Optimized Periodontal Regeneration for Orthodontics (O-PRO): A Case Series

Junichi Watahiki, DDS, PhD
Rieko Ono, DDS, PhD
Mao Maeda, DDS
Takahiro Hiranuma, DDS
Satomi Naito, DDS, PhD

The fusion of orthodontic treatment and periodontal tissue–regeneration therapy has attracted attention. However, regenerated bone has a higher density than physiologic bone, which may cause problems including root resorption or stagnation of orthodontic movement. Therefore, the optimized periodontal regeneration for orthodontic movement (O-PRO) approach was developed with the aim of regenerating periodontal tissues with sparse bone quality. Unlike conventional methods, this concept is specifically suited for orthodontic movement. A new classification for the preoperative evaluation of periodontal tissues was also devised, and results are reported from cases where orthodontic treatment was implemented using each type of O-PRO method. Int J Periodontics Restorative Dent 2020;40:835–842. doi: 10.11607/prd.4447

There is currently no consensus regarding the timing of orthodontic treatment and periodontal regeneration surgery. Some groups have implemented orthodontic movement after a 3- to 12-month healing period, when the regenerated periodontal tissues have sufficiently stabilized,1 while others have initiated orthodontic treatment approximately 2 weeks postoperatively with the expectation of a regional acceleratory phenomenon (RAP). These reports are based on the concept of proactively using the RAP to contribute to periodontal regeneration when performing bone surgery such as corticotomy. The RAP was discovered in 1981 and involves two processes: accelerated bone turnover and a temporary reduction in bone density, which results in accelerated orthodontic movement.2 Animal studies have shown that early postsurgical orthodontic movement promotes bone augmentation.3 Due to the lack of information regarding regenerative therapy in orthodontic treatment, the present authors herein report several cases that involved periodontal regenerative therapy more suitable for orthodontic treatment. Specifically, the optimized periodontal regeneration for orthodontics (O-PRO) approach was developed with the aim of regenerating periodontal tissues with sparse bone quality. A new

1Private practice, AQUA Nihombashi Dental Clinic, Tokyo, Japan.
2Interdisciplinary Orthodontics Society (IOS), Tokyo, Japan.

Correspondence to: Dr Junichi Watahiki, AQUA Nihombashi Dental Clinic, Ukiyo Shoji Senbikiya Bldg 4F, 2-4-1, Muromachi Nihombashi, Chuo-ku, Tokyo 103-0022 Japan.
Fax: +81 3 6277 5334. Email: aqua@festa.ocn.ne.jp

Submitted May 18, 2019; accepted August 24, 2019.
©2020 by Quintessence Publishing Co Inc.
classification for the preoperative evaluation of periodontal tissues was also devised and utilized in cases where orthodontic treatment was implemented using each type of O-PRO method (Fig 1) based on the new patient periodontal phenotype classifications (Fig 2).

Case Report 1

The patient was a 47-year-old man with no history of smoking or systemic diseases. Approximately 35 years prior, he had undergone orthodontic treatment with the extraction of premolars. He complained of anterior teeth crowding in the maxilla and mandible (Fig 3a). Based on the diagnosis, the goal of the orthodontic treatment was to move the mandibular anterior teeth anteriorly (Fig 3b). However, CBCT scans revealed a lack of adequate bone housing in the planned position (Fig 3c). There-
fore, the patient was classified as Class I (Fig 4a). Orthodontic treatment was prescribed, as well as enlargement of the bone housing with the O-PRO Procedure 2. The patient consented to orthodontic treatment and periodontal regeneration surgery. Orthodontic movement began before the regeneration surgery, and the surgery was performed before leveling was completed. A full-thickness flap was raised along the entire mandible under microscopy, and the remaining soft tissue on the alveolar bone surface was removed using Piezotome 2 (Acteon) BS4 tips. The procedure was as minimally invasive as possible and was discontinued when bleeding was observed at the bone surface. A 1:1 blend of demineralized bovine bone matrix (DBBM; Bio-Oss, Geistlich) and demineralized freeze-dried bone allograft (DFDBA; LifeNet Health) was placed on the bone surface and covered with a collagen matrix (Mucograft, Geistlich; Fig 4b). An atelocollagen plug (Teruplug, Olympus Terumo Biomaterials) was then fitted near the apical area and sutured with 5-0 and 6-0 nylon threads (Prolene, Ethicon; Fig 4c). Postoperatively, the patient was administered analgesics for 5 days and azithromycin for approximately 2 weeks. The sutures were removed after 2 weeks, and orthodontic movement began at that time. Orthodontic treatment was completed approximately 18 months postoperatively without complications. The regenerated area exhibited marked enlargement of the bone housing (Figs 4d to 4g).

