverage.[37, 38] However, since it has never been shown to be detrimental, many clinicians continue to use citric acid. Unfortunately, a universal application procedure has never been adopted. Various concentrations of citric acid have been burnished onto root surfaces with cotton pled-

Figure 26. Citric acid root etching.

Figure 28. EMD kit.

gets for 1 to 5 minutes, after which the roots are thoroughly rinsed with water. Additionally, Miller warned citric acid should be applied before incisions are made because the acid can cause coagulation, potentially compromising blood supply to the graft.[39]

Initially clinicians were very optimistic about tetracycline as a root conditioner due to its reported multitude of effects. (Figure 27) These include inhibition of microbes[40] and collagenases[41], decreased bone resorption[42], enhancement of attachment gain[43], increased collagen formation[44], and increased binding of fibronectin to dentin.[45]

Isik and colleagues reported tetracycline demonstrated a statistically significant opening of the dentinal tubules.[46] Unfortunately, tetracycline has fallen short of these initial expectations. Labahn et al. demonstrated citric acid induced larger dentinal tubule orifice diameters and deeper penetration than tetracycline.[47] Sterrett and colleagues reported tetracycline was much less effective at demineralizing dentin than 30% citric acid.[48] Additionally, using citric acid as the control, Bouchard et al. demonstrated

Figure 27. Tetracycline root etch.

tetracycline and citric acid had comparable effects on subepithelial connective tissue grafts.[49] Erdinc et al. reported tetracycline conditioning of root surfaces during flap surgery had no clinically detectable benefits.[50] Zaman et al. demonstrated citric acid and EDTA, but not tetracycline, enhanced periodontal ligament cell attachment to root surfaces.[51] Histologic studies are needed to evaluate the type of healing produced by citric acid or tetracycline treatments to determine if they are beneficial procedures.

A different type of root treatment, EMD (Emdogain, Biora Company, Chicago, Il) is a complex of proteins consisting predominantly of amelogenins. (Figure 28) Amelogenins are secreted by ameloblasts during enamel development[52] and are believed to be involved in cementogenesis.[53] Using tissue cell cultures, Hoang et al. demonstrated EMD selectively effected periodontal cell proliferation and migration.[54] It is believed PDL cells can differentiate into osteoblast-like and cementoblast-like cells that can contribute to periodontal regeneration.[55, 56]

Clinically, the results using EMD have been mixed. In split mouth studies, Modica et al. and Hagewald et al. reported EMD did not improve

the outcome of coronally positioned flaps for treatment of recession.[57, 58] On the other hand, Berlucchi and colleagues combined EMD with a CPF or SCTG and found the percentage of root coverage comparable or superior to other techniques.[59] In a split mouth study McGuire and Nunn compared the use of EMD under a CPF with a CTG under a CPF and found no difference in the amount of root coverage achieved. If the use of EMD could eliminate the need for donor tissue, it would significantly decrease the morbidity associated with periodontal plastic surgery. More research is required in this area.[60]

Several studies have examined the histologic healing associated with EMD treatment. Heijl was able to generate bone and cementum in an artificially created dehiscence on a mandibular incisor using EMD.[61] Rasperini et al. examined the histologic healing of a mandibular canine treated with EMD and a SCTG. The results demonstrated formation of woven bone and connective tissue fibers anchored in new cementum.[62] However, in Carnio and colleagues' histologic studies of 4 teeth treated by CTG and EMD periodontal regeneration occurred in few regions. The majority of healing was connective tissue adhesion to the root with minimal junctional epithelium.[63] These conflicting results suggest further studies are necessary to determine the actual mechanism of action of EMD to establish its parameters of use and the type of wound healing induced by EMD.

