Corticotomy for orthodontic tooth movement

Won Lee
Department of Dentistry, Uijeongbu St. Mary’s Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea

Abstract (J Korean Assoc Oral Maxillofac Surg 2018;44:251-258)

Corticotomy was introduced as a surgical procedure to shorten orthodontic treatment time. Corticotomy removes the cortical bone that strongly resists orthodontic force in the jaw and keeps the marrow bone to maintain blood circulation and continuity of bone tissues to reduce risk of necrosis and facilitate tooth movement. In the 21st century, the concept of regional acceleratory phenomenon was introduced and the development of the skeletal anchorage system using screw and plate enabled application of orthopedic force beyond conventional orthodontic force, so corticotomy has been applied to more cases. Also, various modified methods of minimally invasive techniques have been introduced to reduce the patient’s discomfort due to surgical intervention and complications after surgery. We will review the history of corticotomy, its mechanism of action, and various modified procedures and indications.

Key words: Corticotomy, Orthodontic tooth movement, Regional acceleratory phenomenon

[paper submitted 2018. 11. 21 / revised 2018. 11. 29 / accepted 2018. 11. 29]

I. Historical Background

One of the dental fields that has made great progress in the modern era is orthodontics. However, orthodontic treatment involves a lot of time and patient pain. Therefore, various methods have been introduced to accelerate tooth movement with stronger orthodontic force. A corticotomy is one of the representative methods for accelerating tooth movement through invasive surgical treatment.

In order for tooth movement to occur, orthodontic force must be applied to the teeth to evoke the biological action and response of the alveolar bone. If the force is too strong, problems will appear. Many studies have been performed to overcome these issues. Methods for moving teeth through surgical techniques and the attendant biological mechanisms has recently been investigated again in various studies even though it has been studied for 100 years. In the past, osteotomies around teeth to be moved including periodontal tissue and surrounding alveolar bone were performed, and the osteotomized complex of the teeth and surrounding tissue was transported to the desired position. Corticotomies for rapid tooth movement were introduced in 1959 by Köle in an effort to cut the alveolar bone and move a tooth. He practiced corticotomies and osteotomies on various malocclusion cases. Vertically, the cortical and marrow bone between the teeth were partially removed, and either a subapical horizontal cut with alveolar bone cutting at a distance of 1 cm from the apex or only a cortical osteotomy excluding the marrow bone was performed. Köle reported no problems and no pocket formation in pulp vitality testing performed 6 months later. He theorized that tooth movement involved moving the block bone, including the surrounding tissues. However, this method was not very widely used because of its surgical invasiveness. Then, in order to overcome the disadvantages of a complete resection of the alveolar bone, a treatment method was created to reduce resistance to tooth movement by removing only the cortical bone that resisted tooth movement. Düker reported that both the pulp and periodontium of the teeth in beagle dogs were not damaged after corticotomy surgery based on Köle’s technique, and suggested a design that leaves at least 2 mm of bone at the level of the alveolar crest. Many papers have been published since then, and all tooth movement after corticotomies was believed to promote tooth

Won Lee
Dental Clinic, The Catholic University of Korea, Uijeongbu St. Mary’s Hospital, 271 Cheonbo-ro, Uijeongbu 11765, Korea
TEL: +82-31-820-3574 FAX: +82-31-847-2894
E-mail: cmfs21@catholic.ac.kr
ORCID: https://orcid.org/0000-0002-6383-8754

© This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.
Copyright © 2018 The Korean Association of Oral and Maxillofacial Surgeons. All rights reserved.
movement by eliminating the physical obstruction. However, Wilcko et al.\(^6\) in 2001 introduced Frost’s regional accelerating phenomenon (RAP) concept. Tooth movement by corticotomies was not caused by the movement of the bone block, but by the demineralization-mineralization process around the corticotomy. Wilcko et al.\(^7\) called it “bone matrix transportation”. Recently, interest in corticotomies has increased again, and the development of the skeletal anchorage system has enabled the application of orthodontic forces as strong as desired, which not only moves the teeth physiologically, but also facilitates tooth movement mechanically. Corticision\(^8-10\), piezocision\(^11,12\), micro-osteoperforation\(^13,14\), and discision\(^15\) procedures have been used to perform corticotomies with minimal invasiveness.

II. Physiological Background

Frost\(^16\), an orthopedic surgeon, observed sudden reformation around the damaged area of bone and referred to this physiological reaction as a RAP, which resulted in a local transient burst of hard tissue. RAP is a reaction that occurs to heal the damaged area not only in the hard tissue, but also in soft tissues. In the case of hard bone tissue, the reaction increases bone turnover and decreases bone density to promote bone healing. These tissue responses vary depending on the duration, strength, and size of the harmful stimulus. Shih and Nordin\(^17\) showed a regional change in modeling and remodeling of bone defects in beagle dogs. Yaffe et al.\(^18\) reported that a cascade of physiologic events occurred only at the corticotomy area and that RAP occurred in the mandible of rats even though only a mucoperiosteal flap was elevated.

