REVISTA ESPAÑOLA DE ORTODONCIA

Review Article

Alveolar corticotomy. Are we looking at it in the right way?

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ABSTRACT

Alveolar corticotomy (AC) is advocated to accelerate orthodontic tooth movement and reduce treatment time. It has been clearly demonstrated in both clinical patients and experimental animals that after a surgical insult to the alveolar bone a regional acceleratory phenomenon (RAP) reaction and a temporary increase of the speed of tooth movement follow. Reduction of treatment time is still a discussed topic: it is still unclear in which clinical situations AC is more effective, the extent of treatment reduction, and how it influences the quality of end result and patient's satisfaction. So far, integration of AC in an orthodontic treatment with the simple intention of reducing the length of the treatment of just few months seems not to justify the risk and the cost. Differently, AC may be associated to orthodontic treatments to reduce tooth resistance to orthodontic forces and simplify complex biomechanical situations. In this paper, a distinct perspective of the biological, biomechanical, and therapeutic advantages of this surgical periodontal procedure is described. Six rules, based on current clinical and experimental research, to be effective, efficient, and patient-friendly are advised. (Rev Esp Ortod. 2018;??:??).

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Key words: *Accelerated tooth movement. Facilitated tooth movement treatment time reduction. Regional acceleratory phenomenon reaction.*

Corticotomía alveolar. ¿La estamos mirando de manera correcta?

R. Spena

RESUMEN

La corticotomía alveolar (CA) está recomendada para acelerar el movimiento dental de ortodoncia y reducir el tiempo de tratamiento. Se ha demostrado claramente en pacientes clínicos y en experimentos con animales que después de una lesión quirúrgica en el hueso alveolar, se produce una reacción del fenómeno acelerador regional (RAP) y un aumento temporal de la velocidad del movimiento del diente. La reducción del tiempo de tratamiento sigue siendo un tema discutido: aún no está claro en qué situaciones clínicas la CA es más efectiva, el grado de reducción del tratamiento y cómo influye en la calidad del resultado final y la satisfacción del paciente. Hasta ahora, la integración de CA en un tratamiento de ortodoncia con la simple intención de reducir la duración del tratamiento de solo algunos meses parece no justificar el riesgo y el costo. De manera diferente, la CA puede estar asociada a tratamientos de ortodoncia para reducir la resistencia del diente a las fuerzas de ortodoncia y simplificar situaciones biomecánicas complejas. En este trabajo, se describe una perspectiva distinta de las ventajas biológicas, biomecánicas y terapéuticas de este procedimiento periodontal quirúrgico. Se recomiendan seis reglas, basadas en la investigación clínica y experimental actual, para ser eficaz, eficiente y gentil con el paciente.

Palabras clave: *Movimiento dental acelerado. Reducción del tiempo de tratamiento del movimiento dental facilitado. Reacción regional del fenómeno acelerador.*

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INTRODUCTION

In the past two decades, the efficiency of orthodontic tooth movement (OTM) has greatly improved both at biomechanical and biological level. Brackets with an improved design, new alloys for archwires, refined force delivering auxiliaries, reliable and easy to insert miniscrews and plates for skeletal anchorage, and stimulation of the metabolism of the alveolar bone with surgical and non-invasive protocols have become commonly used in many orthodontic treatments.

At the present time, however, alveolar corticotomy (AC) seems to be the only reliable, safe, and effective way to cause an acceleration and facilitation of OTM with a reduction of the side effects as root resorption, loss of vitality, periodontal damage when dealing with complex OTM[1,2].

Clinical and scientific hypothesis on AC has changed from a mechanical to a more biological effect.

In 1983 Suya[4] proposed a great improvement of the surgical approach described by Kole[3] in 1959 modifying the surgical procedure. The horizontal cut became a corticotomy instead of an osteotomy, the alveolar crest was avoided in the vertical cut, and the luxation of the blocks was eliminated. This «corticotomy facilitated orthodontics» was to treat adult patients, ankylosed teeth, and crowded malocclusions to avoid premolar extractions. Like Kole, Suya believed he was creating bony blocks and suggested to accomplish most of the movements in the first 3-4 months after the corticotomy before the fusion of the blocks (healing of the bone).

In 2001, Wilcko et al.[5] drastically reformulated the concepts of the corticotomy-assisted OTM. In this «two case-report» paper, two adult patients were treated with corticotomy associated to alloplastic resorbable grafts to increase bone levels and avoid risks of recessions. After raising flaps to the entire dental arches, numerous vertical and horizontal cuts, and numerous holes in the cortex, a bleeding bed was created to host the grafting. Computed tomography scans before and after the surgery revealed that no movement of tooth/bone-blocks but, more simply, a transient reduction of mineralization and temporary modifications similar to those described by Frost[6-9] in the healing process of fractured bones and named regional accelerated phenomenon (RAP) most likely occurs. Wilcko and Wilcko have subsequently improved and patented the surgical protocol as periodontally accelerated osteogenic orthodontics (PAOO)[10-12].

The benefits of the PAOO should be: (1) acceleration of the OTM with reduction of the total treatment time; (2) osteogenic modifications with bony matrix transportation; (3) improved dental supporting tissues at the end of the orthodontic treatments; and (4) increased stability of orthodontic treatments.

