Regenerative Orthodontics: GBR and Corticotomy to Stretch the Limits of Orthodontic Treatment

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Orthodontic therapy could lead to marginal bone resorption in cases where the teeth are moved outside the envelope of bone. The purpose of this case series was to test corticotomy with a guided bone regeneration (GBR) procedure to regenerate bone in the direction of movement outside the original bony housing. Ten adult patients (60 anterior teeth), all presenting with severe anterior crowding, were enrolled in the study. Orthodontic therapy in all investigated sites was associated with selective surgical corticotomies and a simultaneous GBR procedure. CBCT examinations were performed before starting orthodontic treatment (T0) and at the end of treatment (T1; mean: 7 months; range: 6 to 9 months). Pre- and postoperative CBCTs were superimposed with a DICOM viewer (3D Slicer) and studied with an image-processing software (ImageJ, National Institutes of Health) to measure the area of interest of the buccal plate. The average area was found to be 0.58 ± 0.22 mm^2 *at T0 and 1.76 ± 0.4 mm*^{2} *at T1, with a statistically significant difference (P < .05). The combination of corticotomy and a regenerative procedure seems to have the ability to augment the original osseous anatomy when the root is moved outside of the original bony envelope.*
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Gingival recession is a highly prevalent mucogingival alteration,[1] yet its multifactorial etiology often does not conduce to a simple pathogenic hypothesis.[2] The ectopic eruption of a dental element outside the osseous envelope has been regarded as a predisposing factor for gingival recession,[3] as well as other "threats" to the mucogingival integrity such as osseous dehiscence and fenestrations.[4]

The main goal of orthodontic therapy is the realignment of the deviated dentition to improve occlusal function while creating a pleasant and harmonious smile. Orthodontic movements should be obtained within the confines of the maxillary osseous structures. Traditional animal experiments have demonstrated how orthodontic movement of teeth outside the osseous cortical plate, followed by a period of retention, resulted in loss of bone and soft tissues.[5,6] The potential to reverse the phenomenon when replacing the dental elements within the confines of the osseous envelope was also reported.[5,6]

Controversial results can be inferred from retrospective observations studying the influence of proclination of mandibular incisors and recession genesis. Some authors could not link orthodontic treatment to increased recession,[7,8] while others noted that orthodontics may be a risk factor for the development of labial gingival recessions.[9] A systematic review reported a potential association between orthodontic proclination outside the envelope of bone and a higher occurrence or severity of gingival recession.[10]

Orthodontists routinely compare the length of the dental arch perimeter to the mesiodistal dimension of teeth. Depending on the difference between these two measurements, a decision is made to either strategically extract or interproximally strip teeth to allow for realignment of the dentition. From the periodontal perspective, however, space analysis does not evaluate the buccolingual (sagittal) dimension of the teeth nor the alveolar bone perimeter compared to the root dimensions.

Some authors propose individual clinical reference points to establish the greatest possible arch expansion. Richman, examining 72 teeth from 25 consecutively treated patients with facial clinical gingival recession of more than 3 mm, pointed out that conventional orthodontic space analysis does not evaluate the buccolingual dimension of the tooth associated to the alveolar bone present at that level.[11] Using CBCT, the authors showed that although all teeth were periodontally healthy, they all had significantly prominent facial tooth contours and associated alveolar bone dehiscences. A radiographic supporting bone index (the sagittal difference between the alveolar bone width measured 2 to 3 mm apical to the cementoenamel junction [CEJ]) and the width of the tooth measured at that level were proposed as aids to evaluate the eventual risk of periodontal damage after orthodontic treatment.

To address both the duration of orthodontic therapy and the potential for a detrimental periodontal outcome, periodontally accelerated osteogenic orthodontics (PAOO) was introduced in 2001.[12] The PAOO technique allows for faster and easier orthodontic movement through selective decortication, which, coupled with alveolar augmentation, expands the boundaries of the preexisting osseous perimeter, thus permitting further tooth movement. This approach is intended to treat moderate to severe malocclusions in both adolescents and adults while significantly reducing the need for extractions.[13] The simultaneous osseous grafting performed during PAOO allows a broader osseous base into which teeth can be moved while at the same time remediating alveolar inadequacies and henceforth theoretically reducing the risk for future gingival recessions.[14] The PAOO technique has recently been modified in order to decrease its surgical invasiveness where indicated.[15,16]

