This report describes the clinical application of an in situ formed barrier of poly(DL-lactide) used in combination with a composite graft of demineralized freeze-dried bone allograft (DFDBA) mixed with calcium sulfate and tetracycline in a ratio of 7:2:1 and citric acid root conditioning for the treatment of intrabony and furcation defects. The clinical outcome was assessed by changes in clinical attachment level (CAL) and probing depth (PD) in 18 consecutively treated patients with 17 intrabony and 5 furcation lesions. After patients demonstrated acceptable oral hygiene, the lesions were surgically treated with combination therapy using an in situ formed barrier over a DFDBA composite graft. Patients followed a stringent postoperative protocol and were evaluated at 6 months postsurgery. CAL improved for all sites from a presurgical average of 8.8 ± 2.3 mm to 4.4 ± 1.6 mm at 6 months postsurgery (4.4 ± 1.5 mm gain), while PD was reduced from an average of 8.3 ± 2.1 mm presurgery to 3.3 ± 1.1 mm at 6 months postsurgery (5.0 ± 1.8 mm reduction). Five furcations were treated, of which 4 were Class II and 1 was Class III. Of these furcation lesions, 3 had complete clinical closure, while 1 improved by 1 grade. The Class III furcation remained the same. Results suggest that DFDBA composite graft covered by an in situ formed barrier on root surfaces treated with citric acid can enhance the prognoses of teeth with periodontal lesions as measured by CAL gains and PD reductions. Further studies are warranted to compare this treatment to other more traditional forms of regenerative therapy to determine its comparative efficacy. J Periodontol 1999;70:554-561.

KEYWORDS
Furcation/therapy; guided tissue regeneration; polylactic acid/therapeutic use; grafts, bone; bone, freeze-dried; bone, demineralized; periodontal regeneration.

Regeneration of the periodontium to its pre-diseased state is the optimal therapeutic goal for clinicians, allowing patients to preserve their dentition in a state of health, comfort, and function for a lifetime. Demineralized freeze-dried bone allograft (DFDBA) is a material that has demonstrated regenerative capabilities in humans.1-3 Combining DFDBA’s use with a barrier material such as expanded polytetrafluoroethylene (ePTFE) has been done in an effort to enhance regenerative outcomes beyond those of a single technique.4-9 The barrier provides added wound stability,10 space maintenance,11,12 epithelial exclusion13,14 and graft containment. Several studies have shown in Class II furcations that the combination of a graft and barrier membrane results in clinically superior outcomes compared to either the graft alone6,7 or to the ePTFE barrier alone.4,5,9 A re-entry study by Guillem et al.8 has also shown trends towards greater bone fill with a combined approach compared with DFDBA alone. Sites with a combined approach had 71% bone fill while those with DFDBA alone had 58% bone fill.

Recent efforts have been aimed at developing bioabsorbable materials that maintain the qualities desired for a barrier in either a combined approach with a graft material or in guided tissue regeneration without bone graft replacements. All of these barriers carry the benefit of avoiding a second-stage surgery for their removal. However, the surgical placement of these materials, with the exception of calcium sulfate, involve trimming, fitting, and suturing the barrier material to its final shape and position, making such procedures less user-friendly than optimally desired.

A novel technique to barrier placement has recently been introduced in which a polymer of poly(DL-lactide) in a carrier of N-methyl-2-pyrrolidone5 can be flowed and precipitated in situ to form a custom-fitting barrier for a combined regenerative approach.15 A preliminary study16 of the preset form of the product indicated this material to be safe, non-toxic, bioabsorbable, and efficacious. A pilot17 and multi-center study18 in Class II furcations have indicated favorable regenerative outcomes with its use.
The purpose of this paper is to report on the clinical outcomes of an in situ method of forming a poly(DL-lactide) barrier for use in combination with a DFDBA composite graft in consecutively treated patients with intrabony and furcation lesions.

