Comparison of corticotomy-facilitated vs standard tooth-movement techniques in dogs with miniscrews as anchor units

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Introduction: One method used to accelerate orthodontic tooth movement is the corticotomy-facilitated (CF) technique. The purposes of this study were to (1) identify the effect of the CF technique on orthodontic tooth movement compared with the standard technique, and (2) explore the histologic basis of the difference between the 2 techniques. Methods: Six dogs, aged 6 to 9 months, were used in this study. Extraction of the maxillary second premolar and miniscrew placement were done bilaterally in the maxilla. On the right side, the corticotomy was performed. The first premolars were distalized against the miniscrews with nickel-titanium coil springs on both sides. One dog was killed each week after orthodontic force application. Results: The first premolar on the CF side moved significantly more rapidly (P < 0.05). Histologic findings showed more active and extensive bone remodeling on both the compressive and tension sides in the CF group. Conclusions: The CF technique doubled the rate of orthodontic tooth movement. Histologically, the more active and extensive bone remodeling in the CF group suggested that the acceleration of tooth movement associated with corticotomy is due to increased bone turnover and based on a regional acceleratory phenomenon. (Am J Orthod Dentofacial Orthop 2009;136:570-7)

Orthodontic treatment usually lasts 1 to 2 years, and even more time is required for extraction cases. To shorten the time for orthodontic tooth movement, various attempts have been made. These attempts fall into 3 categories. The first is local or systemic administration of medicines. The second category is mechanical or physical stimulation such as direct electrical current or a samarium-cobalt magnet. The last category is oral surgery, including dental distraction, alveolar surgeries to undermine interseptal bone, and alveolar corticotomies, which have been used to correct malocclusions for over 100 years. Kole used a combined intraradicular corticotomy and supra-apical osteotomy technique for rapid tooth movement. Duker, in 1975, duplicated Kole’s technique in a report of alveolar corticotomies using beagle dogs. By using only labial and lingual corticotomy cuts to circumscribe the roots of the teeth, Generson et al in 1978 revised Kole’s technique and reported successful results with a 1-stage corticotomy-only technique without the supra-apical osteotomy. Gantes et al in 1990 also reported rapid tooth movement and reduced treatment time. In 2001, Wilcko et al reported a revised corticotomy-facilitated (CF) technique that included periodontal alveolar augmentation, called accelerated osteogenic orthodontics; it demonstrated acceleration of treatment to one third of the usual time.

Anchorage control is a fundamental concept in orthodontic treatment. Various types of miniscrews were introduced for different orthodontic applications. In 2003, Kyung et al introduced Absanchor titanium miniscrews, which were specifically designed for orthodontic use. Specific implant heads were introduced to facilitate easier attachment to orthodontic appliances; they are small enough to be placed in any area of the alveolar process. These miniscrews can be immediately loaded, and their effectiveness as anchor units has been satisfactory.

The previous evaluations of the CF technique were mainly based on case reports and clinical evidence rather than on detailed histologic investigations. This study was designed to answer the following questions. Compared with the standard tooth-movement technique (S), to what extent will the CF technique...
speed up tooth movement? What is the histologic explanation of the difference between the 2 techniques?

MATERIAL AND METHODS

Six dogs (ages, 6-9 months) were kept for this study in a well-controlled animal facility. They were caged individually and fed soft dog chow and water. All experimental procedures, including surgical and clinical examinations, were performed aseptically by using sodium pentobarbital (25 mg per kilogram of body weight) for intramuscular anesthesia. Intravenous injections of penicillin were given for 3 days postsurgically. The dogs were humanely killed with intravenous injections of pentobarbital (50 mg per kilogram). All procedures were approved by the Animal Ethics Committee of Cairo University.

The following surgical procedures were performed.

1. Absoanchor miniscrews (Dentos, Daegu, Korea) were used. The small head type (diameter, 1.2 mm; length, 8 mm) was selected for this study. Screws were placed bilaterally between the roots of the maxillary third premolar and the maxillary first molar. They were placed above the gingival margin by approximately 5 mm. With the self-tapping technique, the following were done: an indentation of 0.9 mm with a pilot drill was made near the screw with water cooling, and the miniscrew was placed by using a long miniature screwdriver.

