

# Coronally positioned flap procedures with or without a biodegradable membrane in the treatment of human gingival recession. A 6-year follow-up study

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Leknes KN, Amarante ES, Price DE, Bøe OE, Skavland RJ, Lie T. Coronally positioned flap procedures with or without a biodegradable membrane in the treatment of human gingival recession. A 6-year follow-up study. *J Clin Periodontol* 2005; 32: 518–529. doi: 10.1111/j.1600-051X.2005.00706.x. © Blackwell Munksgaard, 2005.

## Abstract

**Background:** Short-term data have indicated that treatment of gingival recession type defects by coronally positioned flap procedures with or without biodegradable membranes may result in similar treatment outcome. The aim of this study was to compare 12-month and 6-year follow-up results for these two treatment approaches.

**Methods:** Twenty patients with buccal bilateral Miller Class I or Class II gingival recession defects in cuspids or bicuspid were treated randomly by coronally positioned flap alone (20 sites) or in combination with a biodegradable membrane (20 sites). Clinical measurements at baseline, 6, 12 months and 6 years included apical extent of gingival recession, width of the defect at the cemento-enamel junction (CEJ), width of keratinized tissue, as well as attachment level and probing depth. Eleven patients were available for the 6-year evaluation.

**Results:** At 12 months (20 sites), both treatments resulted in significant gain of root coverage ( $p < 0.001$ ), stable probing depth, and increased attachment level ( $p < 0.001$ ). The 6-year evaluation (11 sites) showed a significant gain of root coverage for the non-membrane group only ( $p < 0.05$ ). No significant between-group differences were detected for any other treatment variable regardless of smoking status ( $p > 0.05$ ). Compared with baseline, the 6-year results showed that seven membrane sites gained root coverage, three were unchanged and one lost root coverage. For the 11 non-membrane sites, eight gained root coverage, and three were unchanged. The five membrane and the 10 non-membrane sites exhibiting complete root coverage at 6 months were reduced to two and one, respectively, at the 6-year evaluation.

**Conclusions:** The coronally positioned flap procedure offers a simple and reliable treatment alternative as a root coverage procedure in Class I and Class II recession type defects. Placement of a biodegradable membrane underneath the flap does not seem to improve neither the short- nor the long-term results. Long-term outcome stability seems to be critically dependent on a continuous follow-up program with re-instruction in non-traumatic brushing habits.

Key words: coronally positioned flap; gingival recession; guided tissue regeneration; membranes; mucogingival surgery.

Accepted for publication 12 September 2004

Gingival recession is a common, undesirable apical shift of the marginal tissue beyond the cemento-enamel junction (CEJ). Two separate types of gingival recession can be recognized; a more generalized recession often related to plaque-associated, chronic inflammatory periodontal disease and a more localized type usually caused by trauma from toothbrushing (Gorman 1967). The treatment of buccal recession type defects are mainly concerned with reshaping the gingival architecture with or without efforts to increase the amount of keratinized gingiva. In contrast to advanced cases where most of the buccal alveolar bone may be lacking, less advanced or moderate recession type defects do not seem to compromise the long-term periodontal prognosis of affected teeth (Lindhe & Echeverria 1994). The narrow zone of keratinized tissue usually occurring at the defect site is most often the result of and not the cause of the defect (Wennström 1987). Thus, the rationale for treating buccal recessions are mainly aesthetic concerns, primarily in maxillary buccal areas, and clinical situations where unfavourable contour of the gingival margin might be an obstacle for proper plaque control (Wennström 1994).

Gingival recession type defects have been treated by a number of procedures including coronally or laterally positioned pedicle grafts (Robinson 1964, Tarnow 1986, Allen & Miller 1989), rotational flaps (Harvey 1965), epithelialized free tissue grafts (Miller 1982), connective tissue grafts (Edel 1974, Miller 1993) and by applying principles for guided tissue regeneration (GTR) (Cortellini et al. 1991, Pini Prato et al. 1992). The potential advantage of applying GTR to a gingival flap procedure is the possibility of having a different healing pattern and ideally achieving periodontal regeneration rather than connective tissue repair to the exposed root surface (Karring et al. 1993). Histologic observations following GTR in gingival recession defects show evidence of some new cementum with inserting connective tissue fibers and limited bone regeneration (Cortellini et al. 1993, Parma-Benfenati & Tinti 1998, Vincenzi et al. 1998). A thicker and more supported root coverage may potentially improve the long-term stability of the treatment. Furthermore, increased width of keratinized tissue may also reduce the susceptibility of recession recurrence (Pini Prato et al. 1996).

