Accelerating Tooth Movement With Corticotomies: Is It Possible and Desirable?

Peter H. Buschang, Phillip M. Campbell, and Stephen Ruso

Accelerating the rate of tooth movement is desirable to patients because it shortens treatment time and also to orthodontists because treatment duration has been linked to an increased risk of gingival inflammation, decalcification, dental caries, and root resorption. Corticotomies, which some orthodontists are currently using to speed up tooth movements, induce a regional acceleratory phenomenon, which provides the biological basis for accelerated tooth movement. Case reports and limited clinical studies show that corticotomies increase rates of tooth movement and decrease treatment duration. The experimental evidence indicates that corticotomies approximately double the amount of tooth movement produced with orthodontic forces. However, the experimental effects are limited to a maximum of 1-2 months in the canine model, suggesting that the effects of corticotomies in humans may be limited to 2-3 months, during which 4-6 mm of tooth movement might be expected to occur. Based on the available literature, performing corticotomies on a routine basis in private practices may not be justified. Controlled clinical studies are required to better understand the treatment and potential iatrogenic effect(s) of corticotomies. (Semin Orthod 2012;18:286-294.) © 2012 Elsevier Inc. All rights reserved.

Orthodontic treatment time ranges between 21-27 and 25-35 months for nonextraction and extraction therapies, respectively (Table 1). In addition to extractions, factors that have been linked to increased treatment time include the number of missed appointments, number of replaced brackets and bands, number of treatment phases, oral hygiene, and the use of headgears. The ability to accelerate tooth movements would be advantageous for orthodontists because treatment duration has been linked to an increased risk of gingival inflammation, decalcification, dental caries, and, especially, root resorption. Longer treatment times are also expensive, both for the patient and the orthodontist. Shorter treatment durations are important to all patients, especially for the adults, who are seeking treatment in increasing numbers. Unfortunately, adults typically require longer treatment periods because their metabolism is much slower than in younger patients. Probably the best way to shorten treatment time is to speed up tooth movements. It has been estimated that teeth move 0.8-1.2 mm/month when continuous forces are applied. Tooth movements have been experimentally accelerated by local injections of prostaglandins, vitamin D3, and osteocalcin, as well as by the application of pulsed electromagnetic fields and direct electric currents. Whether these approaches can be applied clinically remains questionable; some could illicit a detrimental inflammatory response; regular injections are painful and uncomfortable; pulsed electromagnetic fields could...
adversely affect protein metabolism and muscle activity; and direct current could cause a tissue-damaging ionic reaction.

Over the past 10 years, alveolar decortica-
tions, or “corticotomies,” have become a popu-
lar means of increasing the rate of tooth move-
ments. With corticotomies, the cortical layer is
cut or perforated to the depth of the medullary
bone; corticotomies do not create a mobile seg-
ment. The Wilcko brothers, who brought alveo-
lar decortication into mainstream orthodontics,
were the first to emphasize that the treatment
effect was because of the regional acceleratory
phenomenon RAP.28 The RAP is a normal local-
ized reaction of soft and hard tissues to noxious
stimuli (Fig. 1); it is associated with increased
perfusion and bone turnover and decreased
bone density.29

Importantly, the RAP is simply an accelera-
tion of existing biological processes; it does not
illicit new processes. The processes associated
with corticotomies are similar to the processes
associated with normal fracture healing, which
include a reactive phase, a reparative phase, and
a remodeling phase (Fig. 2). Corticotomies
should be considered as stable, undisplaced,
fractures that injure the periosteum and bone.

