Periodontal Regeneration and Orthodontic Treatment of Severely Periodontally Compromised Teeth: 10-Year Results of a Prospective Study

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The aim of this study was to investigate the long-term clinical conditions of periodontally compromised teeth treated by means of orthodontics after periodontal regeneration (GTR). Forty-eight patients affected by severe periodontitis who presented at least one nonmolar, malpositioned tooth with a pocket depth (PD) ≥ 7 mm, were consecutively enrolled in a private specialist practice. The treatment consisted of the following steps: infection control, provisional splinting, GTR, orthodontic treatment, final splinting, and supportive periodontal therapy (SPT). Thirty-six patients completed the 10-year study, as 12 were lost to follow-up. The total number of sites with PD ≥ 7 mm decreased from 25.4 ± 16.7 to 1.8 ± 2.1. PD of the teeth involved in the orthoperio treatment significantly decreased from 6.3 ± 1.5 mm to 3.1 ± 0.6 mm. One test tooth had to be extracted before the final examination due to root fracture, while two teeth lost vitality and received a root canal treatment. Eight episodes of recurrence, which required additional treatment, occurred during the 10 years of follow-up. The results of this study suggest that if a periodontal infection is under control, the orthodontic treatment does not reduce the long-term benefits of periodontal regeneration, even where the disease has caused massive tissue destruction. Int J Periodontics Restorative Dent 2018;38:801–809. doi: 10.11607/prd.3756

Periodontitis is an inflammatory disease characterized by tissue destruction with consequent progressive attachment loss, which leads to tooth loss if not properly treated.¹ Pathologic tooth migration (PTM) is commonly found in periodontally compromised patients (PCP), and it occurs when the balance of physiological forces that maintain teeth in a physiological position is absent.² Indeed, PCP often present proinclination, irregular interdental spacing, rotation, diastema, migration, and extrusion of one or more teeth.³,⁴ PTM is often the initial motivation for PCP to seek periodontal treatment.⁵ In such clinical scenarios a multidisciplinary approach is required, as the treatment of occlusal discrepancies is a significant factor for a successful periodontal treatment.⁶ Indeed, several clinical studies have illustrated the benefit of orthodontic treatment after periodontal surgery,⁷–¹⁰ but the sequence of procedures is inevitably based more on personal clinical experience than scientific evidence.³

Ideally, following a nonsurgical infection-elimination phase, teeth affected by periodontal disease should be treated by means of various regeneration techniques to restore the destructed tissues. Several systematic reviews support the use of enamel matrix derivative (EMD) alone and in association with various grafts for the treatment of intrabony

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defects, resulting in clinical improvements in terms of clinical attachment level (CAL) gain and pocket depth (PD) reduction.\textsuperscript{11–13} It therefore seems reasonable to assume that the ideal treatment of teeth presenting both PTM and infrabony defects should be based on an adequate orthodontic treatment following periodontal regeneration.\textsuperscript{14}

The combination of regenerative procedures and orthodontic movement has been investigated in only a few studies.\textsuperscript{15,16} Diedrich\textsuperscript{15} published a pilot experiment on dogs in which the intrusive effects of periodontally affected teeth were analyzed after the use of a resorbable membrane. More recently, Araújo et al\textsuperscript{16} demonstrated moving a tooth into an area of an alveolar ridge previously augmented with a biomaterial; the graft material (Bio-Oss) was degraded and eliminated from the part of the alveolar ridge that was utilized for the orthodontic tooth movement. Cardaropoli et al\textsuperscript{17} presented a 6-month case series in three patients to test the feasibility of orthodontically moving migrated teeth into infrabony defects augmented with collagen bovine bone mineral. Ghezzi et al\textsuperscript{18} presented the use of different grafting materials (ie, EMD alone or in association with a bone graft and a resorbable membrane) for periodontal regeneration followed by orthodontic treatment in 14 patients with a 1-year follow-up. More recently, Cao et al\textsuperscript{19} presented results on 14 adults with 56 elongated maxillary incisors. The authors reported that “periodontal regenerative surgery and guided tissue regeneration were performed on the anterior teeth with angular bone defects after orthodontic treatment,” but no details regarding the procedure were indicated.