Case Report 2

The patient was a 32-year-old woman with no history of smoking or systemic diseases who wanted to improve her tooth alignment and treat her gingival recession. At the initial consultation, the patient exhibited gingival recession throughout her entire mouth. Her periodontal tissue phenotype was thin and scalloped, and thus her mandible was classified as Classes II and III (Figs 5a to 5c). It was decided to perform orthodontics with the
extraction of the maxillary and mandibular bilateral first premolars. The O-PRO was used for both arches. Orthodontic movement was implemented prior to the regeneration surgery; after the teeth were completely leveled, the canines were moved distally, and the surgical procedure was performed. O-PRO Procedures 1b and 3 were used as the surgical regeneration treatments for the maxilla and mandible, respectively. Before incision and separation were performed, the exposed part of the tooth root was debrided with Airflow (EMS Swiss) and AirFlow Powder Plus (EMS Swiss). The full-thickness flap was raised, and

Fig 4 Case 1. (a) Immediately before the O-PRO Procedure 2 surgical treatment. (b) Condition after placing bone filling material and Mucrograft. (c) The sutured surgical site. (d and e) CBCT findings of postoperative changes at 6 and 12 months, respectively. (f) Clinical and (g) CBCT views of the regenerated area at 18 postoperative months, exhibiting marked enlargement of the bone housing.
the soft tissue on the bone surface was removed to promote bleeding, as in Case 1. The exposed root and bone surface were coated with Endogain (Straumann), and a 1:1 blend of DBBM (Bio-Oss) and DFDBA (LifeNet Health) was inserted. Connective tissue from the palate was fitted over the exposed surface and the areas not fully covered by soft tissue (Fig 5d). Orthodontic treatment was completed in approximately 3 years, and there were considerable improvements in gingival recession and malocclusion. Seven years after O-PRO treatment, and approximately 4 years since completion of the orthodontic treatment, both the periodontal tissue and the occlusion remained stable (Figs 5e and 5f). In postoperative CBCT imaging, the distance between the cementoenamel junction and the alveolar crest was shorter than that observed before surgical treatment (Figs 5g and 5h). Moreover, periodontal tissue attachment was observed on the coronal side, and the periodontal membrane and bone demonstrated regeneration.

Discussion

Previous reports have described different postoperative bone densities depending on the filling material used for regeneration.1–6 When Machihaya et al7 implemented orthodontic movement at regeneration sites using bone substitutes, they reported that the degree of orthodontic movement and amount of regenerated bone differed depending on the type of supplementary bone filling material. They observed that Bio-Oss increased the bone density of the transplant site, thereby inhibiting orthodontic movement.7 Based on these findings, the present authors presumed that when implementing orthodontic movement in a bone regeneration site, the density of the regenerated bone may greatly affect the extent of bone regeneration and orthodontic movement. Thus, by mixing the slowly absorbed Bio-Oss with the rapidly absorbed DFDBA (or β-tricalcium phosphate if not using DFDBA) at a ratio of 1:1 in the present cases, the necessary amount of bone regeneration was achieved without inhibition of orthodontic movement.

