Treatment of Gingival Recession Using a Collagen Membrane with or without the Use of Demineralized Freeze-Dried Bone Allograft for Space Maintenance

Kenneth M. Kimble,* Robert M. Eber,† Stephen Soehren,* Yu Shyr,‡ and Hom-Lay Wang†

Background: Studies utilizing collagen membranes for guided tissue regeneration (GTR)-based root coverage procedures have reported promising results. However, creating and maintaining space underneath the membrane remains a challenge. Therefore, the purpose of this clinical trial was to determine whether the addition of bone graft (i.e., demineralized freeze-dried bone allograft [DFDBA]) significantly affects the outcome of collagen membrane GTR-based root coverage procedures.

Methods: Twenty patients participated. One Miller's Class I or II recession defect per patient was treated with a collagen membrane covered by a coronally positioned flap. Half of the patients also had DFDBA placed under the membrane. Clinical parameters recorded included: recession depth, recession width, width of keratinized tissue, clinical attachment level, and probing depth, measured to the nearest 0.5 mm. Presurgery and postsurgery (6-month) data were compared using Student's paired *t* test for parametric data and the Wilcoxon matched pairs test for non-parametric data.

Results: Guided tissue regeneration with collagen (COLL) and collagen + DFDBA (COBA) both resulted in statistically significant ($P < 0.05$) reductions in recession depth (2.1 ± 0.9 mm and 2.5 ± 0.5 mm), recession width (1.5 ± 1.7 mm and 2.2 ± 1.6 mm), increase in keratinized tissue (0.7 ± 0.8 mm and 1.2 ± 1.0 mm), and gain of clinical attachment level (2.1 ± 1.0 mm and 3.0 ± 1.0 mm), when comparing 6-month data to baseline. Mean root coverage was 68.4 ± 15.2% with COLL and 74.3 ± 11.7% with COBA. However, there were no statistically significant differences between groups for recession depth, recession width, width of keratinized tissue, clinical attachment level, and probing depth.

Conclusions: Both techniques are effective in attaining root coverage. Although root coverage tended to be better with the addition of DFDBA, the difference was not statistically significant. Further studies with a larger sample size are needed to determine whether adding DFDBA to GTR-based procedures using collagen membranes is of any benefit. *J Periodontol 2004;75:210-220.*

KEY WORDS

Bone, demineralized; bone, freeze-dried; collagen/therapeutic use; dental esthetics; gingival recession/surgery; gingival recession/therapy; grafts, bone; guided tissue regeneration; membranes, barrier.

* Private practice, Phoenix, AZ.
† Department of Periodontics/Prevention/Geriatrics, School of Dentistry, University of Michigan, Ann Arbor, MI.
‡ Division of Biostatistics, Department of Preventive Medicine, School of Medicine, Vanderbilt University, Nashville, TN.

According to reports based on the third National Health and Nutrition Examination Survey (NHANES III), an estimated 22.5% (23.5 million) of the population has one or more tooth surfaces with ≥3 mm of recession.[1] Problems associated with recession include: 1) compromised esthetics, 2) root hypersensitivity, 3) higher incidence of root caries, and 4) compromised plaque control.[2]

Pedicle flaps, non-contiguous grafts, and combination procedures such as subepithelial connective tissue grafts have all been used with success to gain root coverage.[2] All of these procedures can produce predictable root coverage; however, healing results in formation of a long junctional epithelium (LJE) or an LJE with minor amounts of connective tissue attachment.[3] In the case of subepithelial connective tissue grafts, little or no new cementum or bone is created.[4] The following limitations are often associated with these techniques: the need for a second surgical site, morbidity linked with harvesting donor grafts, post-surgical bleeding, patient discomfort, poor color match between donor tissue and recipient site, limited quantity of donor tissue, and frequent need for multiple procedures to achieve optimal results.

Recently, investigators successfully applied the principles of guided tissue regeneration (GTR) to promote root coverage. A variety of non-resorbable (e.g., expanded polytetrafluoroethylene [ePTFE]) and bioabsorbable (e.g., colla-

gen, polylactide or polyglycolide polymer) occlusive membranes have been used.[5-15] GTR-based techniques yielded clinical results similar to those achieved by traditional root coverage procedures.[16-25] In addition, GTR can potentially result in new attachment formation (new bone, new cementum, new periodontal ligament, and new connective tissue).[14,26-30] Furthermore, it offers an unlimited supply of materials and eliminates the need for a second surgical site to harvest donor tissue.