2. The maxillary second premolar was extracted bilaterally.

3. On the right side of the maxilla, a labial full-thickness mucoperiosteal flap was reflected (CF group). Two vertical and 1 horizontal corticotomy cuts were made mesially, distally, and apically, respectively, in the area of future tooth movement (Fig 1). The vertical corticotomy cuts were made 1 mm apical to the alveolar crest and extended apically to the level of the root apices. Small corticotomy perforations were drilled in the buccal cortical bone. There were 8 to 10 perforations according to the alveolar process area in each dog. These perforations were made to obtain additional bleeding points. The corticotomy cuts and perforations were made with a #2 long-shank round bur in a high-speed hand piece with copious water irrigation and extended barely into the spongy bone.

The following orthodontic procedures were performed on both the right maxillae (CF group) and the left maxillae (S group).

1. A horizontal cervical groove was made encircling the first maxillary premolar below the height of contour by using a 1-mm round bur on a low-speed micromotor.

2. A 0.016-in ligature wire was tightened around the horizontal cervical groove on the first premolar. The pigtail was formed into a hook for the attachment of the eyelet of the coil spring.

3. A nickel-titanium closed-coil spring was stretched between the hook on the first premolar and the head of the miniscrew to distalize the first premolars. The force from the coil was 400 g. Measured with a force gauge, it was equal bilaterally. Loading of the miniscrew began immediately after placement (Fig 2).

4. The distance between a vertical notch on the cervical area of the first premolar and another notch placed similarly on the third maxillary premolar was recorded weekly by using a Boley gauge. The measurements were made to the nearest 0.1 mm (Fig 3).
For the histologic procedures, the first dog was killed after 1 week of force loading, and another dog was killed each week thereafter. Each maxilla was dissected free, and soft tissue was immediately removed. The maxillary segments, including the first premolar and the extraction socket, were dissected. The specimens were processed as described by Callis. After complete decalcification, the specimens were embedded in paraffin with a conventional technique and sectioned mesiodistally (6 μm thick). The sections were stained with hematoxylin and eosin for routine examination and Masson’s trichrome for collagen detection.

Statistical analysis

Within-group differences in tooth movement for the first 4 weeks were analyzed by using the paired

### Table I. Paired t test showing mean differences in tooth movement in each group in the first 4 weeks starting from day 0

<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>Mean ± SD (mm)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>D0-W1</td>
<td>0.92 ± 0.20</td>
<td>0.00011†</td>
</tr>
<tr>
<td>S</td>
<td>D0-W2</td>
<td>1.80 ± 0.57</td>
<td>0.00212†</td>
</tr>
<tr>
<td>S</td>
<td>D0-W3</td>
<td>2.33 ± 0.58</td>
<td>0.01980*</td>
</tr>
<tr>
<td>S</td>
<td>D0-W4</td>
<td>2.33 ± 0.58</td>
<td>0.01980*</td>
</tr>
<tr>
<td>CF</td>
<td>D0-W1</td>
<td>2.00 ± 0.55</td>
<td>0.00029†</td>
</tr>
<tr>
<td>CF</td>
<td>D0-W2</td>
<td>3.30 ± 0.84</td>
<td>0.00091†</td>
</tr>
<tr>
<td>CF</td>
<td>D0-W3</td>
<td>4.25 ± 0.65</td>
<td>0.00095†</td>
</tr>
<tr>
<td>CF</td>
<td>D0-W4</td>
<td>4.67 ± 0.58</td>
<td>0.00506†</td>
</tr>
</tbody>
</table>

D0, Day 0; W, week.
*Significant: P <0.05; †Significant: P <0.01; ‡Significant: P <0.001.

### RESULTS

The mean values for movement of the first premolars from the first to the fourth weeks starting from day 0 in each group are shown in Table I. There was significant movement (P <0.05) in the first 4 weeks in both groups. In the fifth week, a small amount of movement (0.5 mm) occurred in the S group, but there was none in the CF group; no movement was found in the sixth week in either group. There were also significant differences in tooth movement between the 2 groups in the first 4 weeks and in the total amount of tooth movement, as shown in Table II. The mean value of tooth movement in the first 4 weeks in the CF group was 4.67 ± 0.58 mm. This value was twice that of the S group (2.33 ± 0.58 mm). The tooth displacement curve of the first premolar (Fig 4) was similar to the classic tooth displacement curve described by Reitan. Both groups followed the curve, but, in the CF group, the tooth movement values were approximately double those of the S group.

![Figure 3](image-url) Measurement of the distance between vertical grooves on the first and third premolars with the Boley gauge.

![Figure 4](image-url) Tooth displacement curve of the first premolar in the 2 groups.