Amarante et al. (2000) used a split-mouth design in 20 patients to compare coronally positioned flap with and without a biodegradable membrane in the treatment of recession type defects. Treatment evaluation at 6 months post-surgery showed 56% (2.3 mm) root coverage for the membrane sites and 69% (2.5 mm) for the non-membrane sites. Keratinized gingiva increased 0.5 and 0.4 mm for membrane and non-membrane sites, respectively. There were no significant differences between the protocols for any of the parameters evaluated. Thus, the short-term data showed that coronally positioned flap is a simple and predictable treatment of gingival recession defects and that the GTR protocol does not appear to offer any additional advantage. To evaluate the long-term clinical data the same patient group was monitored for 6 years. Specifically, the purpose of the present study was to compare 12-month and 6-year follow-up outcomes following coronally positioned flap procedures in the treatment of Miller Class I and Class II gingival recessions with or without the adjunctive use of a biodegradable periodontal membrane.

## Material and Methods

### Patients and defects

Twenty patients, 10 females and 10 males, with a mean age of 38.4 years and in generally good health without contraindications for periodontal surgery, were recruited for this study at the Department of Periodontology, Faculty of Dentistry, University of Bergen (Amarante et al. 2000). Among the 20 subjects, 12 were non-smokers (five men and seven women) and eight were heavy smokers (five men and three women). Heavy smokers were defined as those smoking one package (20 cigarettes) or more per day. To be enrolled, patients had to be well motivated and to present bilateral buccal gingival recessions in cuspids or bicuspid in the upper or lower jaw. Inclusion criteria required that the paired defects had a recession of  $\geq 3$  mm measured from the CEJ to the free gingival margin, conformed to the Miller Class I or Class II classification (Miller 1985a), and presented with a probing depth of  $< 3$  mm with no bleeding on probing. One defect from each pair was randomly selected to be treated either by a coronally positioned flap only, or by a coronally posi-

tioned flap supported by a biodegradable membrane (GUIDOR, Huddinge, Sweden). The protocol was approved by the Regional Ethics Committee for Medical Research, and all procedures were explained to the patients before signing of an informed consent form.

### Treatments

The patients were instructed in a non-traumatizing buccal brushing technique using a soft toothbrush. Pre-surgical therapy included scaling, polishing, as well as a more general oral hygiene instruction.

The coronally positioned flap procedure started with an intra-sulcular incision at the buccal aspect of the involved tooth. Two horizontal incisions were then made at right angles to the adjacent inter-dental papillae at the CEJ level without interfering with the gingival margin of the neighbouring teeth. To mobilize the flap, two oblique vertical releasing incisions were extended beyond the mucogingival junction. A full thickness trapezoidal flap was then elevated up to the mucogingival junction, and following penetration of the periosteum, a partial thickness flap was dissected further apically. To create a bleeding bed for the sliding flap, the epithelium on the adjacent papillae was stripped away. In addition, small perforations were made by a round bur in the inter-dental bone areas to promote bleeding and stimulate bone marrow cell migration.

The exposed root surfaces were polished with a rubber cup and an abrasive paste to eliminate bacterial plaque. To compensate for the expected postoperative shrinkage, the flap was positioned and sutured by an absorbable suture (VICRYL, Johnson & Johnson, Skillman, NJ, USA) 1–2 mm coronally to the CEJ (for more details see Amarante et al. 2000).

At the membrane-designated site, the first part of the surgical procedure was identical to that of the non-membrane site. However, following reflection of the flap a biodegradable membrane (GUIDOR) was trimmed, positioned and sutured to cover the recession up to CEJ. The flap was then coronally positioned over the membrane and anchored by an absorbable suture (VICRYL, Johnson & Johnson).

Systemic antibiotic (amoxicillin, 3 g) was given prophylactically 1 h before the operation. For one month postsurgically, the patients were instructed to

rinse twice a day with a 0.2% chlorhexidine solution. Toothbrushing was discontinued in the operated areas for 2 weeks. The patients were recalled weekly during the first month. Furthermore, the research protocol scheduled maintenance visits including polishing and re-instruction at 3, 6, 9, and 12 months and then once a year up to 6 years postsurgery.