Lee et al.\(^19\) carried out corticotomies in the mandible of rats and observed demineralization/remineralization changes by micro computed tomography, confirming that RAP occurred at the site of the corticotomy 3 weeks after the operation. When RAP is initiated, the biological response is activated beyond the normal state. Bone metabolism, bone cell differentiation, progenitor cell activity, growth of bone and cartilage, and bone remodeling by bone multicellular units are affected by RAP\(^20-22\). In addition to trauma, RAP can be caused by several stimuli including vitamin D, thyroxine, and electrical stimuli\(^23-25\). In the maxilla and mandible, orthopedic tooth movement as well as physical or infectious stimuli such as extractions, fractures, implant placement, and periodontitis may result in RAP\(^26\).

In 2001, Wilcko et al.\(^6\) published the accelerated osteogenic orthodontics (AOO) technique and then renamed it the periodontally accelerated osteogenic orthodontics (PAOO) technique. It became known as “Wilckodontics” and was patented\(^27\). The Wilcko brothers introduced accelerated osteogenic orthodontics tooth movement (AOOTM) as a method to accelerate tooth movement by selectively decorticating the labial or lingual cortex\(^6,7\). They found that demineralization/remineralization of bone occurred ideally in younger adolescents during tooth movement. However, in adult cases, remineralization did not occur sufficiently\(^28\), so bone grafting was performed at the site where the tooth would move to provide alveolar housing during tooth movement\(^29\). Brugnami et al.\(^30\) also extended the scope of conventional orthodontic treatment by corticotomy in combination with bone grafting, overcoming the limitations of traditional orthodontic treatment.

von Böhl et al.\(^31\) found that in the beagle dog experiment, small focal hyalinization occurred in the pressure side where orthodontic force was applied, and this phenomenon was caused by a difference in tooth movement speed. Verna and Melsen\(^32\) noted that the rate of tooth movement was affected by bone remodeling, bone density, and the hyalinized periodontal ligament. Iino et al.\(^33\) reported decreased periodontal ligament hyalinization in dogs who underwent corticotomies. The root resorption process continued until hyaline tissue disappeared\(^34\).

Verna et al.\(^35\) used finite element analysis (FEA) and stated that tooth movement after corticotomies decreased compressive stresses in the periodontal ligament and increased tensile stresses. Ouejiaraphan et al.\(^36\) also reported that the center of resistance was apically repositioned in the FEA of decorticated bone.

Medeiros et al.\(^37\) performed decortications to upright second molars in adults and studied the bone acquired from the decorticated area using a trephine bur after 0 and 9 days. He reported that corticotomy surgeries inflicted reversible and transient bone injury.

The ossification created by surrounding osteoblasts and the jaw periosteum are main sources of osteogenic precursor cells for osteogenesis\(^38\).

III. Terminology

Different terms may be used depending on the concept when moving teeth using surgical procedures such as a corticotomy. There are many terms for corticotomies for orthodontic treatment such as corticotomy-assisted orthodontic treatment
Corticotomy for orthodontic tooth movement

253

(CAOT)\textsuperscript{39,40}, AOO\textsuperscript{6,7,27,41,42}, PAOO\textsuperscript{6,7,27,41-47}, selective alveolar
decortication (SAD), surgically facilitated orthodontic ther-
apy (SFOT), and corticotomy-facilitated orthodontics (CFO)
known as speedy orthodontics. The only difference is that
SFOT, AOO, and PAOO involve bone grafting in addition
to a corticotomy. In SFOT, both the corticotomy and bone
grafting procedures were performed in the direction of tooth
movement rather than on both the buccal and lingual/palatal
surfaces\textsuperscript{48}.

Speedy orthodontics is defined as corticotomy-facilitated
orthodontic treatment that combines a corticotomy and ortho-
pedic heavy force application on the anterior segment\textsuperscript{49-51}. It
was demonstrated that a perisegmental corticotomy around
the anterior segment could decrease the rigidity of the cortical
bone with bone-bending effects through heavy force applica-
tion on the corticotomized segment.

IV. Conventional Corticotomy Technique

Corticotomy in the alveolar bone refers to a method of thin-
ning the cortical bone without penetrating the marrow bone,
while an osteotomy of alveolar bone involves cutting through
the marrow bone from the cortex\textsuperscript{52}. The corticotomy pro-
cedure initially used handpieces and surgical burs, but various
devices such as a piezoelectric apparatus\textsuperscript{11,12,53-56}, laser\textsuperscript{57}, hard
blade and hammer\textsuperscript{8-10,58}, perforator\textsuperscript{14,59,60}, and disc have gradu-
ally become more involved in order to reduce damage to the
patient. In the case of corticotomy design, vertical corticoto-
mies between roots were carried out initially and the forma-
tion of grooves around the root using only a small round bur
was used later\textsuperscript{61}.

