Enhancing Guided Tissue Regeneration of Periodontal Defects by Using a Novel Perforated Barrier Membrane

Ahmed Y. Gamal* and Vincent J. Iacono †

Background: The present study was designed to determine whether exclusion of the gingival connective tissue (CT) and periosteum with contained stem cells has a positive or negative effect on periodontal regeneration by comparing the use of a novel modified perforated collagen membrane with a traditional cell occlusive barrier membrane.

Methods: Twenty non-smoking patients with severe chronic periodontitis were included in the study. Single deep intrabony defects from each of the patients were randomly divided into two groups, as follows: occlusive bovine collagen membranes (OM control group, 10 sites) and modified perforated bovine collagen membranes (MPM test group, 10 sites). Plaque index, gingival index, probing depth (PD), clinical attachment level (CAL), defect base level (DBL), and crestal bone level (CBL) were measured at baseline and were reassessed at 6 and 9 months after therapy to evaluate the quantitative changes in the defect.

Results: At 6- and 9-month observation periods, the MPM-treated sites showed a statistically significant improvement in PD reduction and CAL gain compared with the OM control group. DBL was significantly reduced with no significant difference between the two groups at 6- and 9-month observation periods. CBL was significantly higher in the MPM group when compared with that of the OM group at both observation periods. The postoperative differences between the two groups were 2 and 1.7 mm at 6 and 9 months, respectively, in favor of the MPM-treated sites.

Conclusions: The present study demonstrated enhanced clinical outcomes when using novel MPMs compared to OMs in guided tissue regeneration procedures. These results may be affected by the penetration of gingival CT contained stem cells and periosteal cells and their differentiation into components of the attachment apparatus. J Periodontol 2013;84: 905-913.

KEY WORDS
Collagen; connective tissue; guided tissue regeneration, periodontal.

The aims of any periodontal therapy are to arrest and control periodontal infection and ultimately to regenerate lost periodontal structures. Because of differences in the healing abilities of different periodontal tissues, full regeneration of the periodontium following different periodontal treatment modalities has been difficult to achieve. A number of resorbable and non-resorbable guided tissue regeneration (GTR) materials have been proposed to exclude epithelium and the gingival corium from the root to delay epithelial downgrowth during healing and to provide an opportunity for the progenitor cells of the periodontal ligament and bone to repopulate previously diseased root surfaces. Several studies in animals and in humans have demonstrated that different levels of periodontal regeneration can be achieved with GTR. Non-resorbable membranes made of expanded polytetrafluorethylene are the most widely investigated barrier membranes. The use of bioresorbable barriers, such as collagen, polyactic acid, and polyglycolic acid, was found to solve several of the shortcomings of the non-resorbable membranes. Bioresorbable barriers eliminate the need for a second surgery to remove the membrane and
decrease the associated disturbances of the newly formed osteoid that may result in bone resorption.

Multiple factors influence the predictability of treatment outcomes after GTR procedures. Clinically, the amount of new attachment achieved may be directly related to patient factors (oral hygiene, smoking, and systemic health), root anatomy, and the surgical technique.\textsuperscript{10-13} The degree of periodontal breakdown and the remaining periodontal–osseous components (depth, width, and number of osseous walls) are other critical factors that may cause wide variations in the outcome of GTR. Perhaps the most important factor that affects GTR treatment outcome is periosteal isolation. During a GTR procedure, the periosteum is elevated with the flap, and the barrier is placed over the defect, thereby excluding any contribution of mesenchymal stem cells and osteoblasts from the periosteum. This actually deprives the wound area of the regenerative power of the periosteum, limiting the number of progenitor cells and the amount of biologic mediators required to repopulate periodontal defects. In addition, recent isolation of gingival stem cells from the gingival connective tissue (CT) elements makes it necessary to reevaluate gingival CT guided tissue membrane isolation. A new population of stem cells from human gingiva, namely, gingival mesenchymal stem cells (GMSCs), was isolated.\textsuperscript{14-16} They exhibited clonogenicity, self-renewal, and multipotent differentiation capacities. These cells were capable of immunomodulatory functions, specifically suppressing peripheral blood lymphocyte proliferation.\textsuperscript{17} Therefore, by isolation of the wound area from this important source of stem cells that has the capacity to differentiate into any other CT elements through the use of traditional guided tissue membranes, the periodontal defect seemed to be deprived of an important source of regeneration.