### Clinical assessments

The following clinical parameters were recorded by a masked dental hygienist at baseline, 3, 6, and 12 months, and then yearly:

- Gingival recession measured by a manual probe (L-M Dental, Rydön-tie 12 A, Turku, Finland) with mm markings from the cemento-enamel junction (CEJ) to the free gingival margin at the middle of the buccal surface.
- Relative attachment level measured by the Florida Probe device (Florida Probe Corporation, Gainesville, FL, USA) mid-buccally with the disc located at the buccal cusp/incisal edge.
- Width of the recession defect measured by the manual probe across the buccal surface at the CEJ level.
- Width of keratinized gingiva measured by the manual probe from the gingival margin to the mucogingival junction.
- Probing depths at the middle of the buccal surfaces measured by an automated, pressure sensitive probe (Florida Probe Corporation) set at 25 g pressure sensitivity. The computerized probe recorded measurements to the nearest 0.1 mm.
- Gingival thickness was determined only at the 6-year examination by using an ultrasonic device (SDM<sup>®</sup>, Krupp, Essen, Germany). The edge of the transducer probe of the device with a 4 mm diameter was placed at a midbuccal location on the gingival margin (Eger et al. 1996, Müller et al. 1999)

Bleeding on probing as well as presence of plaque were also evaluated on buccal experimental surfaces. All included patients completed the 12-month follow-up maintenance program, while 11 patients were available for the 6-year evaluation.

### Statistical analysis

Total subject mean and standard deviation were calculated for each response variable, and an analysis of variance with repeated measures (BMDP Statistical Software, BMDP 2 V, LA, CA, USA) was employed to reveal any overall statistically significant differences between smokers and non-smokers, between membrane and non-membrane treatments, and between different time periods. The analysis did not disclose any significant difference between smokers and non-smokers at 12 months ( $p = 0.491$ ) and 6-year follow-up ( $p = 0.670$ ), justifying a pooling of the two samples. The Student's *t*-test for paired observations was used to test within as well as between treatment differences at baseline, 6 and 12 months for the 20-patient sample and at baseline, 12 months and 6 years for the 11 patients who completed the 6-year follow-up period. Bonferroni-adjustments were made for multiple comparisons. In all calculations, the patient represented the experimental unit.

### Results

The clinical data are presented separately as 12 months observations for 20 patients and as 6-year follow-up for 11 patients. The overall 12-month findings showed that favourable results were obtained by the coronally positioned flap operation whether or not a biodegradable membrane supplemented the surgical procedure. Among the 20 membrane sites, three stayed unchanged while 17 gained root coverage. Four sites (20%) obtained total coverage to the CEJ. Among the non-membrane sites, all gained root coverage at 12 months, and six sites (30%) showed complete coverage to the CEJ.

Among the 11 patients who completed the 6-year follow-up, one membrane site lost root coverage, three stayed unchanged while seven gained root coverage. Two sites obtained total coverage to CEJ (18.2%). For the 11 non-membrane sites, three stayed unchanged while eight gained root coverage. One site (9.1%) demonstrated total root coverage.

Individual patient data for the 11-patient sample demonstrated that from 12 months to 6 years regardless of smoking six membrane sites lost root coverage, four sites stayed unchanged, and one site gained 1 mm root coverage

(Figs. 1a–e). Among the 11 non-membrane sites, seven sites lost root coverage, and four sites stayed unchanged (Figs. 2a–e). An interesting observation was that stable sites with total root coverage at 6 years were stable for membrane and non-membrane sites within the same patients (Figs. 3 and 4), while unstable sites showed relapse on both sides (Figs. 1 and 2).

### Gingival recession

At 6 months the mean gain of root coverage was 2.1 mm in the membrane group ( $p < 0.001$ ) and 2.3 mm in the non-membrane group ( $p < 0.001$ ; Table 1a). By 12 months the extent of root coverage achieved at 6 months was maintained for the membrane sites, while reduced by 0.1 mm for the non-membrane sites.

Analysis of variance with repeated measures demonstrated a significant difference between the two treatment groups only at baseline ( $p < 0.05$ ) and no significant interaction effect (Table 1a). Both groups showed a significant gain of root coverage from baseline to 12 months ( $p < 0.001$ ).

The 12 months mean gain of root coverage for the 11 patients sample was 1.9 mm in the membrane group ( $p < 0.01$ ) and 2.3 mm in the non-membrane group ( $p < 0.001$ ; Table 1b). At 6 years, the extent of root coverage achieved at 12 months was reduced by 0.5 mm for the membrane sites ( $p = 0.147$ ) and by 1.0 mm for the non-membrane sites, revealing a significant relapse ( $p = 0.03$ ).

Analysis of variance with repeated measures demonstrated a significant difference between the two treatment groups at 12 months ( $p < 0.05$ ) and no significant interaction effect.

### Attachment level

The relative attachment level at one year follow-up for 20 patients is exhibited in Table 2a. At 6 months there was a mean gain of attachment in the membrane group of 1.3 mm ( $p < 0.001$ ) and in the non-membrane group of 1.7 mm ( $p < 0.001$ ). By 12 months the attachment gain was 1.5 mm for the membrane sites and 1.8 mm for the non-membrane sites.