Donor Tissue

Autogenous connective tissue can be obtained from the palate, maxillary tuberosity, or edentulous ridges. The palate is the most common donor site, however, its dimensions can affect the amount of connective tissue that can be harvested. The thickest tissue is found from the mesial line angle of the palatal root of the first molar to the distal line angle of the canine. Care is taken to avoid the greater and lesser palatine nerves and vessels that are anywhere from 7 to 17 mm from the CEJ of the maxillary premolars depending on the height of the palatal vault. This neurovascular bundle courses through a bony groove anterior to the foramen from which it emerges. Once the groove is palpated, a reference line can be drawn on the palate indicating the approximate location of the nerve and vessels. Incisions should be limited to the distal of the canine to avoid the greater palatine nerve and artery as they drop closer to the CEJs in the anterior area[64] and remain at least 2 mm from the palatal gingival margin.[65] According to Reiser and colleagues, very few instances of permanent anesthesia, paresthesia, or serious hemorrhage have occurred.[64] When anesthetizing the palate, avoid infiltration into the graft tissue; otherwise, unwanted vasoconstrictor might be transferred to the recipient site.[66] Every effort should be made to place the graft within 60 seconds of harvesting.[20]

Figure 29. Palatal trap door CTG harvest.

There are several flap designs for harvesting the graft. Edel was the first to describe the trap door technique in which no epithelium is removed from the palate. (Figure 29) This technique utilizes the free gingival graft knife with the cutting shoe reversed so the instrument can be pushed distally along the palate to elevate a partial thickness trap door. Then, with the FGG knife in proper configuration, a connective tissue flap is removed from underneath the trap door by pulling the knife mesially. A releasing incision at the mesial edge releases the graft.[67]

The parallel incision method was developed by Langer and Langer.[9] Incisions are made 10-12 mm deep into the palate with vertical releases at the mesial and distal extent of the incision. An incision at the base of the connective tissue between the parallel incisions frees the graft from the palatal bone. The technique can be simplified by utilizing the Harris Double Blade Graft Knife (Harris Double Blade Graft Knife, H & H Company, Ontario, CA) an instrument with 2 blades mounted 1.5 mm apart. (Figure 30) A limitation of this double bladed instrument is the inflexibility of the blades in areas of anatomic

variation such as tori, shallow palates, and thin tissue.[66] Raetzke employed a similar technique with incisions that intersected deep within the palate, just shy of the bone, producing a wedge of connective tissue.[25]

Harris compared trap door and parallel incision harvesting techniques to find that both resulted in significant root coverage. However, if the trap door sloughed, it caused considerable morbidity.[20]

Hurzeler suggested a single incision technique. Initially, the incision is made with the blade 90 degrees to the palatal bone, after which the blade is angled from 135 to 180 degrees to undermine the palatal tissues toward the midline. The connective tissue is removed by making incisions to bone on all sides of the uncovered connective tissue. Clearly, the advantage of this technique is the simplified closure of the wound, however, the authors admit that visibility can be compromised.[66]

Hirsch obtained graft tissue from the maxillary tuberosity during pocket reduction therapy. The tissue was excised using a distal wedge by creating an inverse full flap on the buccal and a double flap on the palate. The authors de-epithelialized and opened the graft "like a book" before placement. The procedure provided enough tissue to cover several exposed roots and eliminated an additional surgical site.[12]

The decision to maintain or remove the epithelial collar of the graft should be based on the extent of keratinized gingiva at the recipient site. Bouchard compared the healing of 2 surgical groups. In one group the epithelium was maintained and exposed at the graft site. In the second group, the root was treated with citric acid, and the de-epithelialized graft was covered completely with a coronally positioned flap. Both achieved comparable root coverage with two differences noted. The epithelial collar was associated with significantly greater increases in keratinized tissue, however, more aesthetic results were achieved without it.[38] Additionally, the potential exists for the development of a gingival surgical cyst when the epithelium is left intact. Breault et al. and Harris reported the occurrence of cysts after a SCTG in which the epithelium was retained on the graft.[68, 69]

Figure 30. Harris knife used for CTG harvest.

Figure 31. ADMA dermal graft.

Figure 32. Four-mouth healing.

An alternative to the autogenous graft is the acellular dermal matrix allograft (ADMA). (Figures 31 and 32) ADMA is human dermis. It is decellularized and treated to prevent disease transmission, leaving only a scaffold of Type I collagen. The benefit of ADMA is the elimination of the morbidity associated with graft removal from an oral site. Several authors have compared autogenous CTG and ADMA for the treatment of recession to find that both can be used to successfully cover roots. Aichelmann-Reidy and colleagues observed ADMA produced more aesthetic results than autogenous palatal

tissue.[70] Over a 6-month period, Novaes et al. found the only difference was a faster increase in the amount of keratinized gingiva with the autogenous graft.[71] Tal et al., however, found a significantly greater gain in keratinized tissue with a CTG.[72] Paolantonio and colleagues also reported a CTG produced greater increases in keratinized tissue and healed faster.[73]