The present study was designed to determine whether exclusion of the gingival CT and periosteum with contained stem cells has a positive or negative effect on periodontal regeneration. The authors evaluated the clinical effectiveness of the traditional use of occlusive guided tissue membranes (OM) with full-thickness flap reflection that isolates the periosteum and gingival CT from the defect area compared with the use of a novel modified perforated membrane (MPM) with a dense collar that inhibits epithelial downgrowth and a perforated body that could permit gingival CT with its contained stem cells and periosteal osteoblasts as well as stem cells and mediators to enhance periodontal regeneration (Fig. 1).

**MATERIALS AND METHODS**

**Participant Selection**

Twenty non-smoking patients (12 males and eight females), who were 29 to 44 years old at the time of baseline examination (mean age: 32.7 ± 6.1 years) with severe chronic periodontitis, participated in this single-masked preliminary comparative study. Patients were selected from individuals seeking care for periodontal problems at the Department of Periodontology of the Faculty of Dental Medicine, Al Azhar, Cairo, Egypt, from February 2011 to January 2012. The criteria implemented for patient inclusion were as follows: 1) no systemic diseases that could influence the outcome of the therapy; 2) good compliance with the plaque-control instructions after initial therapy; 3) teeth involved were all vital; 4) each participant contributed one interproximal intrabony defect of the premolar or molar teeth; 5) selected probing depths (PDs) were ≥6 mm and clinical attachment levels (CALs) were ≥4 mm 3 weeks after initial therapy; 6) intrabony defects had a minimum depth of 3 mm as detected in diagnostic periapical radiographs; and 7) no or <1 mm gingival recession to allow for supracrestal membrane coverage. Pregnant females were excluded from participating in the study. Patients also were excluded from the study if they presented with inadequate compliance with the oral hygiene maintenance schedule. Research procedures were explained to all patients, and they agreed to participate in the study and signed the appropriate informed consent form of Al Azhar University. The experimental protocol was approved by the Ethical Committee of Al Azhar University (OMD-50012).
Presurgical Therapy and Grouping

Initial therapy consisted of a thorough full-mouth scaling and root planing for all teeth under local anesthesia. This procedure was performed using a combination of hand curets and ultrasonic scaler using the P10 tip. Patients were recalled every other day for 3 weeks and received detailed mechanical plaque-control instructions, which consisted of brushing using a soft toothbrush with a roll technique and flossing. Supragingival plaque removal was performed whenever necessary.

Three weeks after initial therapy, a reevaluation was performed to confirm the need for GTR pocket reconstructive surgery for the selected sites. Criteria used to indicate that surgical treatment was required included the following: 1) the persistence of an interproximal site with PD ≥6 mm and CAL ≥4 mm and 2) interproximal intrabony defects of ≥3 mm. Teeth were randomly assigned to either occlusive bovine collagen membranes (OM control group, 10 sites) or modified perforated bovine collagen membranes (MPM test group, 10 sites). Baseline data for all sites were collected just before the surgical phase of treatment and included plaque index (PI), gingival index (GI), PD, and CAL measurements that were taken with a combination of hand curets and ultrasonic scaler.

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Surgical Procedure

The surgical treatment phase was initiated only if the patient had a full-mouth dental plaque score of <1. After the administration of local anesthesia, patients were assigned to one of the two treatment groups by the selection of sealed envelopes containing a paper labeled “OM” or “MPM.” Immediately before surgery, the treating surgeon (AYG) opened an envelope dictating treatment assignment. OM-selected sites received buccal and lingual crestal internal bevel incisions starting from the gingival margin to the alveolar crest, exposing all of the gingival CT. For better access to the surgical site or to achieve better closure, in most cases, the flap was extended one or two teeth mesially or distally. Mucoperiosteal flaps on the facial and lingual aspects of each involved site were raised, exposing ≥3 mm of the alveolar bone beyond the defect margin. Vertical releasing incisions were used when necessary. Incisions were designed to preserve as much of the interproximal tissue as possible. Debridement of all inflammatory granulation tissue from the intrabony defect was performed until a sound, healthy bone surface was obtained. The teeth were root planed thoroughly using hand and ultrasonic instruments to obtain a smooth and hard root surface. During surgery, the intrabony defect depth and morphology were characterized by recording the number of bony walls. Defects needed to have a minimum depth of 3 mm (as measured from the most coronal point of the bony walls surrounding the defect to the deepest point in the defect) and present with two or three bony walls, measuring the DBL as the distance in millimeters from the CEJ to the base of the defect and the CBL as the distance from the CEJ to the alveolar crest. Collagen membranes were hydrated in sterile saline, trimmed according to the template prepared for each defect, and adapted over the defects in such a manner that the entire defect and ≥2 to 3 mm of the surrounding alveolar bone was completely covered to avoid membrane collapse within the defect. The membranes were extended supracrestally 1 mm below the CEJ to ensure optimum gingival CT involvement in