Analysis of variance with repeated measures demonstrated a significant difference in attachment level between the two treatment groups at 12 months ( $p < 0.05$ ) and no significant interaction



Fig. 1. (a) Pre-operative view of buccal recession type defect on 24 in a smoker. (b) Surgical treatment of the recession on 24: The mobilized flap was coronally positioned over the membrane and anchored by an absorbable suture (membrane site). (c) Two weeks of healing following surgery on 24. A slight membrane exposure is visible (white arrow). (d) Six months postsurgical view of 24. The root coverage is close to cemento-enamel junction. (e) Six years postsurgical view of 24. A relapse of the recession close to baseline level has occurred. Stillman's cleft on 25 indicates an ongoing traumatic buccal brushing technique (white arrow).

effect. The paired *t*-test revealed a significant within treatment change for both groups from baseline to 12 months ( $p < 0.001$ ; Table 2a).

For the 11 patients, the 12-month mean gain of attachment in the membrane group was 1.4 mm ( $p < 0.01$ ) and 2.0 mm in the non-membrane group ( $p < 0.001$ ; Table 2b). At 6 years the gain of attachment compared with baseline was 1.7 mm in the membrane group ( $p < 0.01$ ) and 1.5 mm in the non-membrane group ( $p < 0.01$ ). The within treatment change from 12 months to 6 years were non-significant for both groups (membrane sites;  $p = 0.422$ , non-membrane sites;  $p = 0.105$ ).

Analysis of variance with repeated measures revealed no significant between group differences ( $p = 0.485$ ) and no significant interaction effect.

#### Recession width

At 6 months the width of the gingival recession was reduced by 1.1 mm in the membrane group ( $p < 0.05$ ) and by 1.9 mm in the non-membrane group

( $p < 0.001$ ; Table 3a). From 6 to 12 months the reduction was 0.1 mm for the membrane sites ( $p = 0.725$ ) while increased by 0.3 mm for the non-membrane sites ( $p = 0.262$ ).

Analysis of variance with repeated measures demonstrated an overall significant difference over time ( $p < 0.01$ ) but no significant difference between treatment groups ( $p = 0.08$ ) and no significant interaction effect. The paired *t*-test demonstrated a significant reduction in width of gingival recession from baseline to 12 months for the membrane group ( $p < 0.05$ ) as well as for the non-membrane group ( $p < 0.01$ ; Table 3a).

The width of the gingival recession defects in 11 patients was at 12 months reduced by 1.0 mm from 4.6 mm to 3.6 mm in the membrane group ( $p = 0.228$ ) and by 1.7 mm from 4.6 mm to 2.9 mm in the non-membrane group ( $p < 0.05$ ; Table 3b). At 6 years, a relapse was observed for both groups. Compared with the 12-month values, the recession width increased by 0.4 mm for the membrane sites ( $p = 0.332$ ) and by 1.1 for the non-membrane sites ( $p = 0.104$ ).

Analysis of variance with repeated measures revealed no significant difference between treatment groups ( $p = 0.340$ ) and significant interaction effect.

#### Width of keratinized gingiva

At 6 months the width of the keratinized tissue increased by 0.5 mm in the membrane group ( $p = 0.105$ ) and by 0.4 mm in the non-membrane group ( $p < 0.01$ ; Table 4a). Compared with baseline, the 12-month recordings showed a significant gain in the membrane group of 0.6 mm ( $p < 0.05$ ) while the non-membrane group maintained the 0.4 mm gain ( $p < 0.01$ ).

Analysis of variance with repeated measures revealed an overall significant difference over time ( $p < 0.05$ ) but no significant difference between treatment groups ( $p = 0.387$ ) and no significant interaction effect.

The width of keratinized gingiva in the 11 patients at baseline was 2.6 mm in the membrane as well as in the non-membrane group (Table 4b). At 12 months the width increased by 0.5 mm





Fig. 2. (a) Pre-operative view of buccal recession type defect on 14 in a smoker (the same patients as in Fig. 1). (b) Surgical treatment of recession on 14: The mobilized flap was coronally positioned and anchored by an absorbable suture (non-membrane site). (c) Two weeks of healing following surgery on 14. (d) Six months postsurgical view of 14. The root coverage is close to CEJ. (e) Six years postsurgical view of 14. A relapse of the recession close to baseline level has occurred on 14 as well as on 15. The gingival morphology may indicate an ongoing traumatic buccal brushing technique (white arrow).

in the membrane group ( $p = 0.084$ ) and 0.4 mm in the non-membrane group (0.054). At 6 years the width decreased compared with 12 months by 0.5 mm in membrane sites ( $p < 0.05$ ) and by 0.4 mm in non-membrane sites ( $p = 0.054$ ).