**MATERIALS AND METHODS**

This report describes clinical outcomes of consecutively treated patients who were referred to a private practice limited to periodontics for evaluation and treatment of their periodontal needs. All patients were in good systemic health and underwent initial therapy in either the office of their general dentist or the periodontist. Plaque control orientation was performed in the periodontal practice until an excellent level was achieved, with deposits being either absent or minimal. These instructions consisted of a minimum of 2 visits outside the dental operatory environment where plaque disclosure, technique demonstration and performance were reinforced. Occlusal therapy consisted of bite adjustment or splinting of the teeth to reduce excessive mobility or fremitus patterns. Examination included assessments of periodontal probing depth (PD) and clinical attachment level (CAL). The PD represented the greatest distance from the gingival margin to the base of the pocket, whereas CAL measured the distance from the cemento-enamel junction, crown, or restoration margin to the base of the pocket. Furcation invasion was assessed using the Glickman classification scheme. Clinical closure was determined by a Nabers probe and complete closure was defined as the inability to introduce this probe into the furcation.

Patients rinsed immediately prior to the surgery with a 0.12% chlorhexidine mouthwash. All measurements were performed by the surgical operator (PSR) using a calibrated 15 mm long probe and rounded to the nearest millimeter. A sulcular incision with full-thickness flap was employed. The defects were thoroughly debrided and the roots scaled and planed with ultrasonic and hand instruments. Rotary high-speed instrumentation with flame-shaped finishing burs was used for additional root debridement. Citric acid (pH 1) was applied for further root debridement by vigorously rubbing the roots with moistened cotton pellets for approximately 2 minutes. Intrabony defects were categorized by their morphology. Intramarrow penetration was performed to increase the communication to the marrow vascular spaces. If large ledges or exostoses were present in the surgical area, they were removed/reduced through osteoplasty to aid in primary closure. Defects were treated with a composite graft of DFDBA mixed with calcium sulfate and tetracycline in a ratio of approximately 7:2:1. A composite graft was hydrated with sterile saline and placed with light incremental pressure to fill the intrabony or furcation lesions. The polymer was applied directly over the graft by expressing it from its dose pack through an 18-gauge, 1 inch-long blunt needle after warming to room temperature for a minimum of 20 minutes prior to use. After placement, a high-speed handpiece delivered an atomized spray of sterile water for approximately 30 seconds to form the barrier. This was determined by the surface beginning to opacify. Any portion of the DFDBA not covered with the initial application received additional polymer to fill any voids or gaps. Flaps were positioned over intrabony defects to obtain primary closure. In furcation areas, the flaps were coronally positioned. Suturing was performed with interrupted monofilament 4-0 sutures. A periodontal dressing was placed over the site for 14 days. The dressing was changed at 1 week. The patient was prescribed amoxicillin 2 g immediately postoperative, then 500 mg 3 times daily for 10 days, followed by doxycycline 100 mg twice on the first day and 100 mg per day for an additional 13 days. For patients allergic to amoxicillin, the doxycycline regimen was followed for a total of 21 days. The patients were seen every 7 to 10 days for postoperative treatment during the first month. Sutures were removed at either the first or second visit. Patients were then seen every other week for the second month, and every month for up to 6 months. Postoperative visits included plaque debridement, selective stain polishing, and oral hygiene reinforcement. Patients used chlorhexidine as a postoperative oral rinse and topically swabbed the area for the first 30 days. After 30 days, patients began rinsing with an essential oil mouthrinse twice per day. Patients were instructed to neither brush nor floss the surgical area for the first 4 to 6 weeks and continued to topically apply the chlorhexidine throughout this period. Re-examination of PD and CAL was performed 6 months post-surgery. Selective re-entry was performed for several of the sites. Several case examples (Figures 1A through 1H and 2A through 2J) are presented to demonstrate results seen in this study.
Figure 1A. Pretreatment photograph of the maxillary left first premolar in a 49-year-old male patient demonstrating 11 mm of both clinical attachment loss and probing depth.

Figure 1B. Flap reflection reveals a 2-wall intrabony lesion with a significant concavity at the mesial aspect of the first premolar root.

Figure 1C. Probe in place demonstrates the depth of the intrabony component and the distance to the cemento-enamel junction.

Figure 1D. Following the treatment of the root surfaces with rotary high-speed instrumentation and citric acid root conditioning, the lesion is decorticated and the DFDBA composite graft is placed to slightly overfill the defect.

Figure 1E. The barrier is placed over the graft material by expressing it through a blunt 18-gauge needle that was directly attached to the dose pack. Note that the barrier conforms nicely to the root anatomy.

Figure 1F. The site is closed with 4-0 monofilament sutures and the flaps have been placed to their original position.

Figure 1G. The attachment level has shown improvement of 7 mm from its pretreatment level.