Local anesthesia is sufficient for corticotomies, but intra-
venous sedation may be used for patient comfort. One-stage
techniques are generally used, but two stages are used on oc-
casion. In the two-stage technique, alveolar bone is divided
into palatal and labial/buccal sections and corticotomized at
two weeks intervals\textsuperscript{62}.

1. One stage technique

A vestibular incision is more advantageous in the blood
circulation of the distal side and can reduce complications
caused by blood circulation disturbances to the distal bony
fragment. The periosteum is elevated with a periosteal eleva-
tor, and the buccal and lingual cortical bones are exposed
beyond the apical region of the corticotomy. At this time, tun-
neling of the lingual (or palatal) flap, elevating only the corti-
cal osteotomy site, and performing a corticotomy with a blind
technique are performed to maximize the blood flow supply.
Sufficient saline irrigation and a gentle corticotomy would be
helpful to minimize soft tissue damage and avoid necrosis of
the soft tissue after surgery.

The use of a piezoelectric surgical device can reduce soft
tissue injuries. A high or low speed handpiece can be used.
A round bur with a diameter of 2 to 4 mm is used to perform
the corticotomy with sufficient cooling saline. The bone is
cut relatively shallow to the extent that the marrow bone is
exposed. The corticotomy is then divided into vertical and
horizontal parts. The vertical part must be performed care-
fully so as not to damage the lateral side of the root from 2 to
3 mm below the alveolar crest to the horizontal corticotomy
groove at the apical aspect.

The horizontal corticotomy is performed 3 to 5 mm away
from the lower part of the apical root between both vertical
grooves to prevent root damage. These osteotomies are per-
formed in both buccal and lingual cortical bone, and when the
cortical bone is completely cut, a distal bone block is formed
containing only the teeth that are retained solely by the mar-
row bone. After the corticotomy, the flap is restored to its
original position and a suture is placed. The corticotomized
bone piece is fixed with arch wire and previously attached
brackets. A periodontal pack can be applied for the reattach-
ment of the elevated flap and to remove the dead space that
may cause infection and pain. The suture is removed 5 to 7
days after surgery.

2. AOO and PAOO

A full-thickness flap is raised labially and lingually at the
interdental papillae, except between the maxillary central
incisors. The flaps are raised beyond the apices of the teeth
to avoid damaging the neurovascular complexes exiting the
alveolus. Corticotomy cuts and cortical bone perforations
are performed to the malpositioned teeth using round burs\textsuperscript{6}.
These cuts should not perforate the cancellous bone to avoid
injury to any underlying structures. Particulate bone graft-
ing material is grafted onto the decorticated area. The flap
is repositioned using nonresorbable suture materials. On the
day of the operation, orthodontic forces should be applied to
the teeth. Increased osteoclastic activity results in temporary
intrabony osteopenia for easy tooth movement\textsuperscript{6}. 

253

Corticotomy for orthodontic tooth movement
V. Modified Corticotomy

1. Corticision

Corticision means “cortical bone incision”. It is a minimally invasive periodontal procedure for accelerating tooth movement without flap elevation, but with an enhanced turnover rate of the surrounding structures. The procedure involves using a malleting scalpel through the cancellous bone and into cortical bone by approximately 10 mm and begins at 5 mm below the papilla to preserve the papillary gingiva.

2. Piezocision

In 2007, Vercellotti and Podesta performed corticotomies using conventional flap elevations and piezosurgery for rapid tooth movement. After that, Dibart et al. reported on a method of performing only piezosurgery without flap elevation and named it “Piezocision”.

This technique is performed with an interdental gingival incision followed by a corticotomy with a piezoelectric apparatus. If a bone graft is needed, it is performed after dissection under the periosteum and the incision is sutured. Sutures are not required if a bone graft is not performed. This method has the advantage of reducing tissue damage, but it requires more time than the conventional rotary device. An endoscopically assisted tunnel approach may be used to reduce the number of vertical incisions. The rate of tooth movement was reported to be slightly slower than with a conventional corticotomy. However, it was reported that the time required for the anterior alignment of the mandibular dental arch was reduced by 59% in the experimental group when this procedure was applied to alleviate crowding of the mandibular incisors.

3. Micro-osteoperforation

Micro-osteoperforation uses a handled appliance such as Profel for osteo-perforation without flap elevation. Alikhani et al. divided twenty adults with Class II Division 1 malocclusion into experimental and control groups, and micro-osteoperforation was formed in the first premolar extraction sockets of the experimental group. Micro-osteoperforation was formed 5 mm below the alveolar crest with three holes at the buccal surface of the extraction sockets. Each perforation is formed using a handheld appliance capable of adjusting perforation widths to 1.5 mm with depths of 2 to 3 mm.