Analysis of variance with repeated measures demonstrated an overall significant difference over time ( $p < 0.05$ ) but no significant difference between treatment groups ( $p = 0.453$ ) and no significant interaction effect.

#### Probing depths

At 6 months there was a reduction in probing depth of 0.2 mm in the membrane group ( $p = 0.171$ ) and of 0.3 mm in the non-membrane group ( $p = 0.069$ ; Table 5a). By 12 months the mean probing depth increased by 0.1 mm compared with 6 months for the membrane sites ( $p = 0.463$ ) and was maintained for the non-membrane sites ( $p = 0.787$ ).

Analysis of variance with repeated measures demonstrated an overall significant difference between the two treatment groups ( $p < 0.05$ ) but no difference over time ( $p = 0.101$ ) and no significant interaction effect. The paired

$t$ -test revealed a significant difference between membrane and non-membrane treatment at 12 months ( $p < 0.05$ ; Table 5a).

At baseline, the probing depth measurements in the 11 patients were 1.4 mm in the membrane group and 1.3 mm in the non-membrane group. From baseline to 12 months, the probing depth decreased by 0.2 mm for membrane sites ( $p = 0.221$ ) and by 0.3 mm for the non-membrane sites ( $p = 0.077$ ). At 6 years, the probing depths for the membrane sites rebound to baseline level ( $p = 0.484$ ) while the mean probing depth appeared stable for the non-membrane sites ( $p = 0.833$ ). Analysis of variance with repeated measures revealed no significant difference between treatments ( $p = 0.110$ ) or over time ( $p = 0.252$ ) and no significant interaction effect (Table 5b).

#### Gingival thickness

The gingival thickness measured with an ultrasonic device at the 6-year follow-up was 0.89 mm for the membrane group and 0.80 mm for the non-membrane group (Table 6). The difference was not statistically significant ( $p = 0.107$ ).

#### Discussion

During the last decades, a number of studies have reported successful results following root coverage procedures (Miller 1982, 1985b, Cortellini et al. 1991, Shanaman 1993, Pini Prato et al. 1996, Harris 1998, Amarante et al. 2000, Abbas et al. 2003, Andersen et al. 2003, Cetiner et al. 2003, McGuire & Cochran 2003, Nemcovsky et al. 2004). However, the majority of these reports has a case report design and a rather short-term observation period (Miller 1982, Harris 1998, Abbas et al. 2003, Andersen et al. 2003, McGuire & Cochran 2003). In the present controlled clinical trial a randomized, split-mouth protocol was used to balance inter-individual variations and 20 patients were monitored for 12 months while 11 patients were available for the final 6-year evaluation. In each patient, the two surgical procedures were performed at the same appointment and by the same operator. Furthermore, inter-examiner variability was eliminated by having one masked, calibrated dental hygienist performing all measurements. Because of slight postsurgical exposure of some membranes or membrane ligatures, a double-blinded study design was not feasible.



Fig. 3. (a) Pre-operative view of buccal recession type defect on 33 in a non-smoker. The composite filling in the cemento-enamel area was removed before surgery. (b) Surgical treatment of recession on 33: The mobilized flap was coronally positioned over the membrane and anchored by an absorbable suture (membrane site). (c) Two weeks of healing following surgery on 33. A slight membrane exposure is visible (white arrow). (d) Six months postsurgical view of 33. A complete root coverage to cemento-enamel junction is obtained. (e) Six years postsurgical view of 33. The complete root coverage is maintained.

Table 1a. Gingival recession (in mm) measured by manual probe from CEJ at baseline, 6, and 12 months (N = 20)

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	4.1	0.9	3.0	6.0
Non-membrane	3.6	1.0	3.0	6.0
6 months				
Membrane	2.0	1.3	0.0	4.0
Non-membrane	1.3	1.3	0.0	4.0
12 months				
Membrane	2.0	1.5	0.0	4.0
Non-membrane	1.4	1.3	0.0	4.0

Between treatment differences: \* $p < 0.05$ ;

Within treatment changes over time: \*\*\* $p < 0.001$ .

NS, not significant; CEJ, cemento-enamel junction.