El Gendy, Faculty of Dentistry, Al-Azhar University, Cairo, Egypt, who was not involved in the study in any other way. Intraexaminer reproducibility was assessed with a calibration exercise performed on two separate occasions, 48 hours apart. Calibration was accepted if ≥90% of the recordings could be reproduced within a difference of 1.0 mm.
supracrestal wound healing. Collagen membranes were simply adapted in place according to the surgical protocol of the manufacturer without suturing. The adhesion of membranes to bone and root surface precluded the need for suturing the membranes. Periosteal releasing incisions were made whenever needed to permit tension-free coronal positioning of the flaps and complete coverage of the membranes. The mucoperiosteal flaps were repositioned to cover the membranes and then stabilized with 4-0 polyglactin sutures‡‡ using an interrupted suturing technique. The same procedures were performed for MPM-selected sites except for using perforated collagen membranes with an occlusive collar.

Postoperative Care
All patients received oral and written postoperative instructions. Patients were prescribed 500 mg amoxicillin§§ four times a day for 1 week. Oral analgesics (600 mg ibuprofen, every 8 hours as necessary) were also dispensed. During this initial healing phase, plaque control efforts were supplemented with chlorhexidine mouthrinse for 1 minute (0.12% chlorhexidine digluconateii) three times daily for 2 weeks. The patients were instructed to refrain from toothbrushing and interdental cleaning at the surgical areas during this time. Sutures that loosened prematurely were removed. Sutures were removed 14 days postoperatively, and recall appointments for observation of any adverse tissue reaction and oral hygiene reinforcement were scheduled every second week during the first 2 months after surgery. All patients were instructed to resume their normal mechanical oral hygiene measures, which consisted of brushing using a soft toothbrush with a roll technique and flossing 1 month after surgery. Periodontal maintenance of oral hygiene reinforcement and supragingival scaling, whenever necessary, were performed during each recall appointment. Clinical measurements using the acrylic stents and radiographic measurements were reassessed at 6 and 9 months after therapy to evaluate the quantitative changes in the defects.

Statistical Analyses
Data were presented as mean and standard deviation values. The main outcome variable was the CAL values, and the secondary variables were all the other clinical parameters. Repeated-measures analysis of variance (ANOVA) test was used to study the effect of time, group, and time × group interaction on PD, CAL, DBL, and CBL parameters. Bonferroni test was used for pairwise comparisons when ANOVA test was significant. Friedman test was used to study the effect of time on PI and GI scores. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with statistical software.¶¶

RESULTS
During the course of the study, all patients exhibited good compliance, with uneventful postoperative healing and good soft tissue response to both treatments. Patients in both groups exhibited consistent and comparable oral hygiene standards. All patients continued their clinical follow-up visits. All patients tolerated the surgical procedures well; no site had to be eliminated, and no cases of flap dehiscence or infection were detected. Minimal swelling of soft tissues surrounding the operated areas was observed during the early days of healing. Complete gingival wound closure for primary intention healing was accomplished for all defect sites. Nevertheless, membrane exposure was a common event in both groups. It was observed at 2 to 3 weeks after surgery with minimal inflammation in three of the OM-treated sites and four of the MPM-treated sites. It was decided to include their records in the data analyses.

The OM group consisted of four maxillary and six mandibular teeth: two maxillary premolars, two maxillary first molars, one mandibular premolar, and five mandibular molars. The MPM group consisted of three maxillary and seven mandibular teeth comprising the following tooth types: two maxillary premolars, one maxillary first molar, four mandibular

‡‡ Vicryl, Ethicon, Johnson & Johnson, Somerville, NJ.
§§ October Pharma, Cairo, Egypt.
ii Oraldine, Kahera Pharmaceutical, Cairo, Egypt.
¶¶ SPSS, IBM, Chicago, IL.
premolars, and three mandibular molars. Bony-wall-treated defects were distributed as follows: for OM sites, five predominately 2-wall and five predominately 3-wall defects; for MPM sites, four predominately 2-wall and six predominately 3-wall defects. Table 1 shows the individual defect location and anatomic characteristics.