Kaley and Phillips8 and Goldie and King9 demonstrated that when the density of the alveolar bone surrounding the root is high, the severity of root resorption may be increased. Conversely, Otis et al10 and Araújo et al11 found no significant correlation between the alveolar bone density and the root resorption caused by orthodontic movement. Furthermore, Ren et al12 reported that root resorption severity is increased in adult orthodontics. Therefore, there is no clear consensus regarding the relationship between alveolar bone density and root resorption caused by orthodontic movement. The high density of the regenerated bone may negatively affect the extent and frequency of root resorption in orthodontic movement. According to the Lekholm and Zarb classification, bone quality showed a high correlation with bone density and with the drilling sensation during implant insertion.13 The present results were combined and compared with previous cases performed by the authors at their facility (Table 1). In the comparison at 12 months postoperatively, compact bone was observed in cases treated with guided bone regeneration (GBR), whereas cases treated with O-PRO were classified as Types II and III, and the bone quality had a lower density than in cases treated with GBR. These results suggest that the O-PRO enables formation of regenerated bone more suitable for orthodontic movement by intentionally delaying the rate of bone maturation and healing (Table 1). To inhibit the RAP, corticotomy is intentionally not used in the O-PRO approach. RAP is presumed to have an acceleratory effect on healing, triggered by invasive surgical procedures, and the reduction in alveolar bone density for approximately 3 months postoperatively may promote orthodontic movement. However, compared with preoperative levels, reports indicate an increased reduction of bone density over time.14

Tsai et al15 reported that bone regeneration was implemented using an absorbent collagen membrane for orthodontic movement; however, there have been few articles published on this aspect, and no consensus has been reached. Kim et al16 used collagen membranes in bone regeneration surgeries and found a significantly higher density of regenerated bone than when using bone substitutes alone. Therefore, the present authors suspect that in cases requiring orthodontic
Fig 5  Case 2. (a) Initial intraoral situation before the start of O-PRO Procedure 3 surgical treatment. Note the marked gingival recession. The mandibular (b) right and (c) left canines were classified as Class III and Class II, respectively, based on preoperative CBCT findings immediately before surgical treatment. Both sites had a large distance between the cementoenamel junction (CEJ; top arrow) and the alveolar crest (bottom arrow) and loss of attachment.

(d) Condition after coating the anterior area with EMD and placement of the bone filling material (Bio-Oss:DFDBA = 1:1) and connective tissue. (e) Clinical view at 7 years postoperative and 4 years after orthodontic treatment. (f) Where there was severe gingival recession before orthodontic treatment, there is now increased attached gingiva achieved through surgical periodontal tissue regeneration.

(g and h) CBCT findings 7 years after surgical treatment and 4 years after orthodontic treatment. There is a marked reduction of the distance between the CEJ (top arrow) and the alveolar crest (bottom arrow), as well as regeneration of the bone and periodontal membrane on the buccal side.
Table 1 Comparison of Quality of Regenerated Bone Over Time

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Tooth sites, n</th>
<th>Bone quality (Lekholm and Zarb)\textsuperscript{13}</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBR 6 mo</td>
<td>19</td>
<td></td>
<td>2 (2 nonresorbable)</td>
<td>12 (3 nonresorbable)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>GBR 12 mo</td>
<td>19</td>
<td></td>
<td>10 (4 nonresorbable)</td>
<td>9 (1 nonresorbable)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>O-PRO P1b 6 mo</td>
<td>5</td>
<td></td>
<td>–</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>O-PRO P1b 12 mo</td>
<td>5</td>
<td></td>
<td>–</td>
<td>4</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>O-PRO P2 6 mo</td>
<td>9</td>
<td></td>
<td>–</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>O-PRO P2 12 mo</td>
<td>9</td>
<td></td>
<td>–</td>
<td>8</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>O-PRO P3 6 mo</td>
<td>9</td>
<td></td>
<td>–</td>
<td>–</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>O-PRO P3 12 mo</td>
<td>9</td>
<td></td>
<td>–</td>
<td>7</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>O-PRO (All) 6 mo</td>
<td>23</td>
<td></td>
<td>–</td>
<td>–</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>O-PRO (All) 12 mo</td>
<td>23</td>
<td></td>
<td>–</td>
<td>19</td>
<td>4</td>
<td>–</td>
</tr>
</tbody>
</table>

