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Corticotomy for orthodontic tooth movement

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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

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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[1]. 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[2] 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[2-4]. Düker[5] 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

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movement by eliminating the physical obstruction. However, Wilcko et al.[6] in 2001 introduced Frost's regional accelerating phenomenon (RAP) concept. Tooth movement by corticotomy 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 Norrdin[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[7,29]. 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 decortication 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

(CAOT)[39,40], AOO[6,7,27,41,42], PAOO[6,7,27,41-47], selective alveolar decortication (SAD), surgically facilitated orthodontic therapy (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[48].

Speedy orthodontics is defined as corticotomy-facilitated orthodontic treatment that combines a corticotomy and orthopedic heavy force application on the anterior segment[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 application on the corticotomized segment.

IV. Conventional Corticotomy Technique

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

Local anesthesia is sufficient for corticotomies, but intravenous sedation may be used for patient comfort. One-stage techniques are generally used, but two stages are used on occasion. In the two-stage technique, alveolar bone is divided into palatal and labial/buccal sections and corticotomized at two weeks intervals[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 elevator, and the buccal and lingual cortical bones are exposed beyond the apical region of the corticotomy. At this time, tunneling of the lingual (or palatal) flap, elevating only the cortical 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 carefully 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 performed 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 marrow 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 reattachment 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[6]. These cuts should not perforate the cancellous bone to avoid injury to any underlying structures. Particulate bone grafting 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[6].

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[9].

2. Piezocision

In 2007, Vercellotti and Podesta[63] performed corticotomies using conventional flap elevations and piezosurgery for rapid tooth movement. After that, Dibart et al.[11] 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[39]. An endoscopically assisted tunnel approach may be used to reduce the number of vertical incisions[64]. The rate of tooth movement was reported to be slightly slower than with a conventional corticotomy[56]. 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[53].

3. Micro–osteoperforation

Micro-osteoperforation uses a handled appliance such as Profel for osteo-perforation without flap elevation. Alikhani et al.[59] 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.[15] 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[54].

VI. Rate of Tooth Movement and Force Application

Köle[2] 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[37]. Aboul-Ela et al.[65] 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.[54] 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.[56] reported that corticotomy-facilitated orthodontics exhibited 1.5 to 2 times faster tooth movement compared to conventional orthodontics. Gil et al.[66] 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[13,65,67-69] had forces applied to the teeth immediately after corticotomies. The other

group[70-74] was studied within 2 weeks after corticotomy. Kraiwattanapong and Samruajbenjakun[75] reported that the group with heavy force (50 g) application after corticotomy in rats experienced rapid tooth movement with no difference in alveolar bone change or root resorption compared to the group with light force (10 g).

VII. Indications and Limitations

Tooth movement using corticotomy can be applied in many fields. Noh et al.[76] 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[77].

Kim et al.[78] 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.[79] 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[54,80], anterior teeth retraction, decrowding[53,81], molar uprighting[37], correction of a scissor bite[82], and rapid maxillary expansion. Lines[83] 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.[84] used piezo-bone perforations on the buccal alveolar bone in young patients for maxillary expansion. Le et al.[85] 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.[86] 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[48].

Wilcko and Wilcko[42] 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[43], individuals with inadequately treated endodontic problems, and people who are taking any medications such as bisphosphonates and nonsteroidal anti-inflammatory drugs[6]. 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[87].

VIII. Complications

The side effects are controversial. Although interdental bone loss, periodontal defects, and reduced attached gingiva were reported, Aboul-Ela et al.[65] 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.[67] 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[88]. However, Chan et al.[89] 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.[58] 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[90].

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.

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