A summary of defect characteristics 3 weeks after initial therapy (baseline) for both groups are provided in Table 2. The periodontal status of the two studied groups was demonstrated using the mean and standard deviation for the appropriate clinical measurements: PI, GI, PD, CAL, CBL, and DBL. No statistically significant differences were found preoperatively between treated sites of both groups with respect to soft and hard tissue measurements ($P > 0.05$). All GI and PI scores were within clinically healthy parameters (score $< 1$). The defects had deep PDs and advanced CAL and were associated with deep intrabony defects.

Table 2 indicates the mean, the mean differences, and degree of significance of probing measurements 6 and 9 months after surgery between both groups and compared with baseline. The mean PI and GI were initially low; it remained unchanged by 6 and 9 months for both groups. There were no statistically significant differences between the initial and 6- or 9-month values or between the groups ($P > 0.05$). Target teeth were free of gingival inflammation and plaque before surgery and at the end of the study. Patients were kept under a strict maintenance program, and the overall plaque accumulation was minimal.

Comparison by time for the MPM and OM groups revealed a significant reduction in PD (baseline versus 6 and 9 months, $P \leq 0.05$). The differences between 6 and 9 months were not significant for both the OM and MPM groups ($P > 0.05$). CAL was significantly reduced for both groups when compared to the initial measurements at the 6- and 9-month observation periods ($P \leq 0.05$). The differences between 6 and 9 months were not significant for both OM and MPM groups ($P > 0.05$). DBL was significantly reduced when compared with baseline for both treatments at the 6- and 9-month observation periods. The 9-month observation period showed a statistically significant reduction of the DBL when compared with that of 6-month data for both MPM and OM groups.

For the OM group, CBL was reported at 6-month observation periods when compared with that of the baseline. Postoperative CBL at 6 months reduced by 0.9 mm, which was statistically lower than that of the baseline value. At 9 months, it approached the baseline measures with no statistically significant difference. MPM group showed a statistically significant gain of the CBL at both observation periods when compared with the initial values. There were no statistically significant differences between both observation periods (Table 2).

Comparison between groups revealed that, at the 6- and 9-month observation periods, the MPM-treated sites showed a statistically significant improvement in PD reduction compared with the OM control group. No significant difference was reported between the two

### Table 1.

**Individual Defect Location and Anatomic Characteristics**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Tooth Number and Surface</th>
<th>Defect Type</th>
<th>Bony Walls Present</th>
<th>Tooth Number and Surface</th>
<th>Defect Type</th>
<th>Bony Walls Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 M</td>
<td>2-Wall</td>
<td>DL</td>
<td>5 M</td>
<td>3-Wall</td>
<td>BLD</td>
</tr>
<tr>
<td>2</td>
<td>3 M</td>
<td>3-Wall</td>
<td>BLD</td>
<td>30 M</td>
<td>2-Wall</td>
<td>BL</td>
</tr>
<tr>
<td>3</td>
<td>19 M</td>
<td>3-Wall</td>
<td>BLD</td>
<td>29 D</td>
<td>3-Wall</td>
<td>BLD</td>
</tr>
<tr>
<td>4</td>
<td>19 D</td>
<td>2-Wall</td>
<td>BL</td>
<td>30 M</td>
<td>2-Wall</td>
<td>BM</td>
</tr>
<tr>
<td>5</td>
<td>12 M</td>
<td>2-Wall</td>
<td>BD</td>
<td>12 M</td>
<td>3-Wall</td>
<td>BLD</td>
</tr>
<tr>
<td>6</td>
<td>30 M</td>
<td>3-Wall</td>
<td>BLD</td>
<td>19 D</td>
<td>3-Wall</td>
<td>BLD</td>
</tr>
<tr>
<td>7</td>
<td>30 M</td>
<td>3-Wall</td>
<td>MDL</td>
<td>30 D</td>
<td>3-Wall</td>
<td>BLD</td>
</tr>
<tr>
<td>8</td>
<td>3 D</td>
<td>2-Wall</td>
<td>BD</td>
<td>3 D</td>
<td>2-Wall</td>
<td>BD</td>
</tr>
<tr>
<td>9</td>
<td>31 M</td>
<td>2-Wall</td>
<td>BD</td>
<td>28 M</td>
<td>3-Wall</td>
<td>BLD</td>
</tr>
<tr>
<td>10</td>
<td>29 M</td>
<td>3-Wall</td>
<td>BLD</td>
<td>28 M</td>
<td>2-Wall</td>
<td>BD</td>
</tr>
</tbody>
</table>

$B =$ buccal; $D =$ distal; $L =$ lingual; $M =$ mesial.
observation periods. CAL was statistically higher for MPM when compared with that of the OM-treated sites at both the 6- and 9-month observation periods \((P \leq 0.001)\) (Table 3).