The 6- and 12-month data for 20 patients showed that a coronally positioned flap procedure in Miller Class I and Class II recession defects is as efficient as the combined procedure in terms of root coverage. At 12 months, both treatments resulted in similar and significant gain of root coverage ( $p < 0.001$ ), amounting to 2.1 mm (or 51.2%) in the membrane group and 2.2 mm (or 61.1%) in the non-membrane group. Compared with 12-month data, the 6-year observation for 11 patients showed a reduction in root coverage of 0.5 mm (gain from BL 1.4 mm or 35%) for the membrane group and 1.0 mm (gain from BL 1.3 mm or 34%) the non-membrane sites. The gain of root coverage from baseline to 6 years turned out to be non-significant for the mem-





Fig. 4. (a) Pre-operative view of buccal recession type defect on 43 in a non-smoker (the same patient as in Fig. 3). (b) Surgical treatment of recession on 43: The mobilized flap was coronally positioned and anchored by an absorbable suture (non-membrane site). (c) Two weeks of healing following surgery on 43. (d) Six months postsurgical view of 43. A complete root coverage to cemento-enamel junction is obtained. (e) Six years postsurgical view of 43. The 6-month complete root coverage is still maintained. A ceramic crown has during the maintenance period been placed on 43.

Table 1b. Gingival recession (in mm) measured by manual probe from CEJ at baseline, 12 months, and 6 years ( $N = 11$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	4.0	1.0	3.0	6.0
Non-membrane	3.8	1.2	3.0	6.0
12 months				
Membrane	2.1	1.3	0.0	4.0
Non-membrane	1.5	1.4	0.0	4.0
6 years				
Membrane	2.6	1.5	0.0	4.0
Non-membrane	2.5	1.4	0.0	4.0

Six-year follow-up. Between treatment differences: \* $p < 0.05$ ;

Within treatment changes over time: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

NS, not significant; CEJ, cemento-enamel junction.

brane group ( $p = 0.09$ ) and significant for the non-membrane group ( $p < 0.05$ ). Few studies only have reported the long-

term effect of root coverage following mucogingival surgery, with conflicting results (Pini Prato et al. 1996, Scabbia

& Trombelli 1998, Harris 2002). While two studies reported stable 4-year follow-up results following coronally positioned flap plus membrane (Pini Prato et al. 1996, Scabbia & Trombelli 1998), Harris (2002) reported following the same surgical procedure statistically significant increase in recession (1.4 mm) and loss in attachment level (1.7 mm) between 6-month and the final post-operative evaluation (mean 25.3 months). These conflicting results are probably related to differences in selection of experimental defects (upper *versus* lower sites), in patients' daily oral hygiene, and in postoperative maintenance care.

The clinical buccal attachment level for 20 patients showed a mean gain at 6 months of 1.3 mm for the membrane group, and 1.7 mm for the non-membrane group. At 12 months, 1.5 mm mean gain in attachment level compared

Table 2a. Relative attachment level (in mm) measured by automated disc probe at baseline, 6, and 12 months ( $N = 20$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	13.3	1.5	11.2	15.8
Non-membrane	12.7	1.6	10.6	16.0
6 months				
Membrane	12.0	1.8	9.6	15.4
Non-membrane	11.0	1.8	7.8	14.0
12 months				
Membrane	11.8	1.7	9.2	15.0
Non-membrane	10.9	1.6	8.4	14.6

Between treatment differences: \* $p < 0.05$ ;Within treatment changes over time: \*\*\* $p < 0.001$ 

NS, not significant.

Table 2b. Relative attachment level (in mm) measured by automated disc probe at baseline, 12 months, and 6 years ( $N = 11$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	13.3	1.6	11.2	15.8
Non-membrane	13.3	1.8	10.6	16.0
12 months				
Membrane	11.9	1.7	9.8	15.0
Non-membrane	11.3	1.8	8.4	14.6
6 years				
Membrane	11.6	1.9	8.4	14.4
Non-membrane	11.8	1.9	9.6	15.6

Six-year follow-up. Between treatment differences;

Within treatment changes over time: \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

NS, not significant.

Table 3a. Width of gingival recession defects (in mm) at baseline, 6, and 12 months ( $N = 20$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	4.7	0.9	3.0	6.0
Non-membrane	4.5	1.0	3.0	6.0
6 months				
Membrane	3.6	2.0	0.0	6.0
Non-membrane	2.6	2.5	0.0	7.0
12 months				
Membrane	3.5	2.1	0.0	6.0
Non-membrane	2.9	2.3	0.0	6.0

Between treatment differences;

Within treatment changes over time: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

NS, not significant.

with baseline was recorded for the membrane group and 1.8 mm for the non-membrane group. The 6-year follow-up data for 11 patients exhibited a further non-significant increase in attachment gain of 0.3 mm for the membrane sites, while the non-membrane sites lost 0.5 mm. Clinical trials (Pini Prato et al. 1996, Scabbia & Trombelli 1998) and case reports (Pini Prato et al. 1992, Tinti et al. 1992, Harris 2002) of combined treatments have presented clinical attachment gains ranging from 2.84 to 5.12 mm. The probing depth measurements for the membrane and the non-membrane sites were stable from 12-month to 6-year follow-up indicating that the only possible explanation for loss of attachment in the non-membrane sites is an apical migration of the gingival margin. This assumption is confirmed by the gingival recession measurements showing a decrease in root coverage from 12 months to 6 years for the non-membrane group.