<table>
<thead>
<tr>
<th>Week</th>
<th>Dogs (n)</th>
<th>Mean difference ± SD (mm)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>1.08 ± 0.24</td>
<td>0.00108†</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>1.50 ± 0.45</td>
<td>0.01065*</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>1.92 ± 0.47</td>
<td>0.00979†</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>2.33 ± 0.47</td>
<td>0.00776†</td>
</tr>
</tbody>
</table>

*Significant: P <0.05; †Significant: P <0.01.
The histologic findings on the compressive side were the following. During the first and second weeks, the periodontal ligament (PDL) of the CF group widened, and the interseptal bone resorbed, leaving only sporadic bone areas scattered in the PDL. As a result, the PDL joined the extraction socket that was filled with many dilated blood vessels. On the other hand, the PDL of the S group narrowed, and the fiber bundles were condensed and arranged haphazardly. Thin interseptal bone was seen surrounded by an osteoblastic layer (Fig 5). Neither group had root resorption.

During the third and fourth weeks, the CF group’s PDL fibers were a mature type and arranged somewhat regularly. The extraction socket was filled by thick woven bone with many reversal lines. The PDL of the S group narrowed and included both mature and immature collagen fiber bundles. The continuation between the PDL and the extraction socket was still noticed in the CF group, whereas the alveolar bone in the S group reverted to a nearly normal condition, entrapping wide marrow spaces. Direct bone resorption was indicated by many Howship’s lacunae (Fig 6).

After the sixth week, there was direct resorption on the bone surface in the CF group as evidenced by the many osteoclasts. Dilated blood vessels were noticed especially at the bone surface. The woven bone in the extraction socket was resorbed and replaced by lamellar bone. In the S group, fewer osteoclasts were seen. The PDL turnover was localized in the intermediate zone where hyalinization was noticed. The regenerative bone tissue refilled the extraction socket and was still the woven type (Fig 7).

On the tension side, the periodontium widened, and dilated blood vessels were seen during the first and the second weeks in the CF group. Newly formed bone with numerous osteocytes and wide marrow spaces were noticed. The newly formed woven bone in the S group was thinner and more regular than that in the CF group. Areas of collagen fiber degeneration were seen in the CF group near the bone surface. In the S group, these findings were not observed (Fig 8).

During the third and the fourth weeks, the PDL fibers in the CF group were arranged haphazardly, and mature collagen fiber bundles were observed interlaced with immature ones, especially in the intermediate zone. On the other hand, the collagen fiber bundles in the S group consisted of mature fibers, and the formed bone was thinner compared with that in the CF group (Fig 9).

After the sixth week, the collagen fiber bundles had a normal appearance in both groups. The newly formed bone in the CF group was bulky and lamellar. Many osteoblasts were noticed on the bone surface. Woven bone with wide marrow spaces was seen in the S group (Fig 10).

DISCUSSION

Much of the literature on CF orthodontics is based on empirical evidence and case reports. Experimental animal-based histologic studies, much needed to
elucidate the tissue changes with this technique, are rather few. This study was undertaken to investigate the influence of corticotomy on tooth movement and to compare tissue changes between the CF and the S orthodontic techniques.

Our results showed that the CF technique significantly accelerated tooth movement. The rate of tooth movement in the CF group was twice that in the S group. These results agree with those of Iino et al., who reported significant acceleration of tooth movement in their animal study. The findings of both animal experiments corroborate the clinical observations of Wilcko et al. and Hajji, who reported significant reductions in treatment time with CF orthodontics.

In this study, we modified the technique to suit the extraction case in the dog model; corticotomy cuts were made mesially, distally, and apically to the extraction site to achieve bone activation, and, as recommended by Wilcko et al., corticotomy perforations were used to increase the bleeding points at this area. Tooth movement began immediately after corticotomy. On the other hand, Iino et al. used both labial and lingual corticotomy cuts near the moving premolar. Tooth movement was started 16 weeks after corticotomy.

Fig 6. Photomicrographs of the compressive sides after the fourth week. A, The CF group showing trabeculae of woven bone surrounded by osteoblasts with many reversal lines (arrows). B, The S group showing haphazard fibrous arrangement of the PDL (p). Scalloped bone surface faces the PDL (arrows). a, Alveolar bone. A and B, Masson’s trichrome stain, magnified 200 times.

Fig 7. Photomicrographs of the compressive sides after the sixth week. A, The CF group showing lamellar bone (*). Many osteoclasts are obvious (arrows). B, The S group showing the area of hyalination especially at the intermediate zone (h), and internal bone formation as a reaction to EARR (arrows). a, Alveolar bone. A, Hematoxylin and eosin stain, magnified 200 times; B, Masson’s trichrome stain, magnified 200 times.
Labial and lingual cuts might be justified in a mandible with thick cortical plates. We believed that labial cuts were sufficient in the dogs’ less dense maxillae. In addition, the cuts were made in the area of desired tooth movement rather than around the moving tooth.