The injury causes some cells to die at the same
time, sensitizing the surviving cells to respond to
the insult. The initial response occurs during the
reactive phase, with immediate constriction of
blood vessels to mitigate bleeding, followed by
hematoma or blood clot formation within a few
hours. Whether hematomas develop depends on
the extent of the injury. The essential aspects of
the reactive phase are thought to be completed
within 7 days of the injury.30 The cells within the
hematoma die, as do some of the adjacent
cells.31,32 A loose aggregate of cells is then
formed, made up of fibroblasts, intercellular ma-
terials, and other supporting cells, interspersed
with small blood vessels, collectively referred to
as granulation tissue.33 The formation of granu-
lation tissue takes approximately 2 weeks. Some
days afterward, periosteal cells close to the injury
site, as well as the fibroblasts within the granu-
lation tissue, develop into chondroblasts and
form hyaline cartilage. Periosteal cells distal to
the injury site develop into osteoblasts, which
form woven bone.32 These processes result in a
mass of hyaline cartilage and woven bone, called
the callus.34 During the next phase, the hyaline
cartilage and woven bone are replaced with la-
mellar bone. The formation of lamellar bone
begins as soon as the tissues become mineral-
ized. The duration of time between callus for-
mation and mineralization lasts 1-4 months,30
depending on the extent of the injury. Because
healing times also depend on the stability of the
bony segments, corticotomies might be ex-
pected to heal faster than fractures, where seg-
ments have been displaced or are unstable. Dur-
ing the last phase of healing, bone is remodeled
into functionally competent mature lamellar
bone, a process that takes 1-4 years.

Table 1. Treatment Duration (Months) Associated
With Extraction and Nonextraction Treatments

<table>
<thead>
<tr>
<th>Reference</th>
<th>Extraction</th>
<th>Nonextraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>O’Brien et al1</td>
<td>30.6 ± 10.4</td>
<td>24.8 ± 9.2</td>
</tr>
<tr>
<td>Alger2</td>
<td>26.6</td>
<td>22.0</td>
</tr>
<tr>
<td>Fink and Smith3</td>
<td>26.2</td>
<td>22.0</td>
</tr>
<tr>
<td>Popovich et al4</td>
<td>25.7 ± 6.8</td>
<td>25.0 ± 5.5</td>
</tr>
<tr>
<td>Skidmore et al5</td>
<td>24.6 ± 5.8</td>
<td>21.3 ± 4.4</td>
</tr>
<tr>
<td>Vu et al6</td>
<td>35.2 ± 12.2</td>
<td>27.4 ± 10.1</td>
</tr>
<tr>
<td>Mean</td>
<td>28.1</td>
<td>23.8</td>
</tr>
</tbody>
</table>

Figure 1. The process by which corticotomies bring
about faster tooth movements. (Color version of fig-
ure is available online.)

Figure 2. The 3 phases of the healing process. (Color
version of figure is available online.)

The injury causes some cells to die at the same
time, sensitizing the surviving cells to respond to
the insult. The initial response occurs during the
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Corticotomies initiate the RAP; they increase the rate of bone modeling, reduce mineral density, and create a transient osteopenia. As much as a 5-fold increase in bone turnover has been reported in long bones adjacent to corticotomy sites. Because alveolar decortication also induces a RAP, it might be expected to facilitate orthodontic tooth movement. After all, tooth movement should be faster in less dense alveolar bone that is rapidly being remodeled, for the same reasons that tooth movements are faster in growing children than in adults. The alveolar response to decortication is a function of time and proximity to the injury site. When the maxillary buccal and lingual cortical plates of 36 adult rats were perforated adjacent to the upper left first molars on one side, there were approximately 3 times as many osteoclasts, 3 times the bone apposition rate, a 2-fold decrease in calcified spongiosa, and greater periodontal ligament surface area around the roots of teeth (presumably associated with the decrease in calcified spongiosa). These effects were localized to the area immediately adjacent to the site of injury. Tissue architecture returned to control levels by week 11.

In 2010, Teixeira et al divided 48 adult rats into 4 groups: (1) orthodontic forces (50 cN) only, (2) orthodontic forces plus soft tissue flap, (3) orthodontic forces soft tissue flap plus 3 small perforations in the cortical plate, and (4) a control group. They hypothesized that small perforations of the cortical bone should increase the expression of inflammatory cytokines, increase the rate of bone remodeling, and increase the rate of tooth movement. Of the 92 cytokines that were examined, the levels of 37 were raised in the 3 experimental groups. The 21 cytokines elevated the most were found in the group that received the cortical perforations, the same group that showed the greatest number of osteoclasts and the greatest bone remodeling. The literature clearly demonstrates that corticotomies induce the RAP.