A major problem with non-resorbable membranes is that a second surgical procedure is needed to remove the membrane, which may jeopardize healing and clinical outcomes.[31,32] Studies comparing the efficacy of non-resorbable and bioabsorbable barrier membranes have shown no difference in clinical outcomes.[9,25] Therefore, bioabsorbable membranes such as collagen are generally preferred. Collagen is the primary structural protein of connective tissue and is well tolerated by surrounding tissue. Collagen is semipermeable, allowing nutrient passage and gas exchange, and it supports cell proliferation via its lattice-like structure and cell-binding domains. Collagen also is hemostatic, possessing an ability to aggregate platelets, which helps to facilitate early wound stabilization and maturation. Another useful benefit of collagen is that it might augment tissue volume as it is naturally absorbed and replaced by host tissue.[33]

Collagen membranes have been successfully used for GTR-based root coverage.[10,15,22,24,34] Wang et al. achieved 73% root coverage using collagen membranes and 84% using autologous connective tissue grafts (CT) in conjunction with coronally positioned flaps.[24] In both groups, 7 of 16 sites achieved 100% coverage. Similar gains in CAL were noted for the collagen (2.8 mm) and CT (2.3 mm) groups. A slight probing depth decrease (–0.3 mm) was noted for the collagen group versus an increase (0.4 mm) for the CT group. Width of keratinized tissue was increased similarly for the collagen and CT groups (0.7 mm and 1.1 mm, respectively). They concluded that the two techniques were clinically comparable. However, patients preferred the membrane technique because a second surgery site was avoided.

Creation and maintenance of space between the root surface and the overlying GTR barrier are considered critical to the success of all GTR procedures, including those aimed at achieving root coverage. It is believed that this space is necessary to provide a channel for the migration of progenitor cells toward and onto the detoxified root surface, where they can differentiate into cementum and periodontal ligament-forming cells.[35,36] Unfortunately, it is difficult to achieve space maintenance when treating recession defects because the membrane tends to collapse against the root surface. Several techniques have been used to provide space for regenerating tissue: root modification,[37] tenting sutures,[11] fibrin-fibronectin glue,[13] titanium-reinforced membranes,[12] and bone grafts.[38] The rationale for using bone graft beneath a membrane is that it can prevent collapse of the membrane into the defect, reduce the volume to be filled by regenerating cells, enhance clot stability, and stimulate and facilitate the proliferation of osteogenic progenitor cells.[39] Allografts have been used successfully in periodontics since the early 1970s, primarily to treat intrabony periodontal defects, with more than 60% of intrabony defects healing with greater than 50% bone fill.[40-42] Demineralized freeze-dried bone allograft (DFDBA) is the most commonly used graft material today. DFDBA has osteoinductive activity and the ability to create and maintain space; therefore, it might be an ideal material to use with GTR-based root coverage procedures. Shih and Allen reported 86% root coverage after treating one recession defect with DFDBA under a non-resorbable membrane (ePTFE).[38] Thus, two reasons for using DFDBA are its ability to maintain space and its regenerative potential.[43-49]

DFDBA also has been used as a space maintainer beneath bioabsorbable membranes for root coverage. Dodge et al. used polylactic acid (PLA) membranes with DFDBA and without DFDBA and reported 90% and 74% root coverage, respectively.[50] Similar results were also obtained with PLA membranes by Duval et al., but they found no statistically significant difference between groups.[5] In contrast, Rosetti et al. compared subepithelial connective tissue grafts (SCTG) with collagen membranes plus DFDBA and found that the SCTG group had significantly better recession coverage and width of keratinized gingiva.[20]

Paolantonio compared the use of connective tissue (CT), polylactic acid membrane§ (GTR), and a collagen membrane‖ with a space maintainer/bone graft combination (hydroxyapatite, collagen, and chondroitin sulfate [CPRT])¶ for root coverage.[21] They found 90.0%, 81.01%, and 87.12% root coverage in the CT, GTR, and CPRT sites, respectively. They concluded that all of the techniques were comparable for use in root coverage, but the CT and CPRT treatments resulted in significantly improved gingival thickness. There is limited information on the use of type I collagen membranes combined with bone grafts for the treatment of gingival recession. Therefore, the purpose of this study was to determine whether the addition of bone graft (i.e., DFDBA) significantly influences the clinical outcome of GTR-based root coverage procedures using collagen membranes.