With these findings taken into consideration, it can be concluded that there is a lack of evidence regarding the long-term efficacy of orthodontic treatment of severely periodontally compromised teeth after periodontal regeneration.

Hence, the aim of this prospective study was to report the long-term (10-year) results of surgical treatment, and subsequent orthodontic movement, of periodontally compromised teeth with infrabony defects of patients enrolled in an individually tailored supportive periodontal therapy (SPT) program.

**Materials and Methods**

**Patient Selection**

Between May 1996 and May 2005, 48 patients (20 men and 28 women; mean age 44.3 ± 8.5 years; 4 smokers) affected by severe periodontitis who presented at least one nonmolar, malpositioned tooth with a clinical attachment level ≥10 mm, were consecutively enrolled from those attending the principal investigator’s private specialist practice. The specialist practice receives referrals from general dental practitioners and specialists in orthodontics and/or maxillofacial surgery, mainly located in the northwest of Italy.

Inclusion criteria were as follows: more than 18 years of age and having chronic periodontitis, at least one nonmolar tooth with PD ≥7 mm, and an absence of mucosal diseas-
es. Alcohol and drug abuse, heavy smoking (ie, >10 cigarettes/day), pregnancy or breastfeeding, uncontrolled metabolic disorders, uncontrolled periodontitis, and no interest in participating in the study were applied as exclusion criteria.

Each patient received a written detailed description of the procedure. They also were informed that their data would be used for statistical analysis and gave their informed consent to the treatment. No ethical committee approval was sought to run this observational study, as it was not required by national law or by ordinance of local inspective authority. The prospective observational study was performed in accordance with the principles stated in the revised World Medical Association Declaration of Helsinki and Good Clinical Practice (GCP) Guidelines.

**Initial Phase and Clinical Assessments**

Each patient was initially professionally treated by scaling and root planing in order to obtain infection control. Personalized oral hygiene instruction was also given to ensure proper domiciliary plaque control. Only after these steps—an initial nonsurgical phase, the assurance of good motivation and compliance from each patient (ie, FMPS <20% and FMBS <20%), and the positioning of a provisional splinting of the teeth undergoing periodontal surgery for stabilization—did the surgical phase begin (Figs 1 and 2).

Immediately before surgery (baseline), PD, bleeding on probing
BOP), and pus were assessed at four sites (mesial, buccal, distal, and lingual) by means of a periodontal probe (XP23/UNC 15, Hu-Friedy). When multiple teeth were involved in the same regenerative procedure, the tooth with the deepest PD was chosen for statistical analysis. This same measurement process had previously been performed at the initial visit.

Surgical Procedures

All surgeries were performed by one of the authors (M.R.) with more than 25 years of experience in periodontal surgery.

The area selected for surgery was anesthetized with mepivacaine plus epinephrine 1:100,000. Then, full-thickness, mucoperiosteal flaps were raised by means of different incision techniques according to the intrabony defect anatomy. Subsequently, all granulation tissue was completely removed from the defect area by means of Gracey’s curettes and dedicated ultrasonic device. The debrided root surfaces were then covered with EDTA 24% (Prefgel, Straumann) for 2 minutes followed by a 1-minute rinse of sterile physiologic saline. Periodontal regeneration of the intrabony part of the defect was performed with one of the following modalities, depending on its morphology and anatomy (Figs 3 to 6):

- EMD alone (Emdogain, Straumann)
- EMD + deproteinized bovine bone mineral (DBBM; BioOss, Geistlich)
EMD + DBBM + bioresorbable membrane (BioGide, Geistlich)

Finally, the flap was repositioned coronally and fixed with resorbable Vycril (Ethicon, J&J) sutures to ensure an ideal first-intention wound healing (Fig 7).

Postsurgical Care

Patients were instructed to take 1 g of amoxicillin and clavulanic acid twice a day for 6 days, starting at least 1 hour prior to surgery, and nonsteroidal analgesics as needed. Immediately after surgery, patients applied ice packs at the treated area, and it was recommended to keep them in place for at least 4 hours. Patients were advised to discontinue tooth brushing and to avoid trauma at the site of surgery for 3 weeks. They were also instructed to use 0.2% chlorhexidine digluconate rinse for 1 minute three times a day for the same period of time. Patients were seen after 7 days and then weekly for the first month to monitor healing. The sutures were removed after 10 to 14 days. After the healing phase, patients were placed on an individually tailored supportive periodontal therapy (SPT) program.