DBL was significantly reduced with no significant difference between the two groups at the 6-month observation period. Nine-month data revealed more significant defect base fill compared with that of the 6-month values for both groups. CBL was significantly higher in MPM group when compared with that of the OM group at both observation periods \((P \leq 0.001)\) (Table 3).

**DISCUSSION**

The principle of GTR was based on the exclusion of gingival CT cells from the wound and prevention of epithelial downgrowth.\(^{22}\) These procedures allow cells with regenerative potential (periodontal ligament, bone cells, and possibly cementoblasts) to enter first into the wound site. Although significant progress has been made toward understanding the factors and cells involved in the regeneration of the periodontium, the function and the relative contribution of gingival CT in the regenerative environment is still not entirely understood. Researchers suggested that gingival CT cells lacked the potential for regeneration.\(^{23,24}\) However, later studies have reported that gingival CT cells may also contribute to the regenerative process.\(^{25-30}\)

Recently, a new population of stem cells from human gingiva, GMSC\(^{14-16}\) that exhibit clonogenicity, self-renewal, and multipotent differentiation capacities, were isolated. Therefore, isolation of the wound area from this important source of stem cells that has the capacity to differentiate into any other CT elements appears to be a loss of a great source of regeneration in periodontal defects that suffer from a limited regenerative power.

The present study is designed to clinically evaluate a novel permeable collagen guided tissue membrane (MPM) and to compare its outcome with the traditional OMs. Collagen membrane selection was based on the fact that type I collagen is the main constituent of periodontal CT. In addition, collagen materials exhibit chemotactic function for gingival fibroblasts and osteoblast adhesion activity.\(^{31-33}\) Absorbable collagen barriers have proven to achieve better PD reduction, CAL gain, and defect fill than open-flap debridement and were equally successful in comparative studies with non-resorbable membranes.\(^{34-39}\) The concept of porous guided tissue membrane has been tested recently as a modality that could stimulate bone formation of critical-sized bone defects. Kim et al.\(^{40}\) claimed that asymmetrically porous guided bone regeneration membranes with dual bone morphogenetic protein-2 and ultrasound stimulation may be promising for the clinical treatment of delayed and insufficient bone healing. For GTR in periodontal therapy, membrane perforations could allow for gingival stem cells and periosteal cells to take part in supracrestal regeneration. The perforated section of the membranes would stabilize supracrestal fibrin clot through mechanical interlocking of fibrin strands, with the membrane pores providing more membrane and clot stability. It has been suggested that regenerative failures may result when the tensile strength of the fibrin clot is exceeded, resulting in a tear and a long junctional epithelium-type attachment.\(^{41}\) Mobility of the flap (wound margin) positioned directly adjacent to the potential regenerative site may be a potential cause of this tear.\(^{2}\) Placement of a perforated membrane could allow for more flap stability through membrane pores–gingival CT integration from one side and membrane pore-clot integration from the opposing side. In addition, the authors

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**Table 2.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group OM (mean ± SD)</th>
<th>Group MPM (mean ± SD)</th>
<th>(P)</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD (mm)</td>
<td>6.5 ± 0.5</td>
<td>6.8 ± 0.6</td>
<td>&lt;0.001 *</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>CAL (mm)</td>
<td>5.6 ± 0.7</td>
<td>5.3 ± 0.4</td>
<td>&lt;0.001 *</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>DBL (mm)</td>
<td>9.4 ± 1.0</td>
<td>9.1 ± 0.7</td>
<td>&lt;0.001 *</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>CBL (mm)</td>
<td>5.6 ± 0.7</td>
<td>5.8 ± 0.8</td>
<td>&lt;0.001 *</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>PI</td>
<td>0.3 ± 0.2</td>
<td>0.5 ± 0.2</td>
<td>0.883</td>
<td></td>
</tr>
<tr>
<td>GI</td>
<td>0.4 ± 0.0</td>
<td>0.4 ± 0.1</td>
<td>0.899</td>
<td></td>
</tr>
</tbody>
</table>

Different letters in the same row are statistically significantly different.