4. Discision

Buyuk et al. introduced a method using a disc saw that can be inserted into a handpiece because piezocision is difficult to perform in orthodontic clinics where there are no piezosurgery devices. To remove the cortical bone similar to conventional piezocision, a disc saw is used below the interdental papilla without incisions with blades. The cutting is carried out approximately 3 mm into the bone between the roots. No suturing is performed. The orthodontic treatment is completed within 4 months without side effects such as root resorption.

5. Laser-assisted flapless corticotomy

It is a method for creating small perforations in the buccal gingiva without flap elevation using a laser such as the ER:YAG laser. In comparison with piezocision, a similar degree of tooth movement was reported without side effects.

VI. Rate of Tooth Movement and Force Application

Köle performed active orthodontic treatment for 6 to 12 weeks after corticotomies and a retention appliance was worn for 6 to 8 months to consolidate bone to prevent relapse after removal of the orthodontic appliance. The rate of tooth movement after corticotomies exhibited an average monthly rate that was twice as fast as that of the control side during the first 2 months in the orthodontic patient with a decrease in speed during the next two months. Aboul-Ela et al. reported that canine retraction after a corticotomy was 2-times faster in the first 2 months, 1.6 times in the 3rd month, and 1.06 times in the 4th month. When Alfawal et al. performed piezocisions and laser-assisted flapless corticotomies, they found that RAP was at its peak in the first month and dramatically decreased in the second month due to the less invasive technique compared to conventional corticotomies. Abbas et al. reported that corticotomy-facilitated orthodontics exhibited 1.5 to 2 times faster tooth movement compared to conventional orthodontics. Gil et al. reported that corticotomy-facilitated orthodontic cases required a shorter treatment period with an average of 8.85 months than conventional orthodontic treatment, which took an average of 16.4 months.

Orthodontic forces were applied to the teeth and were divided into two groups. Many studies had forces applied to the teeth immediately after corticotomies. The other
Corticotomy for orthodontic tooth movement

VII. Indications and Limitations

Tooth movement using corticotomy can be applied in many fields. Noh et al. reported good results in patients with severe bimaxillary protrusion by performing a wide-linear corticotomy with a palatal bone-borne type retractor and anterior segmental osteotomy instead of orthognathic surgery. However, cases where the bimaxillary protrusion is accompanied with a gummy smile may benefit more from a segmental osteotomy.

Kim et al. reported that the tooth was moved to the desired position by performing a corticotomy and surgery to expose multiple impacted maxillary teeth. Karthikeyan et al. treated a Class I malocclusion and open bite patient by removing the bulky anterior cortical bone and intruding the anterior teeth. Corticotomies can also be used for canine retraction, anterior teeth retraction, decrowding, molar uprighting, correction of a scissor bite, and rapid maxillary expansion. Lines introduced a method for the correction of a maxillary constriction that applied incisions on the lateral walls of the maxillary sinus and mid-palatal sutures. Echchadi et al. used piezo-bone perforations on the buccal alveolar bone in young patients for maxillary expansion. Le et al. showed that adjunctive buccal and palatal corticotomies on the maxilla enhanced the outcomes of maxillary expansion in adults by two and three folds. Ahn et al. performed orthognathic surgery on the mandible to correct upper incisors after unilateral molar intrusion and occlusal plane canting correction. In addition, alveolar augmentation after corticotomies can increase the maxillary and/or mandibular bone-volume to secure airway dimensions and prevent sleep disorders.

Wilcko and Wilcko reported that ankylosed tooth or vitality loss of the alveolar bone limited tooth movement. In case of the PAOO, they suggested that patients who take corticosteroids which suppress inflammatory reactions were at a disadvantage because the periodontal ligament that mediates the sterile inflammatory process is suppressed. In addition, it is known that a corticotomy is not appropriate for patients with active periodontal disease, individuals with inadequately treated endodontic problems, and people who are taking any medications such as bisphosphonates and nonsteroidal anti-inflammatory drugs. Those who have been treated with radiation therapy are unable to undergo a corticotomy because of their reduced blood supply and less than ideal condition of the surrounding soft tissue.

VIII. Complications

The side effects are controversial. Although interdental bone loss, periodontal defects, and reduced attached gingiva were reported, Aboul-Ela et al. suggested that a flap design leaving two 2 mm of attached gingiva and relieving incisions reduced the periodontal issue by providing vertical orientation without blocking blood flow. In the case of pain or discomfort, Al-Naoum et al. stated that the ingestion of food was painful for the first 2 days, but gradually decreased.

Root resorption occurrence is known to be similar for both corticotomy and noncorticotomy cases. However, Chan et al. performed micro-perforations on the mesial and distal aspects, provided a tipping force to the patient and extracted premolars after four weeks. Forty-two percent more root resorption was observed compared to conventional orthodontic tooth movement.