### Case Reports

Numerous case reports have been published showing accelerated tooth movements associated with corticotomies (Table 2). In 1959, Köle presented several cases showing that corticotomies are useful in treating rotated teeth, maxillary constriction, excessively wide maxillae, excess overbite, lower incisor protrusion, single-tooth displacements, as well as spacing. Anholm et al used corticotomies, along with fixed appliances, to treat a 23-year-old Class II man with constricted arches in 11 months. Owen was able to correct his own mild anterior crowding with corticotomies and Invisalign (San Jose, CA)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Problem</th>
<th>Patient Age</th>
<th>Treatment Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single treatment procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Köle</td>
<td>Rotated teeth</td>
<td>NA</td>
<td>6-8 wks</td>
</tr>
<tr>
<td>Premolar requiring distalization</td>
<td>NA</td>
<td>8-12 wks</td>
<td></td>
</tr>
<tr>
<td>Lower incisor proclination</td>
<td>NA</td>
<td>10-12 wks</td>
<td></td>
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<tr>
<td>Hwang and Lee</td>
<td>Overerupted maxillary first molars</td>
<td>21 y/o</td>
<td>4 wks</td>
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<tr>
<td>Extradural mandibular second molar</td>
<td>20 y/o</td>
<td>4 wks</td>
<td></td>
</tr>
<tr>
<td>Moon et al</td>
<td>Extradural first and second molars</td>
<td>26 y/o</td>
<td>2 mo</td>
</tr>
<tr>
<td>Oliveira et al</td>
<td>Overerupted first and second molars</td>
<td>36 y/o</td>
<td>2.5 mo</td>
</tr>
<tr>
<td>Extradural maxillary molars</td>
<td>39 y/o</td>
<td>4 mo</td>
<td></td>
</tr>
<tr>
<td>Full treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anholm, et al</td>
<td>Narrow arches, unilateral Class II malocclusion</td>
<td>23 y/o</td>
<td>11 mo</td>
</tr>
<tr>
<td>Owen</td>
<td>Mild anterior crowding</td>
<td>Adult</td>
<td>8 wks</td>
</tr>
<tr>
<td>Wilcko et al</td>
<td>Anterior crowding and posterior crossbite</td>
<td>24 y/o</td>
<td>6 mo 2 wks</td>
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<td>Moderate to severe crowding</td>
<td>17 y/o</td>
<td>6 mo 2 wks</td>
<td></td>
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<tr>
<td>Nowzari et al</td>
<td>Class II, division 2 with crowding</td>
<td>41 y/o</td>
<td>8 mo</td>
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<td>Germec et al</td>
<td>Class III with crowding</td>
<td>22 y/o</td>
<td>16 mo</td>
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<td>Iino et al</td>
<td>Class I malocclusion; bimaxillary protrusion</td>
<td>24 y/o</td>
<td>12 mo</td>
</tr>
<tr>
<td>Aljhan i et al</td>
<td>Anterior open bite; flared and spaced incisors</td>
<td>22 y/o</td>
<td>5 mo</td>
</tr>
<tr>
<td>Kanno et al</td>
<td>Skeletal open bite</td>
<td>28 y/o</td>
<td>7 mo</td>
</tr>
<tr>
<td>Spena et al</td>
<td>Class II with proclined maxillary incisors</td>
<td>18 y/o</td>
<td>11 mo</td>
</tr>
<tr>
<td>Hassan et al</td>
<td>Posterior crossbite; deep bite</td>
<td>21 y/o</td>
<td>19 mo</td>
</tr>
<tr>
<td>Anterior and posterior crossbites; open bite</td>
<td>24 y/o</td>
<td>18 mo</td>
<td></td>
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therapy in 8 weeks by changing trays every 3 days. Wilcko et al\textsuperscript{28} described 2 cases that were completed in <7 months, one among them was presenting with significant transverse maxillary constriction. Nowzari et al\textsuperscript{42} used an autogenous bone graft in conjunction with corticotomies to treat a 41-year-old man with a Class II division 2 crowded occlusion in 8 months.