§ Guidor (membrane no longer available; originally manufactured by The John O. Butler Co., Chicago, IL).
‖ Paroguide, Coletica, Lyon, France.
¶ Biostite, Coletica.

MATERIALS AND METHODS

Subjects

This study was approved by the university committee governing the use of human subjects in clinical experimentation. Twenty (20) systemically healthy patients (10 females and 10 males, 21 to 69 years of age, mean age 42.6 years) were selected from the patient pool at the Graduate Periodontic Clinic at the University of Michigan School of Dentistry. Each subject had a Miller's Class I or II facial recession defect measuring ≥3 mm on an incisor, canine, or premolar tooth. Subjects were excluded for the following reasons: poor plaque control, allergy to bovine collagen-containing products, pregnancy, inability to provide informed consent, or unavailability for 6-month follow-up. All patients were periodontally stable upon entry into the study. Patients gave oral and written consent to have one recession defect treated with a collagen membrane with or without the use of DFDBA.

Clinical Measurements (Figure 1)

Clinical data for test and control teeth were collected at each visit by one calibrated (kappa >90%) examiner (KMK). All measurements were made to the nearest 0.5 mm using a periodontal probe with 1 mm increments.# In addition to the direct measurements, a masked examiner (RME) measured recession from standardized photos taken at 1:1 ratio and from study casts.

At baseline and 3 and 6 months post-surgically, the following measurements were recorded for each test and control site: recession depth (RD), mesio-distal recession width at the cemento-enamel junction (CEJ) (RW), width of keratinized tissue (KG), clinical attachment level (CAL), and probing sulcus depth (PD). Measurements of RD and CAL were recorded relative to the CEJ. RD was measured from the CEJ to the free gingival margin. RW was recorded at the level of the CEJ. Additional clinical data were obtained from photographs that were taken at each postoperative visit and from study casts obtained from alginate impressions that were taken at baseline and 6 months. In addition to clinical measurents, the following clinical indices were recorded at baseline; 1, 2, and 4 weeks; and 3 and 6 months: plaque index (PI) according to Silness and Löe[51] and modified gingival index (MGI) according to Lobene et al.[52]

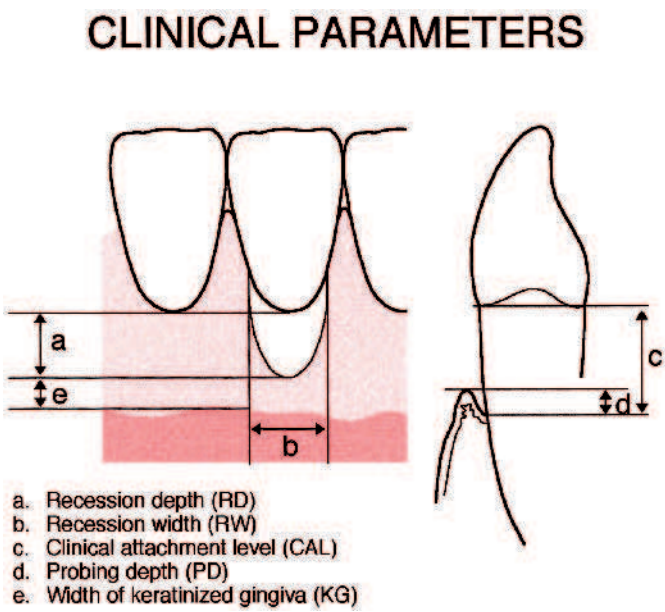

Figure 1.
Method used to measure the recession defect clinical parameters.

At 6 months post-treatment, the percentage of root coverage was calculated according to the following formula:

$$\frac{(\text{postoperative recession depth} - \text{preoperative recession depth})}{\text{preoperative recession depth}} \times 100\%$$

Surgical Protocol (Figures 2 through 4)