Murphy et al. reported that there was no difference in the volume of root resorption when light (10 g) or heavy forces (100 g) were applied after corticision.

Corticotomy was not selected by patients because of their fear of surgery due to its invasiveness.

IX. Conclusion

Although corticotomy is an invasive procedure, RAP appears to reduce the resistance of bone during tooth movement, thereby shortening the period of orthodontic treatment and minimizing adverse effects on teeth. It is believed that there will be a number of ways to speed up tooth movement without side effects while minimizing surgical invasiveness.

Author’s Contributions

W. L. wrote and approved the manuscript.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.
References

1. Colombo, J., Campo, J., Bonilla, E., Colmenero, C. Corticotomy-assisted orthodontics. J Clin Exp Dent 2012;4:e54-9.

2. Köle, H. Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surg Oral Med Oral Pathol 1959;12:515-29 concl.

3. Köle, H. Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surg Oral Med Oral Pathol 1959;12:277-88 contd.

4. Köle, H. Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surg Oral Med Oral Pathol 1959;12:413-20 contd.

5. Dükä, J. Experimental animal research into segmental alveolar movement after corticotomy. Maxillofac Surg 1975;3:81-4.

6. Wilcko WM, Wilcko T, Bouquet JE, Ferguson DJ. Rapid orthodontics with alveolar reshaping: two case reports of decrowding. Int J Periodontics Restorative Dent 2001;21:9-19.

7. Wilcko MT, Wilcko WM, Pulver JJ, Bissada NF, Bouquet JE. Accelerated osteogenic orthodontics: a 1-stage surgically facilitated rapid orthodontic technique with alveolar augmentation. J Oral Maxillofac Surg 2009;67:249-59.

8. Kim SJ, Park YG, Kang SG. Effects of corticision on paradoxal remodeling in orthodontic tooth movement. Angle Orthod 2009;79:284-91.

9. Park YG. Corticision: a flapless procedure to accelerate tooth movement. Front Oral Biol 2016;18:109-17.

10. Murphy CA, Chaudhoke T, Kalajizic Z, Flynn R, Utreja A, Wadhwana S, et al. Effect of corticotomy on tooth movement. J Oral Maxillofac Surg 2014;146:55-66.

11. Dilbar S, Sebaoun JD, Surmenian J. Piezocision: a minimally invasive, periodontally accelerated orthodontic tooth movement procedure. J Periodontol 2016;87:797-808.

12. Sebaoun JD, Surmenian J, Dilbar S. Accelerated orthodontic treatment with piezocision: a mini-invasive alternative to conventional corticotomies. J Periodontol 2011;82:311-9. French.

13. Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami E, et al. Effect of micro-osteoperforations. Authors' response. Am J Orthod Dentofacial Orthop 2014;145:273-4.

14. Prasad S, Ravindran S. Effect of micro-osteoperforations. Am J Orthod Dentofacial Orthop 2014;145:273.

15. Buyuk SK, Yavuz MC, Gene E, Sunar O. A novel method to accelerate orthodontic tooth movement. Saudi Med J 2018;39:203-8.

16. Frost HM. The regional acceleratory phenomenon: a review. Henry Ford Hosp Med J 1983;31:3-9.

17. Shih MS, Norrind RW. Regional acceleration of remodeling during healing of bone defects in beagles of various ages. Bone 1985;6:777-9.

18. Yaffe A, Fine N, Binderman I. Regional acceleration phenomenon in the mandible following mucoperiosteal flap surgery. J Periodontol 1994;65:79-83.

19. Lee W, Karpaytay G, Moats R, Yamashita DD, Moon HB, Ferguson DJ, et al. Corticotomy-/osteotomy-assisted tooth movement microCTs differ. J Dent Res 2008;87:861-7.

20. Frost HM. The biology of fracture healing. An overview for clinicians. Part II. Clin Orthop Relat Res 1989;248:294-309.

21. Frost HM. The biology of fracture healing. An overview for clinicians. Part I. Clin Orthop Relat Res 1989;248:283-93.

22. Wang L, Lee W, Lei DL, Liu YP, Yamashita DD, Yen SL. Tissue responses in corticotomy- and osteotomy-assisted tooth movements in rats: histology and immunostaining. Am J Orthod Dentofacial Orthop 2009;136:770-11; discussion 770-1.

23. Collins MK, Sinclair PM. The local use of vitamin D to increase the rate of orthodontic tooth movement. Am J Orthod Dentofacial Orthop 1988;94:278-84.

24. High WB. Effects of orally administered prostaglandin E-2 on cortical bone turnover in adult dogs: a histomorphometric study. Bone 1987;8:363-73.

25. High WB, Capen CC, Black HE. Effects of thyroxine on cortical bone remodeling in adult dogs: a histomorphometric study. Am J Pathol 1981;102:438-46.