Orthodontic Phase

The orthodontic treatment, aimed at correcting malposition, creating contact points, and providing non-traumatic occlusion, was initiated 8 to 12 months after GTR procedures (Fig 8). Several specialists carried out the treatment, and various orthodontic appliances were used in order to obtain good occlusion. Nevertheless, every patient was strictly followed for ideal hygiene maintenance during this treatment phase, with recalls every 3 to 4 months. At the end of orthodontic treatment, after removal of the appliances, all patients received long-term fixed retentive prostheses to avoid relapse and to improve masticatory comfort.

Follow-up and Clinical Assessments

Motivation, reinstruction, and instrumentation of sites were performed as needed during the 10-year follow-up. If a patient expressed the desire not to regularly attend the recall program or could not be present as requested, he/she was classified as a “dropout.”

Ten years after surgery, an examiner (S.G.) with more than 15 years of experience as a dental hygienist, who was blinded to the treatment provided, recorded PD measured at four sites (mesial, buccal, distal, and lingual) by means of a periodontal probe (XP23/UNC 15, Hu-Friedy) for each treated tooth. At the same time and sites, the presence of BOP and pus were recorded. Moreover, full-mouth plaque score (FMPS), full-mouth bleeding score (FMBS), the number of sites with PD ≥ 7 mm, and the number of teeth lost during SPT were recorded. Figures were rounded off to the nearest millimeter and compared with baseline measurements.

Statistical Analysis

Each patient contributed only one tooth to the study and was therefore considered a statistical unit. Data were expressed as mean ± standard deviation (SD) or percentages. The normality assumption of the quantitative measures was verified by Shapiro-Wilk test. The differences between baseline and the examination at 10 years were assessed using either Student paired t test or Wilcoxon signed rank test, as appropriate, for quantitative parameters and the McNemar test for the qualitative variables. Confidence intervals of the differences were calculated at 95%, and all tests were two-tailed with a significance level set at .05.
Results

In all patients, surgery and healing proceeded with no noteworthy complications and minimal postoperative discomfort. Data regarding patients, defect location, surgical treatment, and main outcomes are shown in Table 1.

From the initial 48 patients included at baseline, 36 completed the 10-year follow-up. Reasons for patient dropout are shown in Table 2.
At the 10-year follow-up, out of the 36 surgically treated test teeth (n = 5 EMD; n = 24 EMD + DBBM; n = 7 EMD + DBBM + CM), only 1 had to be removed due to vertical root fracture, while 2 presented loss of vitality and underwent endodontic treatment.

Mean PD decreased from 6.3 ± 1.5 mm to 3.1 ± 0.6 mm, resulting in a mean reduction of 3.2 ± 1.2 mm with a statistically significant difference between baseline and follow-up (P < .0001). Additionally, a mean soft tissue recession of 0.9 ± 0.6 mm was recorded at the final follow-up. The reduction of the mean deepest PD resulted in a statistically significant difference between baseline and follow-up, from 8.8 ± 1.6 mm to 3.8 ± 0.8 mm (P < .0001).

The local BOP was detected around 80.6% ± 20.8% of the sites at the initial visit and in 7.1% ± 13% at follow-up, resulting in a statistically significant difference (P < .0001).

Pus, considered as a quantitative variable, was assessed at 16 (44.4%) teeth at the initial visit and 0 at the final follow-up, resulting in a statistically significant difference (P = .0001).

The mean number of teeth with PD ≥ 7 mm decreased from 25.4 ± 16.7 to 1.8 ± 2.1, with a statistically significant difference between the two (P < .0001). FMPS and FMBS decreased from 49.9% ± 23.5% to 13.0% ± 6.9% and from 56.0% ± 17.1% to 7.1% ± 4.1%, respectively; both parameters revealed a statistically significant difference between the initial visit and follow-up (P < .0001) (Fig 9).