The type of cells that eventually populate the grafts may explain the variations in the keratinized tissue between the ADMA and autogenous grafts. In 1975 Karring and colleagues demonstrated keratinization is induced by the underlying connective tissue.[74] It can be assumed with non-vital ADMA, some of the cells that invade the collagen scaffold will not be keratin producing cells. On the other hand, the autogenous CTG is entirely comprised of cells able to induce keratinization. Thus, the autogenous grafts should consistently produce keratin, while only the portions of the ADMA grafts populated by keratin producing cells will induce keratinization.[73]

Summary

It is critical for the general practitioner to be knowledgeable about periodontal plastic surgery techniques in order to identify those patients who might benefit from them. This article reviewed a reliable technique for covering denuded root surfaces, the subepithelial connective tissue graft. Specifically, patient evaluation and preparation and the various surgical approaches for recipient site preparation and graft harvesting.

References

1. Bjorn H. Free transplantation of gingival propria. Sven Tandlak Tidskr 1963; 22: 684.
2. King K, Pennel BM. Evaluation of attempts to increase the width of attached gingiva. Presented at meeting of Philadelphia Society Periodontology, April 1964.
3. Miller PD. Root coverage using a free soft tissue autograft following citric acid application. Part III. A successful and predictable procedure in areas of deep-wide recession. Int J Periodontics Restorative Dent 1985;5(2):15-37.
4. Holbrook T, Ochsenbein C. Complete coverage of denuded root surfaces with a one-stage gingival graft. Int J Periodontics Restorative Dent 1983:3(3):9-27.
5. Jahnke PV, Sandifer JB, Gher ME, et. al. Thick free gingival and connective tissue autografts for root coverage. J Periodontol. 1993 Apr; 64 (4): 315-22.
6. Grupe HE, Warren, RF. Repair of gingival defects by a sliding flap operation. J Periodontol 1956;27: 92-95.
7. Cohen DW, Ross SE. The double papillae repositioned flap in periodontal therapy. J Periodontol 1968;39:65-70.
8. Harvey P. Management of advanced periodontitis. Part I Preliminary report of a method of surgical reconstruction. N.Z. Dent. J., 61:180, 1965
9. Langer B, Langer L. Subepithelial connective tissue graft technique for root coverage. J Periodontol. 1985 Dec;56(12):715-20.
10. Nelson SW. The subpedicle connective tissue graft. A bilaminar reconstructive procedure for the coverage of denuded root surfaces. J Periodontol. 1987 Feb;58(2):95-102.
11. Cordioli G, Mortarino C, Chierico A, et. al. Comparison of 2 techniques of subepithelial connective tissue graft in the treatment of gingival recessions. J Periodontol. 2001 Nov;72(11):1470-6.
12. Hirsch A, Attal U, Chai E, et. al. Root coverage and pocket reduction as combined surgical procedures. J Periodontol. 2001 Nov;72(11):1572-9.
13. Harris RJ. Connective tissue grafts combined with either double pedicle grafts or coronally positioned pedicle grafts: results of 266 consecutively treated defects in 200 patients. Int J Periodontics Restorative Dent. 2002 Oct;22(5):463-71.