Corticotomies have also been used to accelerate incisor retraction and retroclination. Germec et al\textsuperscript{43} claimed a significant reduction in treatment time, with no adverse effects on the periodontium or tooth vitality, when they used corticotomies to help retract protrusive mandibular incisors. Corticotomies have also been used to treat an adult bimaxillary protrusion patient, who had 4 premolars extracted, and the treatment only lasted for a year.\textsuperscript{44} Using corticotomies, Aljhani et al\textsuperscript{45} completed treatment of a 22-year-old woman who presented with an anterior open bite and flared/spaced mandibular incisors in 5 months.

Corticotomy procedures have also been shown to speed up the intrusion of supraerupted teeth. Hwang and Lee\textsuperscript{46} used corticotomies to enhance molar intrusion. Moon et al\textsuperscript{47} used corticotomy-facilitated orthodontics to intrude molars (the first and second molars were intruded 3.0 and 3.5 mm, respectively) in only 2 months before prosthodontic treatment. Using a nickel-titanium spring, supported by a full-coverage maxillary splint, Oliveira et al\textsuperscript{48} used corticotomies to intrude supraerupted molars in 2.5 months for one patient, and in 4 months for a second patient. Corticotomies were also used in a 28-year-old woman with a 7.5-mm anterior open bite, whose posterior segments were intruded, and the bite was closed in 7 months.\textsuperscript{49}

Corticotomies have also been used to facilitate molar distalization and arch expansion. Spena et al\textsuperscript{50} distalized molars into a Class I relationship in 8 weeks. Hassan et al\textsuperscript{51} used Wilckodontics\textsuperscript{\textregistered} to speed up expansion of two adults with true unilateral posterior crossbites. Although these case reports consistently show faster than expected treatment changes (6-19 months for full treatment vs 21-35 months with conventional treatment), they provide only anecdotal evidence of actual treatment duration. Case reports may be unintentionally biased by the authors’ desire to demonstrate faster treatment results.

**Prospective Human Trials**

Prospective clinical trials are necessary to determine how much faster treatments actually are with corticotomies. A case series presented by Fischer\textsuperscript{52} evaluated the treatment effects in 6 consecutively treated patients with bilaterally partially impacted canines. They used a split-mouth design, with the canines randomly assigned to one of 4 treatments. The canines that had corticotomies required 28%-33% less treatment time than the contralateral canines treated using conventional surgical techniques (11.5 vs 16.6 months), with no differences between sides in the final periodontal condition.

In 2007, Lee et al\textsuperscript{53} compared 29 adult woman patients who had conventional orthodontic treatment with 20 adult women who had corticotomy-assisted orthodontics in the maxilla and anterior segmental osteotomies in the mandible. The corticotomy-assisted/segmental group completed treatment 8 months faster than the conventional orthodontic group (19 ± 6 vs 27 ± 7 months). As expected, the corticotomy-assisted/segmental group showed a more posteriorly positioned mandible than the orthodontic only group and less mandibular incisor retroclination. Upper lip changes were least in the orthodontics only group. Although they note that the “treatment methods were assigned randomly by the clinician’s decision regarding the same chief complaint,” the sample size differences and pretreatment morphological differences (50% of the measures showed significant differences) suggest that the groups were not initially equivalent.

**Prospective Animal Research**

The suitability of any animal model for evaluating the effects of corticotomies on tooth movements is directly related to the similarity between the results obtained for the model compared with humans. In terms of tooth movements, these differences depend on similarities in bone composition, density and quality, as well as bone turnover rates. With respect to bone composition (ash weight, hydroxyproline, extractable proteins, Insulin-like Growth Factors) and density, Aerssens et al\textsuperscript{54} found that the characteristics of human bone are more closely approximated by canine bone than by sheep, pig, cow, or chicken bone. Their work supports the work
of Gong et al\textsuperscript{55} who showed that the cortical and cancellous bone of dogs and humans were similar in terms of water fraction, organic fraction, volatile inorganic fraction, and ash weight. Although it is difficult to compare dogs and humans in terms of bone turnover, due to variability within and across sites, the formation rates of trabecular iliac bone of beagles have been shown to be approximately twice that of humans.\textsuperscript{56} Canine bone also has significantly higher mineral density than human bone.\textsuperscript{57} Single-cycle skeletal-remodeling duration of the canine model has also been shown to be approximately 42% faster than in humans.\textsuperscript{58} Despite the differences that exist, the similarities between canine and human bone has led to the conclusion that, with the exception of other primates, dogs have the most similar bone structure to humans.\textsuperscript{54,59} Large animal models, such as dogs, are superior to small animals for studying the microstructure of cancellous bone.\textsuperscript{60}