All surgeries were performed by one surgeon (KMK). One Miller's Class I or II recession defect was treated per subject. Treatment was performed as described previously by Wang et al.[53] After local anesthesia, root planing was performed with hand instruments and rotary burs to detoxify the accessible root surface and to de-epithelialize the gingival sulcus. Initial horizontal incisions were made following surgical calculations so that the coronal flap margins would be at the CEJ and tip of the papillae without need for flap trimming. At this point, mesial and distal horizontal split-thickness incisions to within 1 mm of the adjacent teeth were made, becoming full thickness apical to the CEJ. Mesial and distal full-thickness releasing incisions, with a slight divergence, were connected by the horizontal incision. Following flap reflection, intra-bone marrow perforations were made on the mesial and distal portions of the root with a 1/2 round bur. A collagen membrane** was trimmed such that 2 to 3 mm of surrounding adjacent bone was covered and the membrane was at the level of the CEJ. Randomization was performed at this point by an assistant who drew one slip of paper from a bag that initially contained equal numbers of slips with "bone" or "control" written on them. To ensure that groups would be of equal sample size, slips were not returned to the bag. If "bone" was chosen, DFDBA was layered evenly to a thickness of about 1 mm to cover the root to the CEJ and 2 mm of adjacent bone. In both groups, the membrane was sutured at the level of the CEJ using a 5-0 chromic gut sling suture. Next, the periosteum at the base of the pedicle flap was incised, and the flap was undermined to allow tension-free coronal positioning.

UNC-15, Hu-Friedy Mfg. Co. Inc., Chicago, IL.
** BioMend Regular, Zimmer Dental, Carlsbad, CA.

Figure 2.
Test group: GTR-based root coverage utilizing demineralized freeze-dried bone allograft (DFDBA) and a collagen membrane. ***A)*** *Presurgery showed 3.5 mm of buccal gingival recession (tooth #6).* ***B)*** *Two divergent vertical releasing incisions were made.* ***C)*** *Full-thickness flap was raised and root surface debrided with intra-bone marrow penetration (accomplished with a 1/4 round carbide bur).* ***D)*** *DFDBA and collagen membrane were placed, and membrane was secured with 5-0 sutures.* ***E)*** *Membrane in place prior to flap closure.* ***F)*** *Flap coronally advanced and sutured.* ***G)*** *One week healing.* ***H)*** *Healing at 6 months showed 100% root coverage.*