14. Tozum TF, Dini FM. Treatment of adjacent gingival recessions with subepithelial connective tissue grafts and the modified tunnel technique. Quintessence Int. 2003 Jan;34(1):7-13.
15. Tinti C, Vincenzi GP. The treatment of gingival recession with “guided tissue regeneration” procedures by means of Gore-Tex membranes. Quintessence Int 1990;6: 465-468.
16. Harris RJ. GTR for root coverage: a long-term follow-up. Int J Periodontics Restorative Dent. 2002 Feb;22(1):55-61.
17. Nordland, WP, Tarnow, DP. A classification system for loss of papillary height. J Periodontol 1998 Oct; 69 (10): 1124-1126.
18. Miller PD Jr. A classification of marginal tissue recession. Int J Periodontics Restorative Dent. 1985;5(2):8-13.
19. Allen AL. Use of the supraperiosteal envelope in soft tissue grafting for root coverage. II. Clinical results. Int J Periodontics Restorative Dent. 1994 Aug;14(4):302-15.
20. Harris RJ. A comparison of two techniques for obtaining a connective tissue graft from the palate. Int J Periodontics Restorative Dent. 1997 Jun;17(3):260-71.
21. Allen AL. Use of the supraperiosteal envelope in soft tissue grafting for root coverage. I. Rationale and technique. Int J Periodontics Restorative Dent. 1994 Jun;14(3):216-27.
22. Langer L, Langer B. The subepithelial connective tissue graft for treatment of gingival recession. Dent Clin North Am. 1993 Apr;37(2):243-64.>
23. Langer B, Calagna L. The subepithelial connective tissue graft. J Prosthet Dent. 1980 Oct;44(4): 363-7.
24. Bruno, JF. Connective tissue graft technique assuring wide root coverage. Int J Periodontics Restorative Dent 1994; 14: 127-37.
25. Raetzke PB. Covering localized areas of root exposure employing the “envelope” technique. J Periodontol. 1985 Jul;56(7):397-402.
26. Mormann W, Meier C, Firestone A. Gingival blood circulation after experimental wounds in man. J Clin Periodontol. 1979 Dec;6(6):417-24.
27. Tarnow DP. Semilunar coronally repositioned flap. J Clin Periodontol. 1986 Mar;13(3):182-5.
28. Caffesse RG, Burgett FG, Nasjleti CE, et. al. Healing of free gingival grafts with and without periosteum. Part I. Histologic evaluation. J Periodontol. 1979 Nov;50(11):586-94.
29. Blanes RJ, Allen EP. The bilateral pedicle flap-tunnel technique: a new approach to cover connective tissue grafts. Int J Periodontics Restorative Dent. 1999 Oct;19(5):471-9.
30. Santarelli GA, Ciancaglini R, Campanari F, et. al. Connective tissue grafting employing the tunnel technique: a case report of complete root coverage in the anterior maxilla. Int J Periodontics Restorative Dent. 2001 Feb;21(1):77-83.
31. Tozum TF. A promising periodontal procedure for the treatment of gingival recession defects. Journal of the Canadian Dental Association. 2003 Mar: 69 (3): 155-159.
32. Lowenguth RA, Blieden TM. Periodontal regeneration: root surface demineralization. Periodontol 2000. 1993 Feb;1:54-68.
33. Register AA, Burdick FA. Accelerated reattachment with cementogenesis to dentin, demineralized in situ. II. Defect repair. J Periodontol. 1976 Sep;47(9):497-505.
34. Woodyard SG, Snyder AJ, Henley G, et. al. A histometric evaluation of the effect of citric acid preparation upon healing of coronally positioned flaps in nonhuman primates. J Periodontol. 1984 Apr;55(4):203-12.
35. Common J, McFall WT Jr. The effects of citric acid on attachment of laterally positioned flaps. J Periodontol. 1983 Jan;54(1):9-18.
36. Gottlow J, Nyman S, Karring T, et. al. Treatment of localized gingival recessions with coronally displaced flaps and citric acid. An experimental study in the dog. J Clin Periodontol. 1986 Jan;13(1): 57-63.
37. Caffesse RG, De LaRosa M, Garza M, et. al. Citric acid demineralization and subepithelial connective tissue grafts. J Periodontol. 2000 Apr;71(4):568-72.
38. Bouchard P, Etienne D, Ouhayoun JP, et. al. Subepithelial connective tissue grafts in the treatment of gingival recessions. A comparative study of 2 procedures. J Periodontol. 1994 Oct;65(10):929-36.