26. Verma C. Regional acceleratory phenomenon. Front Oral Biol 2016;18:28-35.

27. Wilcko MT, Wilcko WM, Murphy KG, Carroll WJ, Ferguson DJ, Miley DD, et al. Full-thickness flap/subepithelial connective tissue grafting with intramarrow penetrations: three case reports of lingual root coverage. Int J Periodontics Restorative Dent 2005;25:561-9.

28. Wilcko MT, Wilcko WM, Bissada NF. An evidence-based analysis of periodontally accelerated orthodontic and osteogenic techniques: a synthesis of scientific perspectives. Semin Orthod 2008;14:305-16.

29. Wilcko WM, Ferguson DJ, Bouquet JE, Wilcko MT. Rapid orthodontic decrowding with alveolar augmentation: case report. World J Orthod 2003;4:197-205.

30. Brugnami F, Ciazzo A, Mehra P. Can corticotomy (with or without bone grafting) expand the limits of safe orthodontic therapy? J Oral Biol Craniofac Res 2018;8:1-6.

31. von Böhl M, Maltha JC, Von Den Hoff JW, Kuipers-Jagtman AM. Focal hyalinization during experimental tooth movement in beagle dogs. Am J Orthod Dentofacial Orthop 2004;125:615-23.

32. Verna C, Melsen B. Tissue reaction to orthodontic tooth movement in different bone turnover conditions. Orthod Craniofac Res 2003;6:155-63.

33. Iino S, Sakada S, Ito G, Nishimori T, Ikeda T, Miyawaki S. Acceleration of orthodontic tooth movement by alveolar corticotomy in the dog. Am J Orthod Dentofacial Orthop 2007;131:448-1.e1-8.

34. Breznia N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part I: the basic science aspects. Angle Orthod 2002;72:175-9.

35. Verna C, Cattaneo PM, Dalstra M. Corticotomy affects both the modulus and magnitude of orthodontic tooth movement. Eur J Orthod 2018;40:107-12.

36. Ouejjarolph T, Samraujbenakun B, Chaichanasiri E. Determination of the centre of resistance during en masse retraction combined with corticotomy: finite element analysis. J Orthod 2018;45:11-5.

37. Medeiros RB, Pires FR, Kantarci A, Capelli J Jr. Tissue repair after selective alveolar corticotomy in orthodontic patients: a preliminary study. Angle Orthod 2018;88:179-86.

38. Lee JM, Kim MG, Byun JH, Kim GC, Ro JH, Hwang DS, et al. The effect of biomechanical stimulation on osteoblast differentiation of human jaw periosteum-derived stem cells. Maxillofac Plast Reconstr Surg 2017;39:7.

39. Cassetta M, Di Carlo S, Gianmanti M, Pompa V, Pompa G, Barbato E. The impact of osteotomy technique for corticotomy-assisted orthodontic treatment (CAOT) on oral health-related quality of life. Eur Rev Med Pharmacol Sci 2012;16:1735-40.

40. Hassan AH, Al-Saeed SH, Al-Maghlouth BA, Bahammam MA, Linjawi AL, El-Bialy TH. Corticotomy-assisted orthodontic treatment. A systematic review of the biological basis and clinical effectiveness. Saudi Med J 2015;36:794-801.

41. Wilcko MT, Ferguson DJ, Makki L, Wilcko WM. Keratinized gingiva height increases after alveolar corticotomy and augmentation bone grafting. J Periodontol 2015;86:1107-15.

42. Wilcko WM, Ferguson DJ, Makki L, Wilcko WM. Keratinized gingiva height increases after alveolar corticotomy and augmentation bone grafting. J Periodontol 2015;86:1107-15.

43. Wilcko MT. Accelerating tooth movement: the case for corticotomy-induced orthodontics. Am J Orthod Dentofacial Orthop 2013;144:4-12.

44. Amit G, Jps K, Pankaj B, Suchinder S, Parul B. Periodontally accelerated osteogenic orthodontics (PAOO) - a review. J Clin Exp Dent 2012;4:e292-6.
Corticotomy for orthodontic tooth movement

45. Binderman I, Gadbh N, Bahar H, Herman A, Yaffe A. Commentary on: periodontally accelerated osteogenic orthodontics (PAOO) - a clinical dilemma. Int Orthod 2010;8:268-77.

46. Munoz F, Jimenez C, Espinoza D, Verville A, Beugnet J, Haitz G. Use of leukocyte and platelet-rich fibrin (L-PRF) in periodontally accelerated osteogenic orthodontics (PAOO): clinical effects on edema and pain. J Clin Exp Dent 2016;8:e119-24.

47. Suchetha A, Lakshmi P, Prasad K, Akanesha G, Sm A, Darshan M. PAOO for faster function, aesthetics and harmony. N Y State Dent J 2014;80:53-7.

48. Zimm O, Saleh Kh, Mandelhas GA, Chan HL, Wang HL. Corticotomies-assisted orthodontics: a comprehensive review and update. Compend Contin Educ Dent 2017;38:17-25; quiz 26.