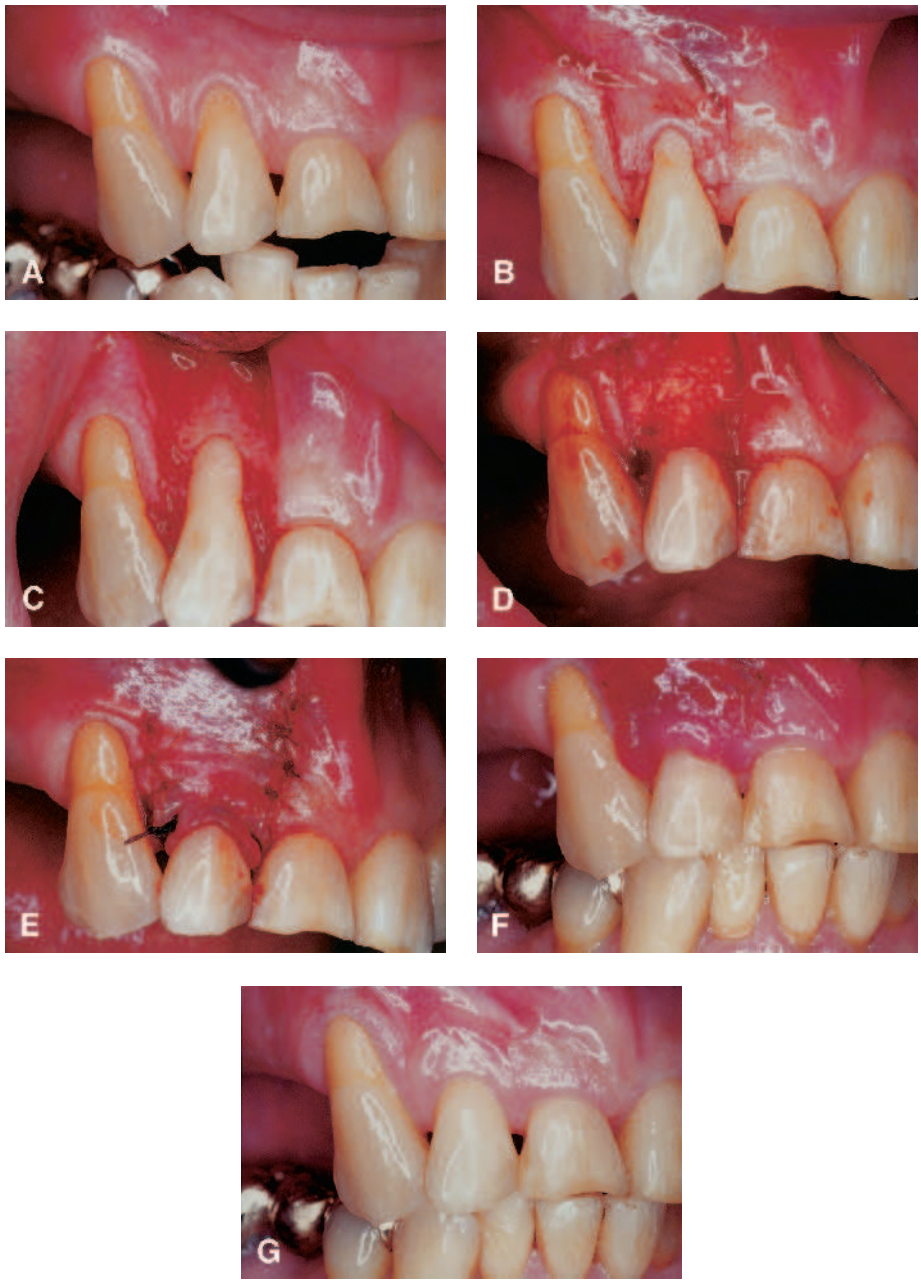

Figure 3.
Control group: GTR-based root coverage utilizing a collagen membrane. ***A)*** *Presurgery showed 3.0 mm of buccal gingival recession (tooth #7).* ***B)*** *Two divergent vertical releasing incisions were made.* ***C)*** *Full-thickness flap was raised and root surface debrided with intra-bone marrow penetration (accomplished with a 114 round carbide bur).* ***D)*** *Collagen membrane was trimmed and placed over the defect. Membrane was then secured with 5-0 sutures.* ***E)*** *Flap coronally advanced and sutured.* ***F)*** *One week healing.* ***G)*** *Healing at 6 months showed 100% root coverage.*

The pedicle was sutured with a 5-0 bioabsorbable material†† to a level coronal to the CEJ via a sling suture. The releases were sutured using the same material to complete primary closure of the area. No pack was placed. Following surgery, routine written and oral postoperative care instructions were given to each patient. To control plaque at the surgical site, the patient was instructed to apply a 0.12% chlorhexidine solution with a cotton swab twice daily and avoid the use of a toothbrush in the area for 4 weeks. A non-steroidal anti-inflammatory analgesic was prescribed. No antibiotics were used throughout the study.

Statistical analysis was performed using Student's paired *t* test to evaluate pre- and post-surgical outcomes. The non-parametric Wilcoxon matched pairs test was used to analyze the significance of PI and GI at different time intervals. Significance was reported at the 95% confidence level.

RESULTS

Twenty patients with Miller Class I or II recession defects measuring ≥3 mm participated in the study. Treated teeth in the COLL group included three maxillary canines, one maxillary lateral incisor, two mandibular central incisors, and four mandibular premolars. Treated teeth in the COBA group included three maxillary canines, one maxillary pre-molar, one mandibular central incisor, three mandibular canines, and two mandibular premolars. Eighteen patients completed the study (eight in the collagen alone group and 10 in the collagen + bone group). Of the two patients who were lost to follow-up, one was unable to be contacted following 4 weeks of treatment and the other moved out of state following 3 months of participation.

There was no difference noted among the three different measuring techniques (direct clinical measurements, standardized photos, and study casts) for recession depth. To avoid any potential bias during data analysis, it was decided to use only study cast measurements since this was performed by a blinded examiner.

Tables 1 and 2 show the clinical parameters at baseline and 6 months. At baseline, no statistically significant differences were noted between the groups. For the COLL group, recession depths decreased from 3.1 ± 0.8 mm to 1.0 ± 0.7 mm, for a difference of 2.1 ± 0.9 mm. For the COBA group,

†† Vicryl, Ethicon Inc., Johnson and Johnson Co., Somerville, NJ.