39. Miller PD Jr. Root coverage using the free soft tissue autograft following citric acid application. II. Treatment of the carious root. Int J Periodontics Restorative Dent. 1983;3(5):38-51.
40. Genco RJ. Antibiotics in the treatment of human periodontal diseases. J Periodontol. 1981 Sep;52(9):545-58.
41. Ingman T, Sorsa T, Suomalainen K, et. al. Tetracycline inhibition and the cellular source of collagenase in gingivalcrevicular fluid in different periodontal diseases. A review article. J Periodontol. 1993 Feb;64(2):82-8.
42. Gomes BC, Golub LM, Ramamurthy NS. Tetracyclines inhibit parathyroid hormone-induced bone resorption in organculture. Experientia. 1984 Nov 15;40(11):1273-5.
43. Christersson LA, Norderyd OM, Puchalsky CS. Topical application of tetracycline-HCl in human periodontitis. J Clin Periodontol. 1993 Feb;20(2):88-95.
44. Sasaki T, Ramamurthy NS, Golub LM. Tetracycline administration increases collagen synthesis in osteoblasts of streptozotocin-induced diabetic rats: a quantitative autoradiographic study. Calcif Tissue Int. 1992 May;50(5):411-9.
45. Terranova VP, Franzetti LC, Hic S, et. al. A biochemical approach to periodontal regeneration: tetracycline treatment ofdentin promotes fibroblast adhesion and growth. J Periodontal Res. 1986 Jul;21(4):330-7.
46. Isik AG, Tarim B, Hafez AA, et. al. A comparative scanning electron microscopic study on the characteristics of demineralized dentin root surface using different tetracycline HCl concentrations and application times. J Periodontol. 2000 Feb;71(2):219-25.
47. Labahn R, Fahrenbach WH, Clark SM, et. al. Root dentin morphology after different modes of citric acid and tetracycline hydrochloride conditioning. J Periodontol. 1992 Apr;63(4):303-9.
48. Sterrett JD, Simmons J, Whitford G, et. al. Tetracycline demineralization of dentin: the effects of concentration and application time. J Clin Periodontol. 1997 Jul;24(7):457-63.
49. Bouchard P, Nilveus R, Etienne D. Clinical evaluation of tetracycline HCl conditioning in the treatment of gingival recessions. A comparative study. J Periodontol. 1997 Mar;68(3):262-9.
50. Erdinc M, Efeoglu A, Demirel K. Clinical evaluation of the effect of tetracycline hydrochloride root conditioning during flap surgery. Periodontal Clin Investig. 1995 Spring;17(1):6-9.
51. Zaman KU, Sugaya T, Hongo O, et. al. A study of attached and oriented human periodontal ligament cells to periodontally diseased cementum and dentin after demineralizing with neutral and low pH etching solution. J Periodontol. 2000 Jul;71(7):1094-9.
52. Slavkin HC. Towards a cellular and molecular understanding of periodontics. Cementogenesis revisited. J Periodontol. 1976 May;47(5):249-55.
53. Brookes SJ, Robinson C, Kirkham J, et. al. Biochemistry and molecular biology of amelogenin proteins of developing dental enamel. Arch Oral Biol. 1995 Jan;40(1):1-14.
54. Hoang AM, Oates TW, Cochran DL. In vitro wound healing responses to enamel matrix derivative. J Periodontol. 2000 Aug;71(8):1270-7.
55. Davidson D, McCulloch CA. Proliferative behavior of periodontal ligament cell populations. J Periodontal Res. 1986 Jul;21(4):414-28.
56. Mariotti A, Cochran DL. Characterization of fibroblasts derived from human periodontal ligament and gingiva. J Periodontol. 1990 Feb;61(2):103-11.
57. Modica F, Del Pizzo M, Roccuzzo M, et. al. Coronally advanced flap for the treatment of buccal gingival recessions with and without enamel matrix derivative. A split-mouth study. J Periodontol. 2000 Nov;71(11):1693-8.
58. Hagewald S, Spahr A, Rompola E, et. al. Comparative study of Emdogain and coronally advanced flap technique in the treatment of human gingival recessions. A prospective controlled clinical study. J Clin Periodontol. 2002 Jan;29(1):35-41.
59. Berlucchi I, Francetti L, Del Fabbro M, et. al. Enamel matrix proteins (Emdogain) in combination with coronally advanced flap or subepithelial connective tissue graft in the treatment of shallow gingival recessions. Int J Periodontics Restorative Dent. 2002 Dec;22(6):583-93.
60. McGuire MK, Nunn M. Evaluation of Human Recession Defects Treated with Coronally Advanced Flaps and Either Enamel Matrix Derivative or Connective Tissue. Part 1: Comparison of Clinical Parameters. J Periodontol 2003; 74: 1110-1125