A variety of animal experiments have been conducted to better understand the biological effects of corticotomies. After performing vertical buccal corticotomies and horizontal bicortical osteotomies 5 mm above maxillary root apices in 6 beagle dogs, Düker\textsuperscript{61} demonstrated pulp vitality and a healthy periodontium after 4 mm of tooth movement, produced over a 8- to 20-day period with elastics from a metal arch splint.

Cho et al\textsuperscript{62} extracted the second premolars of 2 beagle dogs and, after 4 weeks of healing, retracted a mucoperiosteal flap and made 12 perforations with a round bur into the buccal and lingual cortical plates in the right maxillary and mandibular quadrants. They then protracted all 4 third premolars with 150-g nickel-titanium coil springs. After 8 weeks, they reported approximately 4 times as much tooth movement on the corticotomy side of the maxilla and approximately twice as much tooth movement on the corticotomy side of the mandible. The velocity curves generated from the data provided in their tables showed that differences in rates of tooth movement between the corticotomy and control sides increased over time in the maxilla and decreased in the mandible (Fig. 3).

Using a larger sample of 12 adult beagle dogs, Iino et al\textsuperscript{63} extracted the mandibular second premolars, allowed the sites to heal for 16 weeks, and then performed corticotomies around the left third premolars. The third premolars were then moved mesially with an approximately 51 g nickel-titanium coil spring. After 4 weeks, the corticotomy side showed approximately twice as much tooth movement as the sham control side. Velocities of tooth movement were significantly faster on the experimental than sham control side for the first 2 weeks only; no significant difference in rates of tooth movement were observed between weeks 2– and 4 (Fig. 4A). The corticotomy side showed hyalinization of the periodontal ligament at week 1 only, whereas the control side showed evidence of hyalinization throughout the 4-week experimental period.

Mostafa et al\textsuperscript{64} extracted the maxillary second premolars of 6 dogs, immediately raised a full-thickness mucoperiosteal flap, performed corticotomies, and distalized the first premolars using miniscrews as skeletal anchors. Buccal corticotomies, consisting of 8-10 perforations, were drilled on the right side only; the left side

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Maxillary and mandibular third premolar movements’ rates on the experimental corticotomy and control sides (from data reported by Cho et al\textsuperscript{62}). (Color version of figure is available online.)}
\end{figure}
served as a control. Using nickel-titanium coil springs, 400g forces were applied to both sides to distalize the maxillary first premolars for 5 weeks. Once again, the teeth on the corticotomy side moved approximately twice as far (2.3 vs 4.7 mm) as the premolars on the control side. Differences in tooth movements, which were statistically significant after only 1 week, increased to 2.3 mm by week 4. Velocity curves show that differences in rates of tooth movement between sides decreased during the first 4 weeks (Fig. 4B). There were no differences in tooth movements between sides after the fourth week. Their histomorphometric analyses showed that bone remodeling was more active and extensive on both the compressive and tension sides of the teeth on the corticotomy side.

Sanjideh et al\textsuperscript{65} performed a split-mouth experimental study to determine whether (1) corticotomies performed immediately after extractions increased rates of tooth movement, and (2) a second corticotomy performed after 4 weeks further increased tooth movements. The maxillary second premolars and mandibular first premolars were extracted in 5 foxhound dogs. Immediately after the extractions, flap surgeries and corticotomies were performed on the buccal and lingual surfaces around the second mandibular premolar on one randomly chosen side; the other side served as the control. Both maxillary quadrants had initial buccal flaps and corticotomies; one randomly selected quadrant had a second buccal flap surgery and corticotomy after 28 days. A 200-g nickel-titanium coil spring provided a constant mesial force on the teeth for the entire 56 days of the experiment. Total mandibular tooth movements were about twice as much on the experimental side (2.4 mm) than on the control (1.3 mm) side. Rates of tooth movement increased, peaked between 22 and 25 days, and then decelerated, with no significant differences between sides after 7-8 weeks (Fig. 5). In the maxilla, there was significantly more tooth movement on the side that had 2 corticotomies than the side that had only one corticotomy performed, but the differences were small and of questionable clinical significance.