49. Chung KR, Kim SH, Lee BS. Speedy surgical-orthodontic treatment with temporary anchorage devices as an alternative to orthognathic surgery. Am J Orthod Dentofacial Orthop 2009;135:787-98.

50. Chung KR, Mitsugi M, Lee BS, Kanno T, Lee W, Kim SH. Speedy surgical orthodontic treatment with skeletal anchorage in adults: sagittal correction and open bite correction. J Oral Maxillofac Surg 2009;67:2130-40.

51. Krishnan KV, Kumar N, Rajasigamani K, Vijay V, Rajaram RS, Bhaskar V. Speedy orthodontics: a case report. Orthodontics (Chic) 2013;14:e96-100.

52. Alghamdi AS. Corticotomies facilitated orthodontics: review of a technique. Saudi Dent J 2010;22:1-5.

53. Gibreal O, Hajeer MY, Brad B. Efficacy of piezocision-based flapless corticotomy in the orthodontic correction of severely crowded lower anterior teeth: a randomized controlled trial. Eur J Orthod 2018. doi: 10.1093/ejo/cjy042. [Epub ahead of print]

54. Alfaraw AMH, Hajeer MY, Ajaj MA, Hamadah O, Brad B. Evaluation of piezocision and laser-assisted flapless corticotomy in the acceleration of canine retraction: a randomized controlled trial. Head Face Med 2018;14:4.

55. Sathyanarayana HP, Srinivasan B, Nailasam V, Padminabhan S. Corticotomy and piezocision in rapid canine retraction. Am J Orthod Dentofacial Orthop 2016;150:209-10.

56. Abbas NH, Sabet NE, Hassan IT. Evaluation of corticotomy-facilitated orthodontics and piezocision in rapid canine retraction. Am J Orthod Dentofacial Orthop 2016;149:473-80.

57. Han KH, Park JH, Bayome M, Jeon IS, Lee W, Wook YA. Effect of frequent application of low-level laser therapy on corticotomized tooth movement in dogs: a pilot study. J Oral Maxillofac Surg 2014;72:1182.e1-12.

58. Murphy C, Kalajzic Z, Chandhoke T, Utreja A, Nanda R, Uribe F. The effect of corticision on root resorption with heavy and light forces. Angle Orthod 2010;80:17-23.

59. Alkilani M, Raptis M, Zoldan B, Sangsawon C, Lee YB, Alyami B, et al. Effect of micro-osteoperforations on the rate of tooth movement. Am J Orthod Dentofacial Orthop 2013;144:639-48.

60. Cheung T, Park J, Lee D, Kim C, Olson J, Javadi S, et al. Ability of mini-implant-facilitated micro-osteoperforations to accelerate tooth movement in rats. Am J Orthod Dentofacial Orthop 2016;150:958-67.

61. Patterson BM, Dalci O, Darendeliler MA, Papadopoulou AK. Corticotomies and orthodontic tooth movement: a systematic review. J Oral Maxillofac Surg 2016;74:453-73.

62. Choo H, Heo HA, Yoon HJ, Chung KR, Kim SH. Treatment outcome analysis of speedy surgical orthodontics for adults with maxillary protrusion. Am J Orthod Dentofacial Orthop 2011;140:e251-62.

63. Vercellotti T, Podesta A. Orthodontic microsurgery: a new surgically guided technique for dental movement. Int J Periodontics Restorative Dent 2007;27:325-31.

64. Hernández-Allafro F, Guijarro-Martínez R. Endoscopically assisted tunnel approach for minimally invasive corticotomies: a preliminary report. J Periodontol 2012;83:574-80.

65. Aboul-Ela SM, El-Beialy AR, El-Sayed KM, Selim EM, El-Manoury NH, Mostafa YA. Miniscrew implant-supported maxillary canine retraction with and without corticotomy-facilitated orthodontics. Am J Orthod Dentofacial Orthop 2011;139:252-9.

66. Gil APS, Haas OI, Jr, Méndez-Manjón I, Masía-Griddilla J, Valls-Ontañón A, Hernández-Allafro F, et al. Alveolar corticotomies for accelerated orthodontics: a systematic review. J Craniomaxillofac Surg 2018;46:438-45.

67. Al-Naoum F, Hajeer MY, Al-Jundi A. Does alveolar corticotomy accelerate orthodontic tooth movement when retracting upper canines? A split-mouth design randomized controlled trial. J Oral Maxillofac Surg 2014;72:1880-9.

68. Shoreibah EA, Salama AE, Attia MS, Abu-Seaida SM. Corticotomy-facilitated orthodontics in adults using a further modified technique. J Int Acad Periodontol 2012;14:97-104.

69. Shoreibah EA, Ibrahim SA, Attia MS, Diab MM. Clinical and radiographic evaluation of bone grafting in corticotomy-facilitated orthodontics in adults. J Int Acad Periodontol 2012;14:105-13.