61. Heijl L. Periodontal regeneration with enamel matrix derivative in one human experimental defect. A case report. J Clin Periodontol. 1997 Sep;24(9 Pt 2):693-6.
62. Rasperini G, Silvestri M, Schenk RK, et. al. Clinical and histologic evaluation of human gingival recession treated with a subepithelial connective tissue graft and enamel matrix derivative (Emdogain): a case report. Int J Periodontics Restorative Dent. 2000 Jun;20(3):269-75.
63. Carnio J, Camargo PM, Kenney EB, et. al. Histological evaluation of 4 cases of root coverage following a connective tissue graft combined with an enamel matrix derivative preparation. J Periodontol. 2002 Dec;73(12):1534-43.
64. Reiser GM, Bruno JF, Mahan PE, et. al. The subepithelial connective tissue graft palatal donor site: anatomic considerations for surgeons. Int J Periodontics Restorative Dent. 1996 Apr;16(2):130-7.
65. Studer SP, Allen EP, Rees TC, et. al. The thickness of masticatory mucosa in the human hard palate and tuberosity as potential donor sites for ridge augmentation procedures. J Periodontol. 1997 Feb;68(2):145-51.
66. Hurzeler MB, Weng D. A single-incision technique to harvest subepithelial connective tissue grafts from the palate. Int J Periodontics Restorative Dent. 1999 Jun;19(3):279-87.
67. Edel A. Clinical evaluation of free connective tissue grafts used to increase the width of keratinised gingiva. J Clin Periodontol. 1974;1(4):185-96.
68. Breault LG, Billman MA, Lewis DM. Report of a gingival “surgical cyst” developing secondarily to a subepithelial connective tissue graft. J Periodontol. 1997 Apr;68(4):392-5.
69. Harris RJ. Formation of a cyst-like area after a connective tissue graft for root coverage. J Periodontol. 2002 Mar;73(3):340-5.
70. Aichelmann-Reidy ME, Yukna RA, Evans GH, et. al. Clinical evaluation of acellular allograft dermis for the treatment of human gingival recession. J Periodontol. 2001 Aug;72(8):998-1005.
71. Novaes AB Jr, Grisi DC, Molina GO, et. al. Comparative 6-month clinical study of a subepithelial connective tissue graft and acellular dermal matrix graft for the treatment of gingival recession. J Periodontol. 2001 Nov;72(11):1477-84.
72. Tal H, Moses O, Zohar R, et. al. Root coverage of advanced gingival recession: a comparative study between acellular dermal matrix allograft and subepithelial connective tissue grafts. J Periodontol. 2002 Dec;73(12):1405-11.
73. Paolantonio M, Dolci M, Esposito P, et. al. Subpedicle acellular dermal matrix graft and autogenous connective tissue graft in the treatment of gingival recessions: a comparative 1-year clinical study. J Periodontol. 2002 Nov;73(11):1299-307.
74. Karring T, Lang NP, Loe H. The role of gingival connective tissue in determining epithelial differentiation. J Periodontal Res. 1975 Feb;10(1):1-11.

About the Authors

Constance L. Sedon, DMD, MS

Captain Sedon graduated from the Advanced General Dentistry Program (AGDP-1) at Fort Benning in 2003. She presently is assigned to the 561st Medical Company in Grafenwöhr, Federal Republic of Germany.

Lawrence G. Breault, DMD, MS

Dr. Breault currently serves as a Colonel in the United States Army and is a Diplomate of the American Board of Periodontology. He is the Periodontic mentor and Chief of Periodontics, U.S. Army Dental Activity, Fort Benning, GA.

Lemuel L. Covington, DMD

Colonel Covington is the Director of the Advanced General Dentistry Program at Fort Benning, Georgia.

Barry G. Bishop, DDS

Colonel Bishop is the Director of the AGDP-1 at Fort Benning, GA. He is a Master in the Academy of General Dentistry and a Diplomate of the American Board of General Dentistry.

Acknowledgment

The authors would like to thank the mentors and residents of the 2002-2003 U.S. Army AGDP-1 program at Fort Benning, GA for all their encouragement and support during the writing of this manuscript.

The authors would also express their appreciation to the following Periodontists for their contribution of clinical photos: Drs. Edward Fowler, Paul Francis, Harold Snyder, Charlene Czuszak, and George Tolson, IV.

Disclaimer

The opinions expressed in this article do not represent the views of the United States Department of Defense, the Department of the Army, or the United States Army Dental Corps. Use of any commercial products in this report does not imply endorsement by the U.S. Government.