Figure 1H. Re-entry photo at 7.5 months shows complete fill of the intrabony defect with hard tissue while the height of bone at the distal of the canine has been preserved. There is some suggestion of supracrestal apposition at the midpoint of what was the intrabony lesion.
Figure 2A. Pretreatment view of the distal aspect of the mandibular right second molar in a 41-year-old female. The lesion had 9 mm of clinical attachment loss and probing depth.

Figure 2B. Pretreatment radiograph suggests an intrabony lesion at the distal of tooth 31.

Figure 2C. Reflection of the area shows the broad 3-wall intrabony lesion present at the distal of the second molar.

Figure 2D. DFDBA composite graft was placed to fill the lesion after treating the root surface with citric acid.

Figure 2E. The barrier has been applied in situ and is formed by applying an atomized sterile water spray with the high-speed handpiece.

Figure 2F. The midcrest incision has been closed with monofilament 4-0 sutures.

Figure 2G. Postoperative view at 6 months shows favorable soft tissue healing.

Figure 2H. Probe in place shows a gain of 6 mm in attachment level and also a 6 mm reduction in probing depth from the original 9 mm.

Figure 2I. Radiograph taken at 6 months postsurgery suggests favorable hard tissue fill of the lesion.

Figure 2J. Re-entry performed at 6.5 months post-treatment confirms the hard tissue fill.
RESULTS
A total of 22 patients with 28 lesions who ranged from 20 to 72 years of age were treated with this combined technique. Of these patients, 18 (average age 45.1 years) with 22 lesions completed the prescribed care and were available for postoperative follow-up at 6 months. Of the 4 who were not evaluated, 1 moved from the area, 1 failed to comply with postoperative prescribed visits, and 2 were unavailable for follow-up evaluation. A total of 17 intrabony and 5 furcation lesions evaluated at 6 months are reported. The average CAL at pretreatment was 8.8 ± 2.3 mm (range 5 to 13 mm), while PD was 8.3 ± 2.1 mm (range 5 to 12 mm) for all sites. Six-month results showed mean residual CAL of 4.4 ± 1.6 mm (range 1 to 9 mm) and mean residual PD of 3.3 ± 1.1 mm (range 1 to 5 mm). These changes represent a mean gain of 4.4 ± 1.5 mm for CAL and a mean reduction of 5.0 ± 1.8 mm for PD (Table 1 and Fig. 3).

Looking at the 17 intrabony sites alone, the CAL at pretreatment was 8.8 ± 2.1 mm and PD was 8.2 ± 1.9 mm. Six-month results demonstrated a gain of 4.1 ± 1.4 mm in CAL and a reduction of PD by 4.7 ± 1.6 mm (Table 2 and Fig. 4).

There were 5 furcations treated in the mandible and maxilla. All were buccal Class II furcations with the exception of 1 mandibular molar with a Class III furcation. Of the furcations, 3 of the 5 were completely closed. One furcation improved to a Class I, while the Class III furcation remained the same.

DISCUSSION
This combined surgical approach in intrabony lesions demonstrated favorable results, with a mean gain of 50% in CAL from baseline. The mean PD at 6 months was reduced on average by 60.2% to 5 mm or less. Improvements for CAL were also consistent, with 18 of the 22 sites gaining greater than 2 mm of attachment. Because these cases were treated in a private practice, the use of control sites, i.e., non-treatment or standard comparison to other modalities, was not possible. The same type of calibrated probe was used throughout this study. The most recent World Workshop in Periodontics reviewed the literature on automated versus manual probing and showed no clear benefit to either method. The study would have been further strengthened had there been a longer evaluation period to determine the stability of the results over time.

The CAL gains in these consecutively treated cases compare favorably to other studies that have looked at a combined approach using other barriers for treatment. However, comparison to these other approaches is difficult since some of the studies did not report on baseline levels; evaluation time periods differ; and protocols show wide variability.

The use of a combined approach, graft plus a barrier membrane, has demonstrated both clinically and statistically significant benefits in the treatment of furcations compared with either a barrier or a graft alone. This advantage, however, has not been demonstrated for intrabony lesions. It has been the authors’ experience that graft containment in interproximal intrabony lesions can be difficult, leading to diminished regenerative outcomes; and in larger, more critical sized lesions, space maintenance is not optimal with graft use alone. Containment of the graft appears critical to the regenerative outcome. The use of a barrier is one way to gain this clinical advantage.

