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

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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.)

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.[7] 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,[8-10] and, especially, root resorption.[11,12] 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.[13-16] Unfortunately, adults typically require longer treatment periods[17] because their metabolism is much slower than in younger patients.[18] 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.[19-22] 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.[23-27] 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

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

Reference	*Extraction*	*Nonextraction*
O'Brien et al[1]	30.6 ± 10.4	24.8 ± 9.2
Alger[2]	26.6	22
Fink and Smith[3]	26.2	22.0
Popovich et al[4]	25.7 ± 6.8	25.0 ± 5.5
Skidmore et al[5]	24.6 ± 3.8	21.3 ±4.4
Vu et al[6]	35.2 ± 12.2	27.4 ± 10.1
Mean	28.1	23.8

adversely affect protein metabolism and muscle activity; and direct current could cause a tissue-damaging ionic reaction.

Over the past 10 years, alveolar decortications, or "corticotomies," have become a popular means of increasing the rate of tooth movements. With corticotomies, the cortical layer is cut or perforated to the depth of the medullary bone; corticotomies do not create a mobile segment. The Wilcko brothers, who brought alveolar 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 localized 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 acceleration 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.

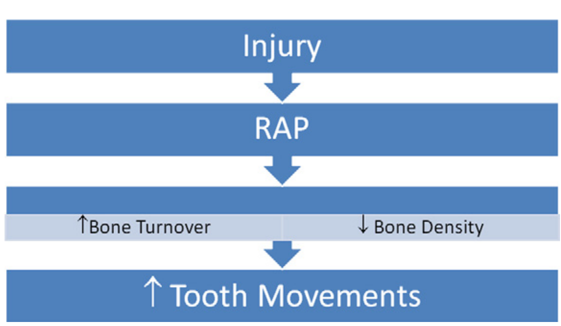

Figure 1. The process by which corticotomies bring about faster tooth movements. (Color version of figure is available online.)

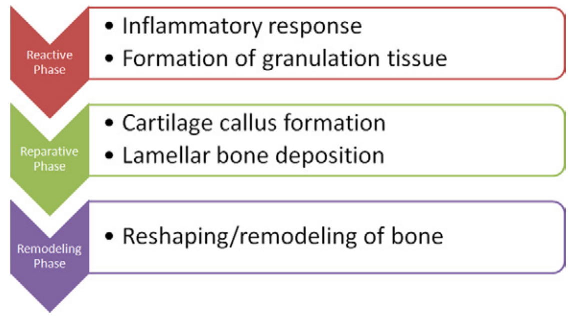

Figure 2. The 3 phases of the healing process. (Color version of figure is available online.)

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 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 materials, and other supporting cells, interspersed with small blood vessels, collectively referred to as granulation tissue.[33] The formation of granulation tissue takes approximately 2 weeks. Some days afterward, periosteal cells close to the injury site, as well as the fibroblasts within the granulation 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 lamellar bone. The formation of lamellar bone begins as soon as the tissues become mineralized. The duration of time between callus formation 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 expected to heal faster than fractures, where segments have been displaced or are unstable. During the last phase of healing, bone is remodeled into functionally competent mature lamellar bone, a process that takes 1-4 years.

Corticotomies initiate the RAP;[35,36] they increase the rate of bone modeling, reduce mineral density, and create a transient osteopenia.[29] As much as a 5-fold increase in bone turnover has been reported in long bones adjacent to corticotomy sites.[37] 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.[36] 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[38] 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[39] 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[40] used corticotomies, along with fixed appliances, to treat a 23-year-old Class II man with constricted arches in 11 months. Owen[41] was able to correct his own mild anterior crowding with corticotomies and Invisalign (San Jose, CA)