Figure 4.
Treatment outcomes of mandibular recession defects. ***A)*** *Presurgery view shows tooth #22 with 3.5 mm facial gingival recession. This was treated by DFDBA and collagen membrane (test group).* ***B)*** *Six-month post-surgery view shows that 100% root coverage was attained at tooth #22.* ***C)*** *Presurgery view shows tooth #21 with 3.0 mm facial gingival recession. This defect was treated with collagen membrane only (control group).* ***D)*** *Six-month post-surgery view shows that 100% root coverage was attained at tooth #21.*

Table 1.

Gingival Recession Depth at Baseline and 6 Months (mean ± SD, mm)

	Collagen (COLL)	Collagen + DFDBA (COBA)	
	N = 8	N = 10	Difference
Baseline	3.08 ± 0.81	3.40 ± 0.47	
6 months	0.96 ± 0.69	0.90 ± 0.60	
Difference	2.11 ± 0.89*	2.50 ± 0.52*	0.38 ± 0.71
% coverage	68.4 ± 15.2%	74.3 ± 11.7%	6.00 ± 14.7%

* Statistical difference at $P<0.05$ level.
COLL: GTR-based root coverage utilizing collagen membrane.
COBA: GTR-based root coverage utilizing collagen membrane + DFDBA.

recession depths decreased from 3.4 ± 0.5 mm to 0.9 ± 0.6 mm, for a difference of 2.5 ± 0.5 mm. The percentage of root coverage for COLL and COBA was 68.4 ± 15.2% and 74.3 ± 11.7%, respectively. Although no statistically significant difference was noted between the groups, both showed a statistically significant reduction in recession ($P<0.05$) from baseline.

In addition to recession depth, recession width, clinical attachment level, and width of keratinized gingiva were significantly improved at 6 months for both groups ($P<0.05$); however, there were no significant differences between groups (Table 2). In the COLL group, recession width decreased 1.5 ± 1.7 mm (from 3.9 ± 1.1 mm to 2.4 ± 1.7 mm). For the COBA group, recession width decreased 2.2 ± 1.6 mm (from 4.0 ± 0.8 mm to 1.8 ± 1.7 mm). In both groups, a significant gain in CAL was noted from baseline. The COLL and COBA groups gained 2.1 ± 1.0 mm and 3.0 ± 1.0 mm, respectively. Also, both groups had significant increases in keratinized tissue from baseline. The COLL and COBA groups gained 0.69 ± 0.75 mm and 1.15 ± 1.03 mm, respectively.

No statistical difference was noted in GI or PI (Table 3) at any of the time periods (1 week, 2 weeks, 4 weeks, 3 months, and 6 months).

DISCUSSION

The purpose of this randomized, controlled clinical trial was to compare the clinical outcomes using a collagen membrane with or without the adjunctive use of demineralized freeze-dried bone allograft (DFDBA) for root coverage. While results tended to favor the collagen + bone group (COBA), the differences between groups were not statistically significant. A significant reduction in recession depth (2.1 ± 0.9 mm for COLL and 2.5 ± 0.5 mm for COBA) was noted for each group from baseline. This corresponded to an overall percent root coverage of 68.4% and 74.3% for the COLL and COBA groups, respectively. These results correlate well with both non-resorbable and bioabsorbable barrier studies in overall root coverage.[7,8,10,12,16,18,22,24,31,37,54-59] In these studies, root coverage ranged from 55% to 75%. However, the results are less favorable compared to other studies such as Roccuzzo et al.[9] (83.2% for ePTFE and 82.4% for PLA), Zahedi et al.[15] (82.2%), Zucchelli et al.[25] (85.7% for PLA and 80.5% for ePTFE), Jepsen et al.[17] (87.1%), Harris[18] (92.3%), Rosetti et al.[20] (84.2%), Duval et al.[5] (81.6% for PLA + DFDBA and 90.1% for PLA), Boltchi et al.[60] (92.7%), Jepsen et al.[6] (91.9%), Tatakis and Trombelli[23] (81%), and Paolantonio[21] (81.0% for PLA and 87.1% for CPRT). Study differences including percentage of maxillary teeth, larger initial recession, measurement methods, number of defects treated in an area, smoking criteria, root biomodification, tissue

Table 2.