One of the main benefits to a dynamic flowable barrier that is formed in situ is defect conformity without the need for trimming, thereby limiting barrier handling and potential for bacterial contamination. Traditional barrier systems that come in stock shapes...
are exposed to unavoidable contact with saliva and the operator’s surgical gloves during trimming and suturing. Several studies\textsuperscript{31-35} have demonstrated that bacterial contamination of the barrier from postoperative exposure has led to diminished regenerative outcomes. These results have led some individuals to recommend the presurgical use of systemic antibiotics (unpublished data). During this study, when the barrier became exposed, the soft tissue appeared to have no untoward inflammatory reaction up until loss of the exposed portion at approximately 3 to 4 weeks. This may be related to a potential intrinsic antibacterial property associated with this particular barrier.\textsuperscript{36}

Root anomalies, such as grooves and concavities,\textsuperscript{37} are a dilemma for clinicians because of the potential for poor adaptation of the barrier to the root surface.\textsuperscript{38,39} Such root anomalies may require, in some clinical situations, coronal advancement of the barrier to obtain a tight collar position, leading to either continuous exposure or possible compromise of the flap when attempting to completely cover the barrier. DeSanctis et al.\textsuperscript{35} demonstrated that absorbable barriers which were completely covered by soft tissue had the most favorable regenerative outcomes. A flowable material which forms in situ in an aqueous environment should ensure coverage by the soft tissue while completely sealing the defect from epithelial and gingival connective tissue cell migration.

Barriers formed using this technique have variable thickness. However, the bioabsorption of this polymer is related to its molecular weight and the ability of water to penetrate throughout the barrier beginning the process of hydrolyzing the polymer chains. The pore size of this barrier (150 microns at its surface and 6 to 10 microns at its center) allows penetration of fluids and biodegradation of the barrier.

The most frequent untoward effect seen in this study was limited barrier exposure in 17 of 22 intrabony sites and 1 of the 5 furcation sites. As previously mentioned, this was not associated with any unusual inflammation. One of the methods used to minimize barrier exposure was to trim the exposed portion with a sharp scalpel blade once the flap had been completely sutured.

The use of antibiotics for postsurgical plaque control has been beneficial for regenerative therapy. Employing the antibiotic therapy for a period of up to 24 days is empiric; however, the authors have seen decreased postoperative complications related to site infection with longer-term use following regenerative surgeries.

The use of citric acid is advantageous as a biologic root surface modifier. Judicious use of citric acid helps to eliminate any smear layer,\textsuperscript{40} reduce any potential residual bacteria in the dentinal tubules,\textsuperscript{41} and expose collagen fibers to allow for new attachment.\textsuperscript{42} The impressive histologic results of new attachment that Cole et al.\textsuperscript{43} demonstrated in humans should not be discounted when considering chemotherapeutic root modification with citric acid.

Use of DFDBA and tetracycline was influenced by the consistent results of Yukna and Sepe\textsuperscript{44} and Mabry et al.\textsuperscript{45} Retrospective evaluation of tetracycline incorporated with DFDBA has indicated trends toward improved attachment levels versus DFDBA alone in intrabony sites followed 2 to 5 years (unpublished data). The incorporation of tetracycline with DFDBA may be beneficial for both its bacteriostatic properties and its stabilization of collagen.\textsuperscript{46} The clinician must not be overzealous when using tetracycline, because high concentrations may denature some of the essential morphogenetic proteins or interfere with fibroblastic proliferation.\textsuperscript{47} The use of calcium sulfate in this clinical situation was simply to enhance graft handling.

<table>
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<th>Measures</th>
<th>Pretreatment</th>
<th>6 Months</th>
<th>Mean Change</th>
<th>Percent Change</th>
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<tr>
<td>CAL (mm)</td>
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<tr>
<td>PD (mm)</td>
<td>8.2 ± 1.9</td>
<td>3.5 ± 0.9</td>
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Values represent mean ± standard deviation. N = 17 sites.
These results suggest that DFDBA combined with calcium sulfate and tetracycline in a ratio of 7:2:1 covered by an in situ formed polymer barrier on roots treated with citric acid can enhance the clinical outcome of periodontal lesions as measured by changes in CAL and PD. Further investigation is warranted to compare the efficacy of this technique to other regenerative therapeutic approaches.

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REFERENCES

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