Table 2. Case Reports of Patients Treated With Corticotomy-Assisted Orthodontics

Reference	*Problem*	*Patient Age*	*Treatment Duration*
Single treatment procedures			
Köle[39]	Rotated teeth	NA	6-8 wks
	Premolar requiring distalization	NA	8-12 wks
	Upper incisor proclination	NA	8-10 wks
	Lower incisor proclination	NA	10-12 wks
Hwang and Lee[46]	Overerupted maxillary first molars	21 y/o ♀	4 wks
	Extruded mandibular second molar	20 y/o ♀	4 wks
Moon et al[47]	Extruded first and second molars	26 y/o ♀	2 mo
Oliveira et al[48]	Overerupted first and second molars	36 y/o ♀	2.5 mo
	Extruded maxillary molars	39 y/o ♂	4 mo
Full treatment			
Anholm, et al[40]	Narrow arches, unilateral Class II malocclusion	23 y/o ♂	11 mo
Owen[41]	Mild anterior crowding	Adult ♂	8 wks
Wilcko et al[28]	Anterior crowding and posterior crossbite	24 y/o ♂	6 mo 2 wks
	Moderate to severe crowding	17 y/o ♀	6 mo 2 wks
Nowzari et al[42]	Class II, division 2 with crowding	41 y/o ♂	8 mo
Germec et al[43]	Class III with crowding	22 y/o ♀	16 mo
Iino et al[44]	Class I malocclusion; bimaxillary protrusion	24 y/o ♀	12 mo
Aljhani et al[45]	Anterior open bite; flared and spaced incisors	22 y/o ♀	5 mo
Kanno et al[49]	Skeletal open bite	28 y/o ♀	7 mo
Spena et al[50]	Class II with proclined maxillary incisors	18 y/o ♀	11 mo
Hassan et al[51]	Posterior crossbite; deep bite	21 y/o ♀	19 mo
	Anterior and posterior crossbites; open bite	24 y/o ♀	18 mo

therapy in 8 weeks by changing trays every 3 days. Wilcko et al[28] described 2 cases that were completed in <7 months, one among them was presenting with significant transverse maxillary constriction. Nowzari et al[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[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.[44] Using corticotomies, Aljhani et al[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[46] used corticotomies to enhance molar intrusion. Moon et al[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[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.[49]

Corticotomies have also been used to facilitate molar distalization and arch expansion. Spena et al[50] distalized molars into a Class I relationship in 8 weeks. Hassan et al[51] used Wilckodontics® 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[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[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[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[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.[56] Canine bone also has significantly higher mineral density than human bone.[57] Single-cycle skeletal-remodeling duration of the canine model has also been shown to be approximately 42% faster than in humans.[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.[54,59] Large animal models, such as dogs, are superior to small animals for studying the microstructure of cancellous bone.[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[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[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[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 a 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[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

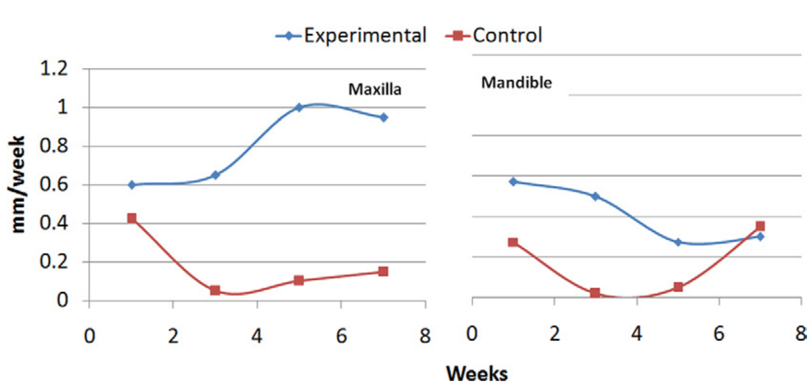

Figure 3. Maxillary and mandibular third premolar movements' rates on the experimental corticotomy and control sides (from data reported by Cho et al[62]). (Color version of figure is available online.)