Guided bone regeneration (GBR) is based on the principles of guided tissue regeneration, where a barrier membrane is utilized to create a space for blood clot formation that will eventually mature into new functional osseous tissue.[17] Both bioabsorbable and nonresorbable membranes are currently being used for GBR. The preference for resorbable barriers is justified by their efficacy and lower number of membrane exposures.[18]

The combination of deproteinized bovine bone mineral (DBBM; Bio-Oss, Geistlich) and a porcine collagen membrane (Bio-Gide, Geistlich) has already been reported for lateral ridge reconstruction with clinical results that fulfill expectations.[19,20]

The purpose of the present study is to test the applicability of the GBR principles, utilizing DBBM and a collagen membrane (Bio-Gide), with a modified, less-invasive rapid orthodontic approach via selective corticotomies. This investigation evaluated pre- and postoperative radiographic changes in alveolar bases and periodontal clinical parameters.

Materials and Methods

Ten patients (7 women and 3 men) aged 18 to 41 years (mean: 26.6 ± 8.2 years) were enrolled in this case series study at the practices of two authors (F.B. and A.C.). All patients agreed to participate in the study and signed a detailed informed consent. The participants had to present with a permanent dentition altered by severe anterior crowding and be in good general health; smokers were excluded from the study. Other exclusion criteria were pregnancy, use of medications (such as bisphosphonates, antiepileptic drugs, corticosteroids, estrogen, calcitonin, and vitamin D), previous orthodontic treatment, periodontal disease, severe periodontal recession, and history of root resorption. The study was conducted following the principles outlined in the Decla-

Fig 1 *The osseous incisions are limited to the cortical aspect of the bone and stop at least 3 mm from the peak of the interdental bone.*

Fig 2 *Deproteinized spongy bovine bone is layered on top of the corticotomies.*

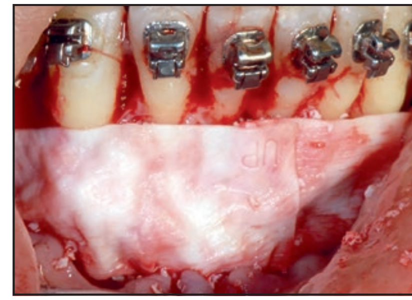

Fig 3 *The porcine collagen membrane is adapted to cover the grafted biomaterial before suturing the gingival flap.*

ration of Helsinki on experimentation involving human subjects. At the time of enrollment, all patients had full-mouth plaque and bleeding scores ≤ 20%.

Before starting orthodontic treatment (T0) assisted by selective surgical corticotomies, every patient underwent a CBCT and a comprehensive periodontal examination. The aim of this investigation was to evaluate the preoperative thickness of the alveolar bases and the modifications produced by the treatment therapy (rapid orthodontics with GBR). All investigated sites were vestibular areas that received surgical corticotomy 2 to 4 weeks after starting orthodontic treatment. Following local anesthesia, buccal mucoperiosteal single flaps were elevated to gain access to the underlying osseous structures. Intrasulcular incisions were placed only in the portion of the patient dentitions involved in the procedure, thereby using a segmental approach. The buccal half of the interdental papillae could be reflected with the flap, leaving the lingual or palatal portion of the interdental soft tissue undisturbed.

Vertical releasing incisions were utilized, mesial and distal to the surgical area, to obtain better visibility, properly mobilize the flaps, and achieve primary closure.

With proper visualization of the dental and osseous anatomy, round burs mounted on rotary instrumentation (or round-tip inserts mounted on piezoelectric units) were used to outline the corticotomy designs following the root profiles. Special care was dedicated to avoid creating ditches on the dental roots and to keep the coronal limit of the performed osseous incisions at least 3 mm away from the marginal bone crest. The depth of the osseous incisions was limited to the cortical bone plate (Fig 1). After completion of the corticotomies, spongy deproteinized bovine bone (Bio-Oss) was layered on top of the surgically injured osseous structure (Fig 2), and a porcine collagenous membrane (Bio-Gide) was carefully trimmed and adapted to completely cover the osseous graft (Fig 3), done in accordance with the principles of GBR. Primary closure of the buccal flaps was obtained with single interrupted sutures. Periosteal release of the flaps was performed when necessary to obtain a complete and tension-free closure of the surgical wounds. In no case was the employed biomaterial left exposed to the oral environment.