During the entire follow-up period, eight teeth received adjunctive surgical procedures (ie, mucogingival or open flap debridement) and/or local antibiotic therapy. Finally, the mean number of teeth lost during the 10 years was 0.64 ± 0.7 per patient. Data are presented in Tables 3 to 5.

### Table 2 Reasons for Dropout

<table>
<thead>
<tr>
<th>Reason</th>
<th>n</th>
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<tbody>
<tr>
<td>Death</td>
<td>1</td>
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<tr>
<td>Severe health problems</td>
<td>2</td>
</tr>
<tr>
<td>Moved</td>
<td>3</td>
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<tr>
<td>Refused to accept a visit</td>
<td>6</td>
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<tr>
<td>Total</td>
<td>12</td>
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</table>

### Table 3 Full-Mouth Plaque Scores (FMPS), Full-Mouth Bleeding Scores (FMBS), and Number of Sites with PD > 7 mm at Initial Visit and 10 Years Following Treatment (Means or Percentages ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Initial visit</th>
<th>10 y</th>
<th>Difference (95% confidence interval)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMPS (%)</td>
<td>49.9 ± 23.5</td>
<td>13.0 ± 6.9</td>
<td>36.9 (30.6–43.1)</td>
<td>&lt; .0001&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>FMBS (%)</td>
<td>56.0 ± 17.1</td>
<td>7.1 ± 4.1</td>
<td>48.9 (43.3–54.6)</td>
<td>&lt; .0001&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>Sites with PD ≥ 7 mm, n</td>
<td>25.4 ± 16.7</td>
<td>1.8 ± 2.1</td>
<td>23.6 (18.2–29.1)</td>
<td>&lt; .0001&lt;sup&gt;a&lt;/sup&gt;</td>
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</table>

PD = pocket depth; SD = standard deviation.
<sup>a</sup>Wilcoxon Signed Rank test.
<sup>b</sup>Student paired t test.

### Table 4 Clinical Parameters of the 36 Teeth that Reached the 10-Year Examination (Means or Percentages ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Initial visit</th>
<th>10 y</th>
<th>Difference (95% confidence interval)</th>
<th>P</th>
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<tr>
<td>PD (mm)</td>
<td>6.3 ± 1.5</td>
<td>3.1 ± 0.6</td>
<td>3.2 (2.7–3.6)</td>
<td>&lt; .0001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Deepest PD (mm)</td>
<td>8.8 ± 1.6</td>
<td>3.8 ± 0.8</td>
<td>5 (4.5–5.5)</td>
<td>&lt; .0001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>BOP at tooth site (%)</td>
<td>80.6 ± 20.8</td>
<td>7.1 ± 13.0</td>
<td>72.9 (66.1–79.6)</td>
<td>&lt; .0001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tooth with pus (%)</td>
<td>16 (44.4)</td>
<td>0 (0)</td>
<td>16 (26.3–65.1)</td>
<td>.0001&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

SD = standard deviation; PD = pocket depth; BOP = bleeding on probing.
<sup>a</sup>Student paired t test.
<sup>b</sup>Wilcoxon Signed Rank test.
<sup>c</sup>McNemar test.
Discussion

The aim of this prospective study is to evaluate the long-term (10-year) clinical outcomes of teeth treated by means of GTR procedures and orthodontic therapy. Until now, despite the high level of evidence regarding the efficacy of regenerative procedures to treat severely periodontally compromised teeth,\textsuperscript{11–13} the literature did not provide significant data regarding the combined GTR-orthodontic approach. Nevertheless, the interest on this specific topic has consistently increased, as demonstrated by a greater number of publications in recent years.\textsuperscript{19}

Several articles presented orthodontics after periodontal treatment.\textsuperscript{7–10} Cardaropoli et al\textsuperscript{8,10} and Corrente et al\textsuperscript{9} reported an open-flap access surgery with no augmentation material and/or barrier membrane. Moreover, Re et al\textsuperscript{7} treated patients with hand instruments or an ultrasonic device following a modified Widman flap surgery. Due to the fact that each patient contributed only one tooth in the present study, it is virtually impossible to assess if the deepest defects were similar to those treated in Re et al’s case series.