For both groups, the horizontal defect width reduction following surgery became stable up to 12 months. Then a slight rebound was observed for the membrane and for the non-membrane sites. Compared with baseline, both treatments showed at 6 years a modest, non-significant 0.6 mm reduction. These modest results are in harmony with a 12 months evaluation of root coverage following coronally positioned flap in combination with a biodegradable membrane (Müller et al. 2001). In shallow gingival recessions ( $< 3$  mm), this study reported a 50% root coverage of recession depth and a width reduction of only 11%. Collectively, these results may indicate that shallow recession defects are not good candidates for membrane treatment.

Historically, the presence of an "adequate" zone of gingiva has been considered critical for the maintenance of gingival health. In the present study the width of keratinized gingiva increased from 2.4 mm at baseline to 2.9 and 3.0 mm at 6 and 12 months, respectively, for the membrane group, and from 2.6 mm to 3.0 mm at both 6 and 12 months for the non-membrane group. At 6-year evaluation, both treatments showed a non-significant rebound to baseline level. Gain of keratinized gingiva has been reported in the majority of studies following surgical treatment of buccal gingival recession (Pini Prato et al. 1996, Trombelli & Scabbia 1997, Scabbia & Trombelli 1998). On the other



Table 3b. Width of gingival recession defects (in mm) at baseline, 12 months, and 6 years ( $N = 11$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	4.6	0.8	3.0	5.0
Non-membrane	4.6	0.9	3.0	6.0
12 months				
Membrane	3.6	1.9	0.0	5.0
Non-membrane	2.9	2.3	0.0	6.0
6 years				
Membrane	4.0	1.5	0.0	6.0
Non-membrane	4.0	1.2	2.0	6.0

Six-year follow-up. Between treatment differences;

Within treatment changes over time: \* $p < 0.05$ 

NS, not significant.

Table 4a. Width of keratinized tissue (in mm) at baseline, 6 months, and 12 months ( $N = 20$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	2.4	0.7	1.0	4.0
Non-membrane	2.6	0.5	2.0	3.0
6 months				
Membrane	2.9	0.7	1.0	4.0
Non-membrane	3.0	0.5	2.0	4.0
12 months				
Membrane	3.0	0.6	2.0	4.5
Non-membrane	3.0	0.5	2.0	4.0

Between treatment differences;

Within treatment changes over time: \* $p < 0.05$ ; \*\* $p < 0.01$ .

NS, not significant.

Table 4b. Width of keratinized tissue (in mm) at baseline, 12 months, and 6 years ( $N = 11$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	2.6	0.7	2.0	4.0
Non-membrane	2.6	0.5	2.0	3.0
12 months				
Membrane	3.1	0.6	2.0	4.5
Non-membrane	3.0	0.6	2.0	4.0
6 years				
Membrane	2.6	0.9	1.0	4.0
Non-membrane	2.6	0.7	1.0	3.0

Six-year follow-up. Between treatment differences;

Within treatment changes over time: \* $p < 0.05$ .

NS, not significant.

hand, some studies (Pini Prato et al. 1995, Tatakis & Trombelli 2000) have observed a very modest increase and even a decrease in the width of keratinized gingiva following coronally position flap procedure (Trombelli et al. 1997). The width of the keratinized gingival epithelium is probably influenced by inductive stimuli from the underlying connective tissue as well as by the genetically determined phenotype of the epithelial cells (Karring et al. 1975, De Luca et al. 1990). Evidently, only minor new connective tissue was formed following the surgical procedures in the present study.

Probing depth was included as a study parameter to potentially detect a direct negative effect of the therapy in terms of increasing buccal probing depth. At baseline, the mean probing depth was 1.4 mm for the membrane group and 1.3 mm for the non-membrane group and none of the included sites exceeded 3 mm. At 6-, 12-month, and 6-year observations, a minor reduction in mean probing depth was detected for both treatment groups. These findings compare well with other studies (Pini Prato et al. 1992, Tinti et al. 1992) indicating that increasing buccal probing depth is not a common side effect following root coverage procedures. Histological evaluation of the soft-tissue healing following membrane treatment (Cortellini et al. 1993, Parma-Benfenati & Tinti 1998, Vincenzi et al. 1998, Tatakis & Trombelli 1999, Harris 2001) have shown limited evidence of new cementum with inserting connective tissue fibers and variable amount of bone regeneration. Actually, one study reported loss of buccal bone (Harris 2001). However, a close adaptation of the new buccal soft tissue is probably an efficient obstacle for probe penetration.