GBR = guided bone regeneration; O-PRO = optimized periodontal regeneration for orthodontics; P1b = procedure 1b; P2 = procedure 2; P3 = procedure 3.

The bone quality of O-PRO was sparse at 6 and 12 months compared to the GBR. However, at 12 months, the O-PRO bone had densities similar to the GBR, and there were no cases with Type I bone quality even at 12 months postoperative, unlike the GBR group. There was also no clear difference in bone quality between P1b, P2, and P3 with the O-PRO method.

In addition to the two O-PRO cases in the present study, this table includes GBR and O-PRO data from previous, unreported cases conducted at the same authors’ clinic as the present patient cases.

Treatment, the use of membranes may cause increased bone density, stagnate orthodontic movement, and increase the risk of root resorption. Although Mucograft was originally proposed as an alternative material for a soft tissue substitute, Basudan et al\textsuperscript{17} used Mucograft as a membrane in GBR and showed that the mass of the regenerated bone was less than that achieved using a normal collagen membrane; this enabled the acquisition of low-density bone\textsuperscript{17}. Therefore, it was presumed that the use of Mucograft (Fig 1) would mitigate the risk of orthodontic movement stagnation and root resorption by inducing lower bone density, although with slightly reduced bone mass (Table 1). Regeneration surgery was performed after the implementation of preoperative orthodontic movement in all cases, generally for the following reasons: (1) to improve the position of the teeth; or (2) to increase blood flow to the periodontal membrane, as bioactivation of periodontal membrane cells may facilitate regeneration\textsuperscript{18}. However, in cases of insufficient healing, orthodontic movement may be disadvantageous for periodontal tissue regeneration\textsuperscript{2}. Therefore, in difficult cases involving loss of attachment, such as Class III cases, the timing of orthodontic movement provides a 3- to 6-month postoperative healing period. If root coverage is performed before orthodontic movement, there is a high risk of gingival recession\textsuperscript{19}. This may be caused by the large area of epithelial attachment created by root coverage. Yet, there is no consensus regarding the timing of orthodontic movement after root coverage\textsuperscript{19}. Moreover, at approximately 1 year postoperative, the majority of healing is reportedly due to the formation of epithelial attachment\textsuperscript{20}. However, when implementing orthodontic movement, the regeneration of connective tissue attachment to the periodontal membrane at the coverage site is preferable at an early postoperative stage. Carnio et al\textsuperscript{21} reported that adjunction of the exposed root surface with enamel matrix derivative (EMD) and connective tissue graft (CTG) during root coverage can increase the connective tissue attachment. Chambrone et al\textsuperscript{20} reported that when the adjacent existing bone is positioned laterally to the area of root surface scheduled for coverage, bone
growth can be induced by combining treatment with EMD, bone substitutes, and absorbent membranes. Typically, teeth that exhibit gingival recession often protrude more towards the buccal side relative to the dental arch; therefore, inducing bone growth is impossible based on conventional concepts. The O-PRO Procedure 3 aimed to maximize regeneration via the following four points: (1) promotion of bioactivation by orthodontics; (2) combined use of EMD and CTG; (3) alteration of orthodontic tooth location for favorable regeneration; (4) a sufficient healing period.

Conclusions

Although further research is necessary, O-PRO treatment resulted in superior outcomes compared with conventional methods.

Acknowledgments

The authors declare no conflicts of interest.

References