A vast number of clinical and experimental studies have followed trying to substantiate and confirm these clinical effects of AC. Different protocols and surgical procedures have been proposed with the aim to reduce invasivity and costs, as well as increase patient's comfort and acceptance.

After more than one and a half decade of clinical experience with AC, in the light of the current literature published on this topic, six rules have been found that should be taken into account when thinking about using AC in complex orthodontic cases. These rules are to be effective and reduce the risks of producing no positive effect or, worse, causing damage. They are: (5) AC is to facilitate OTM, (6) AC has limited effect in time, (7) AC has limited effect in space, (8) Follow a proper surgical protocol, (9) Follow a proper orthodontic management after corticotomy, (10) Select the right patient for corticotomy. An in-depth description of the rules follows.

AC IS TO FACILITATE OTM

Reduction of treatment time is one of the objectives of modern orthodontics. Prolonged therapies may be responsible of caries, root resorption, and alveolar bone loss. Patients, especially adults, require short treatments whenever possible. We must recognize, however, that too many variables may affect the duration of an orthodontic treatment[13-16]. The initial difficulty of the malocclusion and tooth malposition, the age of the patient, the variability of the individual response to the treatment, the quality of the end result, and patient's compliance are just a few of the variables that should be considered. Numerous case reports have been published showing how treatment time can be reduced when patients are treated with corticotomy. Case reports, however, have limited scientific validity. In a recent systematic review, Gil et al.[17] have tried to give scientific validation to the claim. From the selected 13 articles[18-30] that were included in the study, it was concluded that AC may decrease treatment time, but it was recognized that the methodological quality of these studies was low as well as the final scientific evidence. The treated malocclusions, the type of surgical procedure, the final outcome highly differ or were not considered at all in the studies. The lack of randomization and comparison among cases were almost totally absent.

It is evident that the predictability and quantification of treatment time reduction are still not scientifically possible. The additional expenses and morbidity associated with the use of AC should always be carefully evaluated if they are worth just saving few months. A shorter orthodontic treatment is desirable, but certainly not at the expense of a good quality end result.

In addition to the temporary effect of AC (we will discuss it in key 3), numerous studies[31-33] have shown that the

Figure 1. *Adult patient with full Class II molar and canine relationship.*

Figure 2. *Corticotomy performed only on upper first and second permanent molars. Distalization with compressed coils.*

Figure 3. *Final result with no compliance required.*

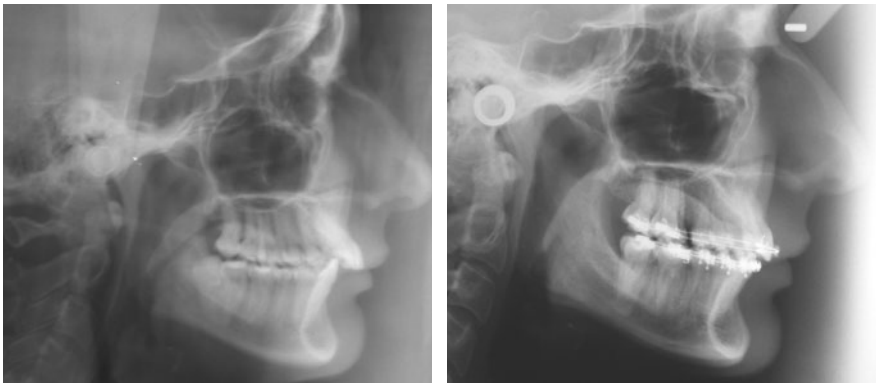


Figure 4. *Cephalometry at the beginning of treatment and at the end of distalization.*

speed of the OTM is not related to the level of the forces, but it is influenced by individual bone turnover and response to mechanical forces. Patients may be slow movers or fast movers, and we will recognize them only during treatment.

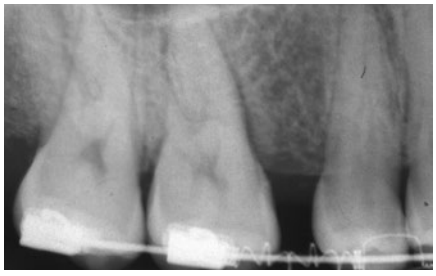
In conclusion, a faster treatment may be the result of many concomitant favorable variables in a single patient. AC may accelerate a therapy because allows a faster solution of a complex phase of the treatment but combining it to orthodontic treatments with the only objective of accelerating OTM and reducing treatment time may be restricting and risky.

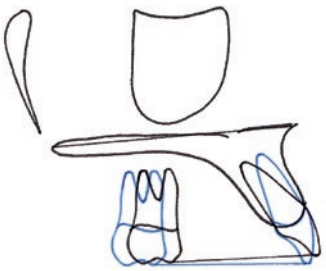
Despite the lack of scientific evidence, AC has its place in orthodontic therapies. The issue should be taken from a different perspective: the RAP reaction produced by the surgical insult increases bone metabolism, the increased osteoclastic activity creates a transient reduced regional density (osteopenia) and reduces the undermining resorption and the hyalinization (we still do not know exactly what happens in humans but these are the major changes). All these modifications at alveolar level bring about biomechanical facilitation of OTM. The «decorticated» tooth will be less resistant to orthodontic forces, easier to move and will require less anchorage.