The gingival thickness was only measured at the 6-year evaluation. The values of 0.9 mm in the membrane group and of 0.8 mm in the non-membrane group are within the range of previous measurements following mucogingival surgery (Müller et al. 1998, Müller et al. 2000). Most of the 12-month follow-up studies have experienced an initial increase in gingival thickness up to 3 months and thereafter a gradually decrease and stabilization at 9 months of about 1 mm (Müller et al. 1998, Müller et al. 2000). The initial increase in thickness may in part be because of a combination of a foreign body reaction to the biodegrad-

Table 5a. Facial probing depths (in mm) measured by the automated probe at baseline, 6, and 12 months ( $N = 20$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	1.4	0.5	0.4	2.6
Non-membrane	1.3	0.5	0.6	2.6
6 months				
Membrane	1.2	0.5	0.6	2.4
Non-membrane	1.0	0.5	0.2	1.8
12 months				
Membrane	1.3	0.5	0.4	2.8
Non-membrane	1.0	0.6	0.4	2.8

Between treatment differences: \* $p < 0.05$ ;  
 Within treatment changes over time;  
 NS, not significant.

Table 5b. Facial probing depths (in mm) measured by the automated probe at baseline, 12 months, and 6 years ( $N = 11$ )

Time/group	Mean	SD	Min	Max
Baseline				
Membrane	1.4	0.5	0.4	2.6
Non-membrane	1.3	0.6	0.6	2.6
12 months				
Membrane	1.2	0.5	0.4	2.0
Non-membrane	1.0	0.4	0.4	1.6
6 years				
Membrane	1.4	0.6	1.0	2.4
Non-membrane	1.0	0.6	0.4	2.4

Six-year follow-up. Between treatment differences;  
 Within treatment changes over time;  
 NS, not significant.

Table 6. Gingival thickness measured with an ultrasonic device at 6-year follow-up ( $N = 11$ )

Time/group	Mean	SD	Min	Max	P-value
6 years					
Membrane	0.89	0.16	0.7	1.1	0.107
Non-membrane	0.80	0.20	0.5	1.2	

able membrane and the formation of granulation tissue beneath the membrane (Tatakis & Trombelli 1999).

Cigarette smoking has been reported to negatively influence some mucogingival surgical procedures (Miller 1987, Trombelli & Scabbia 1997, Martins et al. 2004). This study included 20

subjects, among whom 12 were non-smokers and 8 were smokers. Smoking is a major environmental risk factor for developing periodontal diseases and also carries implications for non-surgical as well as surgical therapy (Preber & Bergström 1990, Linden & Mullally 1994). The mechanisms involved are

not fully understood, but smoking is hypothesized to impair the chemotactic as well as the phagocytotic cell activity (Palmer 1988) and probably also having a disturbing effect on fibroblastic cell replication (Ah et al. 1994). The present as well as other studies have not detected any statistically significant impact of cigarette smoking on root coverage procedures (Tolmie et al. 1991, Harris 1994, Scabbia & Trombelli 1998). Thus, the deleterious effect of smoking even in long-term follow-up studies seems to be limited on buccal surfaces.

Individual 6-year follow-up data revealed stable, root coverage outcomes on the membrane as well as on the non-membrane side in some patients, while the majority of the patients showed unstable, decreasing root coverage on both experimental sides over time. The patients were presurgically and at every maintenance visits instructed in a non-traumatizing brushing technique using a soft toothbrush. However, from 12 months and up to 6 years, the recall program was limited to once a year. The clinical long-term data may indicate that the majority of the patients only temporarily changed their abusive home care procedures and thereby compromising the long-term stability of the surgical treatment. On the other hand, some patients were probably able to permanently adopt to a non-traumatic brushing technique and maintain stable root coverage on both sides. These observations indicate that long-term outcome stability seems to be dependent on a continuous follow-up program with periodic re-instruction in non-traumatic brushing habits.

In conclusion, the present study has shown that the coronally positioned flap procedure provides a simple and predictable treatment of Miller Class I and Class II buccal gingival recessions. Placement of a biodegradable membrane underneath the flap does not seem to improve neither the short-term nor the long-term results.

## Acknowledgements

Sincere thanks are expressed to Ms. Margunn Eidsheim for secretarial assistance, to Mr. Rune Haakonsen for phototechnical assistance, to Dr. Knut A. Selvig for reviewing the manuscript, and to Guidor AB for providing the membranes.

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