Figure 4. Comparisons of tooth movements' rates on the experimental corticotomy and control sides for (A) mandibular second premolars (from data reported by Iino et al\textsuperscript{63}) and (B) maxillary first premolars (from data reported by Mostafa et al\textsuperscript{64}). (Color version of figure is available online.)

Figure 5. Comparisons of tooth movements' rates on the experimental corticotomy and control sides for the mandibular second premolars (modified from data reported by Sanjideh et al\textsuperscript{65}). (Color version of figure is available online.)
Conclusions

The experimental literature clearly shows that the rates of tooth movement can be significantly increased with corticotomies. Well-controlled split-mouth studies have demonstrated that there is approximately twice as much tooth movement with than without corticotomies. However, the amount of time during which corticotomies have an effect on tooth movements is limited to 1-2 months. Assuming that bone turnover rates of dogs is 1.5 greater than human, this suggests that the effects of corticotomies should be limited to 2-3 months in humans, during which time 46 mm (ie, twice the normal amount per month) of tooth movement might be expected. These estimates must be considered rough and preliminary; controlled clinical trials are urgently needed to determine the actual effects of corticotomies.

How much corticotomies might be expected to speed up overall treatment time depends, ultimately, on the type of treatment being rendered and the stage of treatment requiring the greatest amount of tooth movement (Fig. 6). For example, corticotomies might be expected to shorten the treatment of simple Class I nonextraction cases, which involve only 2 stages of treatment, to 18 months or less. For extraction cases, the limited duration of the corticotomy effect might be best applied during the retraction stage of treatment, when the greatest tooth movements are required. In contrast, the leveling and alignment stages might be the best time for corticotomies in Class II and Class III nonextraction cases. Although corticotomies might be expected to accelerate all orthodontic treatments, it remains to be shown whether they can consistently shorten treatment times to <18 months for cases requiring 3 stages of treatment.

Based on the available evidence, performing corticotomies on a routine basis in private practices may not be justified. Controlled clinical studies are necessary to improve on existing corticotomy procedures in terms of how and when they are performed. More experimental studies are necessary to more completely understand the biological effects of corticotomies and to better control the effects that have been shown to enhance tooth movements. For example, it was recently shown that the amount of surgical trauma has an effect on the amount of tooth movements that occur. A randomized split-mouth design with 10 skeletally mature foxhounds showed that tooth movements on the side that had a limited surgical insult was significantly less (1.1 mm or 38%) than tooth movements on the side with more extensive surgical insults. Research is also needed to limit some of the potential iatrogenic effects of corticotomies. Although increases in rates of tooth movement are desirable, the increased inflammation associated with corticotomies could be detrimental. Due to the potential loss of alveolar bone height associated with conventional corticotomies, alternative procedures that do not require flap surgeries need to be tested. Finally, controlled studies are necessary to determine whether grafting is necessary and, if so, which procedures are most effective.

Based on the clinical and experimental studies that have been performed to date, the following conclusions can be drawn:

1. Corticotomies definitively produce a RAP.
2. Case reports and limited clinical studies show that corticotomies increase the rates of tooth movement and decrease treatment duration.
3. The experimental evidence pertaining to dogs indicates that corticotomies, either with cuts or perforations, approximately double the amount of tooth movement produced with orthodontic forces.
4. The experimental evidence indicates that the effects of corticotomies in canines are limited to a maximum of 1-2 months. This suggests that the effects in humans may be limited to 2-3 months, during which 46 mm of tooth
movement might be expected to occur if tooth movement is doubled throughout the duration of the RAP.

5. Whether it is desirable for orthodontists to routinely perform corticotomies depends on future well-controlled clinical studies evaluating ways to enhance current procedures and control potential iatrogenic effects.

References