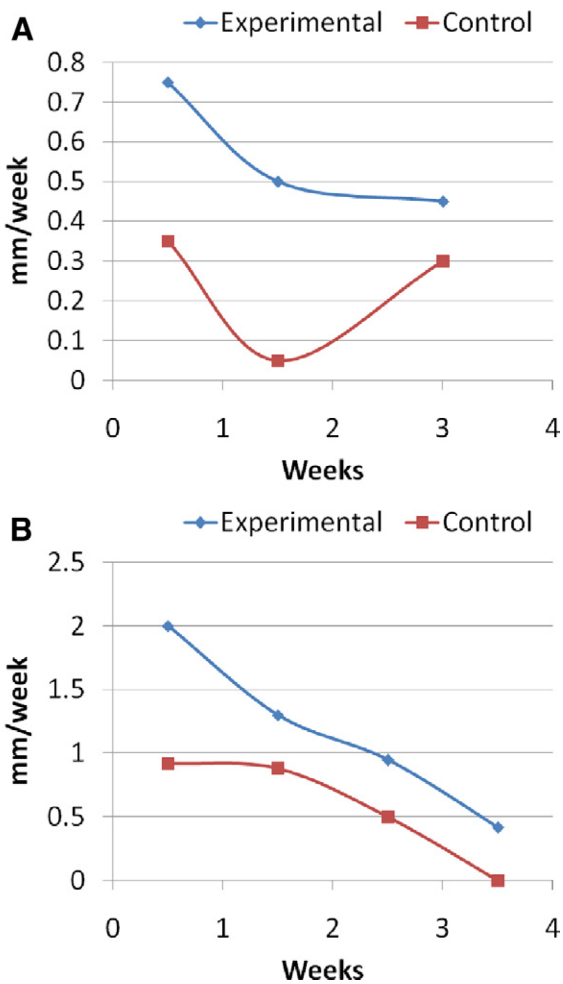

Figure 4. Comparisons of tooth movements' rates on the experimental corticotomy and control sides for (A) mandibular second premolars (from data reported by Iino et al[63]) and (B) maxillary first premolars (from data reported by Mostafa et al[64]). (Color version of figure is available online.)

served as a control. Using nickel-titanium coil springs, 400*g* 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[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.

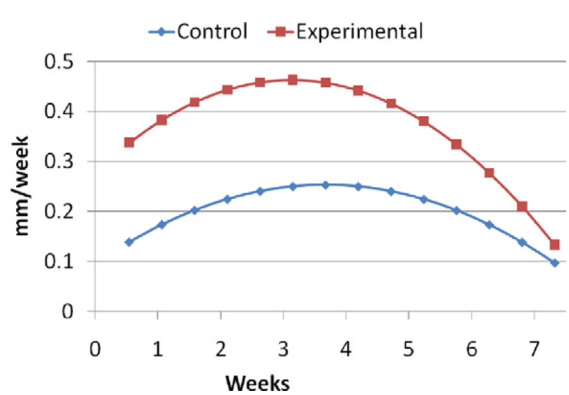

Figure 5. Comparisons of tooth movements' rates on the experimental corticotomy and control sides for the mandibular second premolars (modified from data reported by Sanjideh et al[65]). (Color version of figure is available online.)

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 4-6 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.

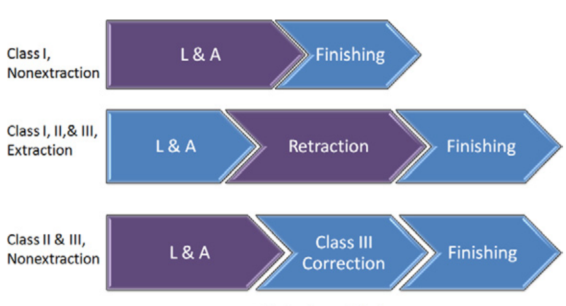

Figure 6. Stages of active orthodontic treatment depending on Class of malocclusion and extraction or nonextraction treatments, emphasizing the stage requiring the greatest tooth movements. (Color version of figure is available online.)

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.[66] 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.[66] 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.[38] 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 4-6 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.

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