Patients were dismissed from the office with a prescription for an anti-inflammatory medication (600 mg ibuprofen every 8 to 12 hours for the first day and as needed thereafter) and an antibiotic (1 g amoxicillin every 8 hours for 5 days). Postoperative instructions were given to the patients with the recommendation to avoid brushing and flossing in the operated area for the first 14 days. During this period a 0.12% chlorhexidine rinse (GUM Paroex 0.12%, Sunstar Suisse) was used to control plaque accumulation. Patients were first recalled at 7 days for a postoperative follow-up, at 15 days for suture removal, and then monthly until completion of the study. During each follow-up, the surgical areas were carefully inspected and gently cleaned with periodontal curettes. All treated patients resumed their normal daily oral hygiene activity after the second postoperative week.

Fig 4 (a) *Preoperative clinical view of the case showing dental crowding.* (b) *Postoperative view showing complete resolution of crowding. Images reprinted with permission from: Brugnami F, Caiazzo A (eds). Orthodontically driven corticotomy: Tissue engineering to enhance the treatment, guided by the orthodontist. In: Orthodontically Driven Corticotomy: Tissue Engineering to Enhance Orthodontics and Multidisciplinary Treatment. Oxford: Wiley Blackwell, 2015:166, 168.*

Orthodontic movement continued immediately after surgery, and the orthodontist scheduled appointments every 2 weeks until completion of the treatment (Fig 4). Every wound healing complication was noted and recorded by the treating surgeons.

Radiographic Examination

CBCT examinations were performed before starting orthodontic treatment (T0) and at the end of treatment, at the final follow-up (T1). All exams were made using a CS 9000 3D CBCT unit (Carestream Health), equipped with a flat-panel detector. The exposed volume was 50 × 30 mm (voxel size 0.679 μ to 0.2 mm, depending on whether a "stitching" of three consecutive volumes was performed to represent the entire arch), encompassing the teeth in the arch where the corticotomy was to be carried out. Exposure parameters were: 70 kV, 8 to 10 mA (based on the subject's size), and a single 360-degree, 24- to 72-second exposure time comprising a range of 235 to 468 projections. CBCTs were performed to evaluate the thickness of bone and the 3D positioning of the roots in the alveolar ridge before treatment.

Preoperative and postoperative data were analyzed with a DICOM viewer (3D Slicer) that allows superimposition of different CBCT exams.[21] Slicer recognizes landmarks in the analysis and highlights volumetric differences. Following CBCT superimposition, reconstructions were made for each individual tooth, and preoperative and postoperative images were obtained. Measurements were then analyzed with an open source image-processing program designed for scientific multidimensional images (ImageJ, National Institutes of Health). The known dimension of the brackets (2 mm) was used as the reference measurement (Fig 5). Once the dimension was calibrated, the measurements were calculated for both pre- and postoperative slices (Fig 6). The long axis of the tooth was then determined by joining the apex and the incised edge. A line was then traced perpendicular to the long axis, passing through the CEJ to determine the length of the root. The root was then divided in two with another line perpendicular to the long axis that passed through the midpoint. This line also divides the buccal plate in two halves, coronal and apical. For two reasons, only the coronal part of the buccal plate was calculated: *(1)* Bone is anatomically thinner at the crestal margin and more prone to resorption during orthodontic movement (proclination); *(2)* coronal osseous augmentation is more challenging due to tension that develops in the flap during healing, possibly displacing grafted materials apically. For these reasons, together with the greater clinical relevance, only the coronal half of the buccal plate was considered for this analysis (Fig 7).

Posttreatment measurements were taken, and the difference between pre- and posttreatment values represented the change in alveolar thickness following surgery and tooth movement. Statistical test

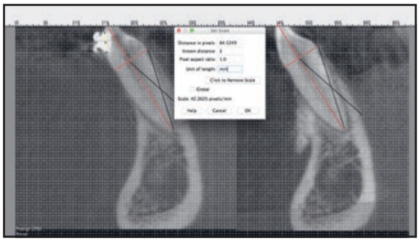

Fig 5 *Measurement calibration with a known measure (width of brackets: 2 mm).*

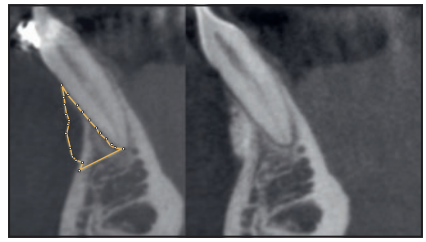

Fig 6 *Outline of the postoperative buccal plate* (yellow line) *as compared to the preoperative image. It is evident that most of the regeneration occurs at the apical level, while the coronal half is the more critical region. For this reason, only the coronal area is calculated.*