Clinical Parameters of Treated Sites at Baseline and 6 Months (mean ± SD, mm)

Treatment	COLL	COBA	Difference
Recession width			
Baseline	3.9 ± 1.1	4.0 ± 0.8	0.1 ± 1.0
6 months	2.4 ± 1.7	1.8 ± 1.7	–0.6 ± 1.7
Diff (baseline to 6 months)	1.5 ± 1.7*	2.2 ± 1.6*	0.6 ± 1.7
Clinical attachment level			
Baseline	4.7 ± 0.7	5.2 ± 0.5	0.5 ± 0.6
6 months	2.6 ± 0.8	2.2 ± 0.8	–0.4 ± 0.8
Diff (baseline to 6 months)	2.1 ± 1.0*	3.0 ± 1.0*	0.8 ± 1.0
Probing depth			
Baseline	1.4 ± 0.5	1.8 ± 0.6	0.4 ± 0.6
6 months	1.5 ± 0.6	1.5 ± 0.5	0.0 ± 0.6
Diff (baseline to 6 months)	–0.1 ± 0.4	0.3 ± 0.8	0.4 ± 0.7
Keratinized gingiva			
Baseline	1.6 ± 0.8	2.0 ± 0.6	0.0 ± 0.8
6 months	2.3 ± 1.0	3.2 ± 1.2	0.2 ± 1.2
Diff (baseline to 6 months)	–0.7 ± 0.8*	–1.2 ± 1.0*	–0.5 ± 0.9

* Statistical difference at $P < 0.05$ level.
COLL: GTR-based root coverage utilizing collagen membrane.
COBA: GTR-based root coverage utilizing collagen membrane + DFDBA.

Table 3.

Clinical Indices of Treated Sites at Different Time Points (mean ± SD)

	GI		PI	
	COLL	COBA	COLL	COBA
Baseline	0.3 ± 0.5	0.7 ± 0.8	0.4 ± 0.5	0.4 ± 0.7
1 week post-op	1.9 ± 1.0	2.0 ± 0.7	1.0 ± 1.1	2.0 ± 0.7
2 weeks post-op	1.1 ± 0.8	1.8 ± 1.0	1.3 ± 1.1	1.7 ± 1.0
4 weeks post-op	1.3 ± 0.9	1.2 ± 0.9	1.6 ± 1.2	1.7 ± 1.0
3 months post-op	0.5 ± 0.8	0.8 ± 0.9	1.1 ± 0.8	0.9 ± 0.7
6 months post-op	0.1 ± 0.4	0.4 ± 0.7	0.9 + 0.8	0.8 ± 0.9

No statistical difference was noted in GI and PI between groups when compared to three different time points.
COLL: GTR-based root coverage utilizing collagen membrane.
COBA: GTR-based root coverage utilizing collagen membrane + DFDBA.

thickness, and surgical experience might have contributed to more favorable results. For example, most studies[9,17,21,25] used ≥4 mm recession defects, while this study used 3 mm defects. In addition, studies[5,9,20] demonstrated better results when maxillary teeth were used, especially canines, compared to our study in which a majority of the teeth (12 out of 20 teeth) were in the mandible. Also, other studies treated multiple recession defects[18,60] instead of single teeth (our study) and showed better results. This might be attributed to better flap tension release and a wide blood supply base.

Gains in CAL of 2.13 mm and 2.95 mm were noted for the COLL and COBA groups, respectively. These gains compare well with other studies treating shallow recessions.[7,10,14,16,18,23,24,37,56-58,61] These studies reported CAL gains ranging from 0.76 mm to 3.1 mm. In our study, the initial recession depths were fairly shallow (3.1 mm for COLL and 3.4 mm for COBA). A probing depth increase of 0.1 mm and decrease of 0.3 mm were noted for the COLL and COBA groups, respectively. These minimal changes in probing depth suggest that the gain in CAL might be from some form of attachment to the root. However, histologic studies are needed to confirm the exact outcome.

Increases in keratinized gingiva (KG) of 0.7 mm and 1.2 mm were noted for the COLL and COBA groups, respectively. This is in agreement with the majority of other studies in which GTR techniques were utilized for root coverage. Studies with greater gains in KG (ranging from 1.8 mm to 2.3 mm) tended to have longer follow-up periods (12 months to 4 years).[50,55,56,62] This difference could be a function of tissue maturation following healing. Some controversy exists as to the cause of gained KG. Some have suggested that the increase is from a post-surgical reversal of the mucogingival junction at its genetically determined position.[55,63,64] Other authors, however, have not recorded a change in the mucogingival junction following recession correction.[65,66] Another possible alternative for the increased KG may be the quality of tissue healing beneath the flap. If tissue regeneration is occurring, the inductive properties inherent in the PDL may be causing surface keratinization.[25,66,67] Reentry and histological studies have verified a connective tissue attachment with functionally oriented PDL fibers inserting into new bone and cementum.[14,27-29,68,69] Thus, increased surface keratinization may be a sign that the healing occurring with membrane-based treatment is regeneration, to a certain extent.