The efficacy of regenerative procedures before orthodontics was proposed by Ghezzi et al,\textsuperscript{18} who reported a mean PD reduction of 5.57 mm in 14 patients by means of EMD alone or in combination with a grafting material. More recently, Cao et al,\textsuperscript{4} in another case series of 14 patients, reported a mean PD reduction of 2.89 mm after a combined ortho-perio treatment, though no details were given regarding the regenerative procedure. These results are similar to the findings of the present study, ie, 3.2 ± 1.2 mm.

Table 5 Deepest PD at Tooth Site at Baseline and 10 Years After Surgery

<table>
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<tr>
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<th>Site (FDI)</th>
<th>Deepest PD at Baseline</th>
<th>PD at 10-y follow-up</th>
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<td>1</td>
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Mean ± SD 8.8 ± 1.6 3.8 ± 0.8

PD = pocket depth; FDI = World Dental Federation tooth-numbering system; SD = standard deviation.
In this study, different orthodontic fixed approaches were used as previously proposed\(^{20}\) in order to obtain satisfactory functional and esthetic results, with care not to increase the risk of further bone loss and gingival recession.

The question of when the orthodontic phase should be initiated is still open. Even though it has been suggested not to start orthodontic therapy until at least 6 months after the completion of periodontal therapy in order to carry out the movement in fully healed sites,\(^{21}\) earlier approaches have been suggested in nonregenerated sites. Corrente et al\(^{9}\) and Re et al\(^ {7}\) proposed to start the orthodontic phase at suture removal, 7 to 10 days after surgery. It must be noted that no regenerative materials were used in Corrente et al’s and Re et al’s defects.

In Cardaropoli et al,\(^ {17}\) the defects were filled with a collagen bovine bone mineral, and orthodontic movement was initiated after 2 weeks. After 6 months, residual mean PD was 3.33 mm, with a mean reduction of 3.67 mm. On the contrary, a later approach by Ghezzi et al\(^ {18}\) waited 12 months after periodontal regeneration before starting the orthodontic treatment. In the present study, the second treatment phase began 8 to 12 months after the regenerative procedure in order to ensure periodontal regeneration.

Given this controversy, it seems that further scientific support is needed to identify the optimal time to begin orthodontic movement after periodontal regeneration. Ideally, long-term randomized controlled trials (RCTs) that follow CONSORT guidelines would be necessary. In reality, practical and ethical reasons make effective RCTs in this field virtually impossible.

The current study presents several limitations. One of the most important is the absence of a control group, as each very deep defect was treated in order to provide the best possible attachment gain for the benefit of the patient. In addition, several different orthodontic appliances were used in order to achieve the best occlusion and avoid relapse. It must be noted that different orthodontic movements were applied (intrusion, extrusion, tipping, and torque) within the same patient. Moreover, some teeth had extensive orthodontic movement, while others had relatively minor ones. This heterogeneity makes it difficult to extrapolate the results to a community-based general population.

Another limitation is the apparent high percentage of dropouts. It must be emphasized that if a patient expressed the desire not to regularly attend recall program or could not be present as requested, he/she was classified as a “dropout.” This strict regimen was based on the assumption that patients’ adhesion to SPT is mandatory to maintain stable long-term results.\(^ {22–24}\) This is crucial in patients treated orthodontically, since plaque control is much more challenging due to orthodontic appliances, and orthodontic treatment can lead to subgingival transposition of the dental plaque.\(^ {19}\) In clinical practice, however, patients tend to disregard professional plaque-control programs over years of treatment, especially if they reach optimal FMPS and live/work far from the specialist’s office.

Finally, due to the lack of a standardized radiologic analysis, the radiologic findings are not presented in numeric measurements.
Conclusions

Within these limitations, the present study is, to the best of the authors’ knowledge, the only one reporting of the efficacy of a regenerative procedure followed by orthodontics over a period of 10 years (Figs 10 and 11). The results of this study suggest that, if periodontal infection is under control, the orthodontic treatment does not reduce the long-term benefits of periodontal regeneration, even where the disease has caused massive tissue destruction.

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