70. Wu J, Jiang J, Xu L, Liang C, Li C, Xu X. [Alveolar bone thickness and root length changes in the treatment of skeletal class III patients facilitated by improved corticotomy: a cone-beam CT analysis]. Zhonghua Kou Qian Yi Xue Za Zhi 2015;50:223-7.

71. Sakthi SV, Vikraman B, Shobhana VR, Iyer SK, Krishnaswamy NR. Corticotomy-assisted retraction: an outcome assessment. Indian J Dent Res 2014;25:748-54.

72. Bhattacharya P, Bhattacharya H, Anjum A, Bhandari R, Agarwal DK, Gupta A, et al. Assessment of corticotomy facilitated tooth movement and changes in alveolar bone thickness - A CT scan study. J Clin Diagn Res 2014;8:ZC26-30.

73. Akay MC, Aras A, Günyüz T, Akyalçin S, Köyuncuo B. Enhanced effect of combined treatment with corticotomy and skeletal anchorage in open bite correction. J Oral Maxillofac Surg 2009;67:563-9.

74. Fischer TJ. Orthodontic treatment acceleration with corticotomy-assisted exposure of palatally impacted canines. Angle Orthod 2007;77:417-20.

75. Kraiwattanapong K, Samruajbenjakun B. Effects of different force magnitudes on corticotomy-assisted orthodontic tooth movement in rats. Angle Orthod 2018;88:632-7.

76. Noh MK, Kim YJ, Chung KR, Kim SH, Nelson G. Corticotomy with a palatal bone-borne retractor for correcting severe bimaxillary protrusion. J Craniomaxillofac Surg 2018;29:e64-8.

77. Oliveira DD, de Oliveira BF, Soares RV. Alveolar corticotomies in orthodontics: indications and effects on tooth movement. Dent Press J Orthod 2010;15:144-57.

78. Kim KA, Hwang HS, Chung KR, Kim SH, Nelson G. Recovery of multiple impacted maxillary teeth in a hyperdivergent class I patient using temporary skeletal anchorage devices and augmented corticotomy. Angle Orthod 2018;88:107-21.

79. Karthikeyan MK, Mathews R, Prabhakar R, Saravana R, Rama-samy M, Vikram NR. Acceleration of intruding anterior tooth by alveolar corticotomy. Ann Maxillofac Surg 2018;8:118-20.

80. Viwattanatipa N, Charmanchierk S. The effectiveness of corticotomy and piezocision on canine retraction: a systematic review. Korean J Orthod 2018;48:200-11.

81. Cassetta M, Altieri F, Pandolfi S, Giannanti M. The combined use of computer-guided, minimally invasive, flapless corticotomy and clear aligners as a novel approach to moderate crowding: a case report. Korean J Orthod 2017;47:130-41.

82. Sakamoto T, Hayakawa K, Ishii T, Nojima K, Sueishi K. Bilateral scissor bite treated by rapid mandibular expansion following corticotomy. Bull Tokyo Dent Coll 2016;57:269-80.

83. Lines PA. Adult rapid maxillary expansion with corticotomy. Am J Orthod 1975;67:44-56.

84. Echchadi ME, Bennechik B, Bellamine M, Kim SH. Corticotomy-assisted rapid maxillary expansion: a novel approach with a 3-year follow-up. Am J Orthod Dentofacial Orthop 2015;148:138-53.

85. Van HM, Lau SF, Ibrahim N, Noor Hayaty AK, Radzi ZB. Adjunc-
tive buccal and palatal corticotomy for adult maxillary expansion in an animal model. Korean J Orthod 2018;48:98-106.
86. Ahn HW, Seo DH, Kim SH, Lee BS, Chung KR, Nelson G. Correction of facial asymmetry and maxillary canting with corticotomy and 1-jaw orthognathic surgery. Am J Orthod Dentofacial Orthop 2014;146:795-805.
87. Kim CM, Park MH, Yun SW, Kim JW. Treatment of pathologic fracture following postoperative radiation therapy: clinical study. Maxillofac Plast Reconstr Surg 2015;37:31.
88. Kurohama T, Hotokezaka H, Hashimoto M, Tajima T, Arita K, Kondo T, et al. Increasing the amount of corticotomy does not affect orthodontic tooth movement or root resorption, but accelerates alveolar bone resorption in rats. Eur J Orthod 2017;39:277-86.
89. Chan E, Dalci O, Petocz P, Papadopoulos AK, Darendeliler MA. Physical properties of root cementum: part 26. Effects of micro-osteoperforations on orthodontic root resorption: a microcomputed tomography study. Am J Orthod Dentofacial Orthop 2018;153:204-13.
90. Zawawi KH. Patients’ acceptance of corticotomy-assisted orthodontics. Patient Prefer Adherence 2015;9:1153-8.