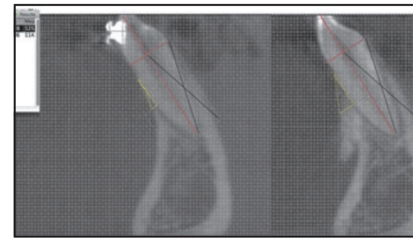

Fig 7 *Osseous area calculation of the treated coronal half of the osseous structure.*

analysis was conducted using the commercial package SPSS (IBM). Student *t* test for the difference of group means was applied, with statistical significance set at $P < .05$.

Results

The study sample included 10 adult patients in whom a total of 60 teeth were orthodontically repositioned outside of their native bony envelope following corticotomy. The average follow-up time was 7 months (range: 6 to 9 months).

The average change in thickness of the coronal buccal plate was indirectly determined by the Slicer software, which analyzed the coronal osseous area of the pre- and postoperative CBCTs. The average area was found to be 0.58 ± 0.22 mm^2 at T0 and 1.76 ± 0.4 mm^2 at T1, with a statistically significant difference ($P < .05$). Further subdivision of the results based on tooth type is summarized in Table 1.

Table 1 Average Thickness of the Coronal Buccal Plate at T0 and T1

	T0	T1
Central incisors, n	20	20
Thickness, mm	0.6850	2.0240
SD, mm	0.2200	0.4110
Lateral incisors, n	20	20
Thickness, mm	0.5910	1.7640
SD, mm	0.2324	0.4063
Canines, n	20	20
Thickness, mm	0.5400	1.5270
SD, mm	0.2785	0.2156

T0 = before orthodontic treatment; T1 = at the end of treatment.

Discussion

Tridimensional radiographic analysis of alveolar bone changes in patients who have undergone orthodontic treatment has shown that teeth may be inadvertently repositioned beyond their bony housing, sometimes resulting in dehiscences and the formation of fenestrations.[22] Garib et al showed a correlation between rapid palatal expansion and thinning of the vestibular plate up to almost 1 mm.[23] The buccal cortical plate of the alveolus has long been considered inviolable, and it was thought that any movement beyond that line might cause bony dehiscences and, eventually, gingival recessions.[24] PAOO refuted this concept and, as shown by Williams and Murphy, the alveolar "envelope," or limits of the alveolar housing, may be "more malleable than previously believed and can be virtually defined by the position of the roots."[25] 3D positioning of the roots inside the bony envelope at the end of the treatment represents a major goal of orthodontic treatment planning.[26–28]

When orthodontic treatment planning anticipates root movements outside of the bony envelope, the orthodontist should consider either modifying the treatment or the alveolar anatomy. The combination of corticotomy and a regenerative procedure has the ability to augment the original anatomy despite unfavorable root movement.[29] In the present analysis, the authors found that the possible detrimental effects of orthodontic movement on periodontal tissues can be overcome even when the movements are outside the original alveolar anatomy. This happens when a regenerative procedure (bone graft and membrane) is combined with a corticotomy. In the authors' experience, when corticotomy is performed alone, the existing bone volume is not consistently preserved.[29] Moreover, in accordance with a recent systematic review,[30] regenerative corticotomy has shown potential to augment and modify the existing bone volumes.

Conclusions

3D positioning of the roots inside the bony envelope has to be considered one of the goals of orthodontic therapy. Whenever orthodontic treatment planning anticipates root movement outside of the alveolus, the orthodontist should consider modifying the treatment or modify the original anatomy. The combination of corticotomy and a regenerative procedure has the ability to augment the original anatomy despite unfavorable root movement. Corticotomy with bone grafting seems to be an effective method in minimizing the risk of marginal bone resorption and fenestration when a tooth is inclined or moved toward the cortical plane. When bone grafting is used, an increase in radiographic thickness of the external plate is noted. This is true even when the movement is in the direction of the cortical plate and outside the boundaries of the original alveolar ridge.

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