The acceleration of tooth movement in this study was similar to that reported by Ren et al, who used a surgical technique that depended on undermining the interseptal bone in a premolar-extraction canine experiment. Although in that study a corticotomy in the
strict sense was not performed, the similarity of findings is remarkable. The anchorage loss was not measured in this study because the first premolars were distalized on miniscrews that give sufficient anchorage.\textsuperscript{18} We focused on the influence of corticotomy on tooth movement and the accompanying tissue changes.

Standard orthodontic tooth movement has 3 periods: initial, lag, and postlag. In this experiment, the tooth displacement curve of the first premolar was similar to the classic tooth-displacement curve described by Reitan\textsuperscript{21} in both groups. However, the initial movement in the first and second weeks was faster in the CF group than in the S group. This could have been due to the extensive alveolar bone septum resorption in the CF group. In the S group, there was thin interseptal bone surrounded by an osteoblastic layer. Ren et al\textsuperscript{8} also found interseptal bone resorption, but after the third and fourth weeks of force application (150 g). The difference in timing between the study of Ren et al\textsuperscript{8} and ours, particularly in the CF group, was probably due to more extensive bone resorption and increased osteoclastic activity caused by the corticotomy; this agrees with the findings of Yaffe et al.\textsuperscript{23} The excessive applied force (400 g) in that study could be another reason for the more rapid bone resorption. However, the absence of microscopic root resorption until the end of the sixth week of force application indicated that this load was tolerated by the dogs’ teeth, even though strong forces are a cause of root resorption during orthodontic treatment.\textsuperscript{24}

After the second week, greater osteoblastic activity in the compressive side was found in the S group. This probably was an attempt to revert to the resorbed alveolar bone and might have hindered tooth movement in the S group.

The lag period, from the third to the sixth weeks in this study, was associated with PDL compression and destruction of its fiber arrangement and structure that were replaced by immature fibers. This observation was more obvious in the S group than in the CF group. Many researchers have stated that the lag period is probably associated with hyalinization in the PDL.\textsuperscript{8,25-29} The PDL fibers in this study did not show hyalinization except in small areas in the S group at the sixth week. This might be due to the high vascularity from the extraction socket, thus preventing the expected ischemia to the PDL fibers. V on Böhl et al\textsuperscript{28} stated that hyalinization was found not only in the phase of arrest, between 4 and 20 days of force application, but also after 40 and 80 days of tooth movement. This suggested that the development and removal of necrotic tissue was a continuous process during tooth displacement rather than a single event.

Although we did not study the postlag period, it was expected from the reappearance of many osteoclasts on the alveolar bone surface in the sixth week. Von Böhl et al\textsuperscript{28} recorded such a postlag period after 40 and 80 days of tooth movement.

Regarding the tension side, new bone formation was similar in both groups except that osteogenesis was more active in the CF group because of more extensive stretching of the periodontium from the faster tooth movement.

**Fig 10.** Photomicrographs of tension sides after the sixth week: A, the CF group and B, the S group showing osteogenesis and PDL fibers reverted to normal arrangement. Thick lamellar bone is seen in A (*); woven bone is seen with many reversal lines in B (*). a, Alveolar bone; c, cementum; p, PDL. A, Hematoxylin and eosin stain, magnified 200 times; B, Masson’s trichrome stain, magnified 200 times.
movement in this group. These results were similar to those of Ren et al., except that the PDL fibers of the CF group showed degeneration at the bone surface. This observation could be because rapid movement in the CF group led to degeneration of the collagen fiber bundles, whereas steady, smooth movement in the S group prevented this. The return to the normal arrangement of the PDL fibers after the fifth and sixth weeks in both groups might be due to the lag period that allowed for this rearrangement. Not only was the thickness of the newly formed bone different in both groups but also the quality of the bone was different. In the CF group, the bone became lamellar; in the S group, the bone was the woven type with wide marrow spaces up to the sixth week. This suggested a greater relapse tendency in the S group.

CONCLUSIONS

The CF technique was found to double the amount of tooth movement compared with the S technique. Histologically, there was more active and extensive bone remodeling in the CF group. This suggests that the acceleration of tooth movement associated with corticotomy is due to increased bone turnover and based on a regional acceleratory phenomenon.

REFERENCES