Also noted in the literature is a trend for areas treated in the maxilla to perform better than in the mandible.[7,31,35,59,64] Trombelli et al. noted that during the removal of non-resorbable barriers, similar amounts of newly formed tissue were present in both the maxilla and mandible.[61] However, attachment gain and recession reduction were consistently greater in the maxilla.

They hypothesized that the inferior outcomes from similar starting points for the mandible may be the result of higher tensile strength forces at the newly formed tissue-flap interface interfering with tissue maturation. Amarante et al. also suggested that more functional forces are in the mandible compared to the maxilla.[59] Stability of the maturing fibrin clot is a requirement for proper healing.[70] The use of a membrane might enhance wound stabilization and protect the adhering clot from tensile forces by projecting these forces onto the external portion of the membrane.[13,70] Of interest is a trend in our data for root coverage in the mandible (73.0%) to be slightly better than the maxilla (71%) (data not shown). This was especially true if bone was placed beneath the membrane (78%) versus membrane alone (64%) in the mandible. Because there are insufficient data to statistically evaluate the differences, all that can be noted is that a subjective trend was noted for improved outcome for the COBA group in the mandible. Hypothetically, the graft could be contributing to the overall stability of the regenerating tissue and dampening the amount of tensile force on the maturing clot.

In addition to wound stability, space maintenance has been shown to be critical to the overall regenerative attempt.[71-75] Maintaining a space beneath the barrier membrane and root surface is considered vital to the success of GTR in terms of providing a channel for the migration of multipotential cells to the denuded root surface.[35,36] Several different techniques have been used to provide space for regenerating tissue: root modification,[37] a tenting suture,[11] fibrin-fibronectin glue,[13] titanium-reinforced membranes,[12] and DFDBA.[38] In our study, we chose to use DFDBA due to its handling characteristics, possible inductive quality,[43-45,76,77] and clinical success.[5,29,46-49] The rationale for the use of bone graft beneath a membrane is to sustain the membrane in the presence of the non-contained defect architecture, avoid collapse of the defect, reduce the volume to be filled by regenerating cells, enhance the stability of the coagulum, and stimulate and facilitate the profileration of osteogenic progenitor cells.[39] The use of DFDBA provided adequate space beneath the membrane, and the material was easy to handle. Further investigations on the ability of DFDBA to provide added stability to the overall regenerating tissue, especially in the mandible, would be of interest. It would also be of interest to investigate whether the addition of DFDBA has any effect on the thickness of the final result.

Several limitations of our study are noted. Lack of power analysis to determine the proper sample size weakened the overall significance noted in this study. The overall numbers of the groups and the loss of two patients from one group are unfortunate. Also, the 6-month follow-up period is relatively short, and additional healing might occur over longer periods. Longer-term studies would also be preferable to document the long-term stability of the healed result. In addition, the quality of the tissue can only be speculated at this point. Only histological studies can prove the true characteristics of the healed area.

In relation to the use of this technique for root coverage, the overall percentage is less than other techniques that employ the use of tissue beneath a flap. In our study, only one patient in each group achieved 100% coverage. Therefore, mucogingival techniques may be superior in treatments for which the goal is total root coverage. Although the majority of healing using soft tissue is by a long junctional epithelium (LJE), several long-term studies have shown that the results are stable, probing depths are shallow, and a healthy non-bleeding sulcus results.[19,55,78,79] Studies have yet to demonstrate that the LJE is an inferior attachment.[80,81]

In conclusion, results from this study indicate that root coverage using a collagen membrane with or without a bone graft results in clinically comparable results. Both groups recorded statistically significant improvements from baseline in decreased recession depth and width, gain in clinical attachment levels, and increases in keratinized tissue.

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Correspondence: Dr. Hom-Lay Wang, Department of Periodontics/Prevention/Geriatrics, University of Michigan School of Dentistry, 1011 North University Avenue, Ann Arbor, MI 48109-1078. Fax: 734/936-0374; e-mail: homlay@umich.edu.

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