* Statistically significant difference at \(P \leq 0.05\).
hypothesized that early gingival CT–root surface adhesion achieved by membrane perforations would eventually provide additional protection against epithelial downgrowth.

Guided tissue membrane applications are usually indicated to treat intrabony defects that protect the blood clot or the clot blended with graft material and provide the defect area with the necessary elements required for regeneration. Supracrestal periodontally affected components are usually lacking the regenerative power because of their anatomic limitations as non-contained defects bordered by epithelial-covered gingival CT from one side and a periodontally affected avascular root surface from the opposing side. Complete isolation of the supracrestal part of the defects with an OM coverage will eventually lead to root surface epithelialization. The use of the MPM will allow gingival CT cells and periosteal cells to repopulate the supracrestal part of the root surface. In the absence of epithelium via the occlusive collar, supracrestal healing will eventually occur by either connective attachment to the root surface via gingival CT and fibroblast–root surface adhesion or enhanced true periodontal regeneration if the gingival stem cells are stimulated by surgical trauma. Mesenchymal stem cells were found to display chemotactic properties similar to immune cells in response to tissue insult and inflammation, thus exhibiting tropism for the sites of injury via production of anti-inflammatory cytokines and anti-apoptotic molecules.42-44

Membrane exposure was a common event in both the MPM and OM groups. It was decided to include the results of the involved cases because it was expected to have a high percentage of membrane exposure as a result of the placement of the membranes in a more supracrestal position just apical to the CEJ to allow for gingival CT healing contribution. Machtei45 reported that, if proper preoperative and postoperative anti-infective care is provided, membrane infection can be controlled and good regenerative results obtained. The present study reveals that MPM-treated sites showed a statistically significant improvement in PD reduction compared with the OM control group. This was associated with a statistically higher CAL in favor of the MPM group at both the 6- and 9-month observation periods (CAL gain of 3 and 3.3 mm for MPM versus 1.7 and 2.1 mm for OM at 6 and 9 months, respectively) (Table 3). OM CAL improvement is in agreement with the conclusions of a systematic review46 that showed that intrabony defects treated with collagen barriers without grafting materials resulted in a mean CAL gain of 2.44 mm, with a range of 2.0 to 2.58 mm. MPM single therapy attachment gain reported in the present study was superior to that of the reported OM CAL gain and comparable to that of the collagen barriers with graft material of the same systematic review46 in which a mean CAL gain of 3.48 mm, with a range of 2.3 to 4.1 mm, was reported. These findings support the hypothesis that it was the presence of the perforated membrane that allowed gingival CT population to the root surface, contributing positively in improving CAL. Furthermore, gingival CT invasion to membrane perforations may contribute to wound stability, which is a crucial factor for obtaining periodontal regeneration.47 This may also be the reason why a lesser gain in CAL was observed in the control group relative to MPM.

The significant reduction in DBL with no significant difference between the two study groups (Table 3) revealed that both OM and MPM reported a similar level of intrabony defect base protection. However, the significantly higher CBL that was reported in the MPM group when compared with that of the OM group at both observation periods could reflect the enhanced osteogenic effect of periosteal active charity through membrane perforations in contrast to periosteal isolation by OMs. Yadav et al.48 reported crestal bone resorption of 0.5 mm at 6 months after the use of OMs for treating intrabony defects.

## Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline to 6 Months</th>
<th>Baseline to 9 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OM</td>
<td>MPM</td>
</tr>
<tr>
<td>PD (mm)</td>
<td>2.9 ± 0.8</td>
<td>3.7 ± 0.7</td>
</tr>
<tr>
<td>CAL (mm)</td>
<td>1.7 ± 0.7</td>
<td>3.0 ± 0.9</td>
</tr>
<tr>
<td>DBL (mm)</td>
<td>−1.8 ± 0.4</td>
<td>−2 ± 0.5</td>
</tr>
<tr>
<td>CBL (mm)</td>
<td>1 ± 0.4</td>
<td>−1.1 ± 0.3</td>
</tr>
</tbody>
</table>

Values are mean ± SD. * Statistically significant difference at P ≤0.05.
CONCLUSIONS

In conclusion, the present study demonstrates enhanced clinical outcomes when using novel MPM compared with OM in GTR procedures. These results may be affected by the penetration of gingival CT contained stem cells and periosteal cells and their differentiation into components of the attachment apparatus. More studies are required to investigate the feasibility of specific gingival stem cell stimulation to differentiate into cells involved in true periodontal regeneration. In addition, studies with a larger sample size and long-term observations would verify the findings presented.

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