In a recent study on a finite element model, Verna et al.[34] have shown how the reduced bone density caused by corticotomy influences both the amount and the type of tooth movement. The centre of rotation (CR) shifts more apical in any type of movement. This is nothing new. Glenn et al.[35] and Tuncay et al.,[36] in two experimental studies on animals found that fiberotomy of the dentogingival and the interdental fibers affected the rate of OTM and shifted the CR toward the apex of the roots thus modifying the biomechanical behavior of the teeth under an orthodontic force. The authors of these two studies, published before the new trend on corticotomy, were not aware the link between fiberotomy of the dentogingival and the interdental fibers and RAP reaction was not known yet. Only in 2010, Bindermann et al.[37] confirmed that fiberotomy may stimulate accelerated alveolar bone metabolism and tooth movement.

Spena et al.[38,39] in two studies conducted on a total of 12 adult patients with Class II malocclusions treated with distalization of the upper molars showed how upper molars could be bodily distalized with simple buccal mechanics and no anterior anchorage. Corticotomy was performed only on the teeth to move thus reducing their resistance to distal forces, modifying their biomechanical response to distal forces applied at the tube and reducing the anchorage needs (Figs. 1-5).

Oliveira et al.[40] stated that corticotomies should be used to «…facilitate the implementation of mechanically





Figures 5. *Periapical X-ray and superimposition reveal the bodily molar distalization.*

challenging orthodontic movements and enhance the correction of moderate to severe skeletal malocclusions.» The term Periodontally Facilitated Orthodontics (PFO) is preferred to PAOO to describe any procedure that has the primary goal to «simplify, enhance and improve» OTMs that are difficult or risky from a biomechanical and biological point of view. The surgical procedure and the associated orthodontic treatment and biomechanics depend on the initial problems and the goals of every single specific treatment.

AC HAS LIMITED EFFECT IN TIME

The altered metabolism of bone after a traumatic (or surgical) event has a limited duration. It is the natural search for equilibrium or homeostasis. This is well known since the early studies of Frost on the biology of fracture healing. The increased remodeling of hard and soft tissue starts few days after the insult, peaks at the 1-2nd month, returns to a normal rate after no more than 4-6 months. At the alveolar level, this RAP reaction causes an accelerated/facilitated movement of teeth subjected to applied orthodontic forces. The effect lasts as long as there is this reaction, so for a limited part of orthodontic therapy. This is confirmed by experimental studies on animals as well as by clinical studies on patients[26,41]. Clinically, this temporary phenomenon leads to the need of performing the AC when the RAP is necessary. Timing is fundamental as well as the following management of the orthodontic movement (see in key 5).

Research has been made to verify if AC may be repeated during the treatment with the objective of prolonging the effect. Sanjideh et al.[42] in split-mouth research on foxhounds found that a second corticotomy performed after 28 days in the mandible produced a higher rate of tooth movement and a greater total tooth movement. However, they conclude that proper timing for a second corticotomy needed to be better determined.

Effective benefit, cost, and risks of repeated surgeries must be considered: corticotomy performed during another surgery (i.e., exposure of impacted teeth[43] or orthognathic surgery[23]) does not add cost and risk and may give benefit as well as micro-osteoperforations (MOPs) that are performed with a powerful anesthetic gel and may be easily repeated at a reduced cost and risk.

Wilcko[10-12], Murphy,[44,45]and Dibart[46,47] claimed that a prolonged osteopenia state during which teeth can be moved rapidly may be maintained by a constant mechanical stimulation through a continuously activated orthodontic force applied after decortication. They recommend seeing patients frequently (every 2 weeks) and keep activating the applied orthodontic forces. If not, remineralization completes the healing process and brings the bone metabolism at a normal level. These claims, however, have never been demonstrated neither clinically nor histologically.

AC HAS LIMITED EFFECT IN SPACE

The effects of AC are localized to the area immediately adjacent to the site of injury[48]. Different surgeries may affect differently the resulting OTM. This finding is of outmost importance.

If the surgical insult is limited to a specific area of the alveolar bone (i.e., middle third and only buccal surface) (Fig. 6), the RAP reaction most likely will not be extended to the entire root area. The modifications at the bone level (osteopenia) will be limited to the area of the decortication, and the apical and lingual sides will not be affected as desired.

As a general rule, if a bodily movement or a better control of the apical area are the biomechanical needs of the OTM to be achieved and enhanced (i.e., intrusion/extrusion and distalization/mesialization), the decortication needs to be extended to the entire alveolar bone surrounding the roots of the tooth, buccal, and lingual (Fig. 7); if the desired movement is not bodily or anatomical limitations of the surgical site impede an extended decortication, the surgical insults may be limited in the direction of the OTM (Fig. 8).

The biomechanical needs determine the type of procedure in both the open flap and the flapless surgeries.

FOLLOW A PROPER SURGICAL PROTOCOL

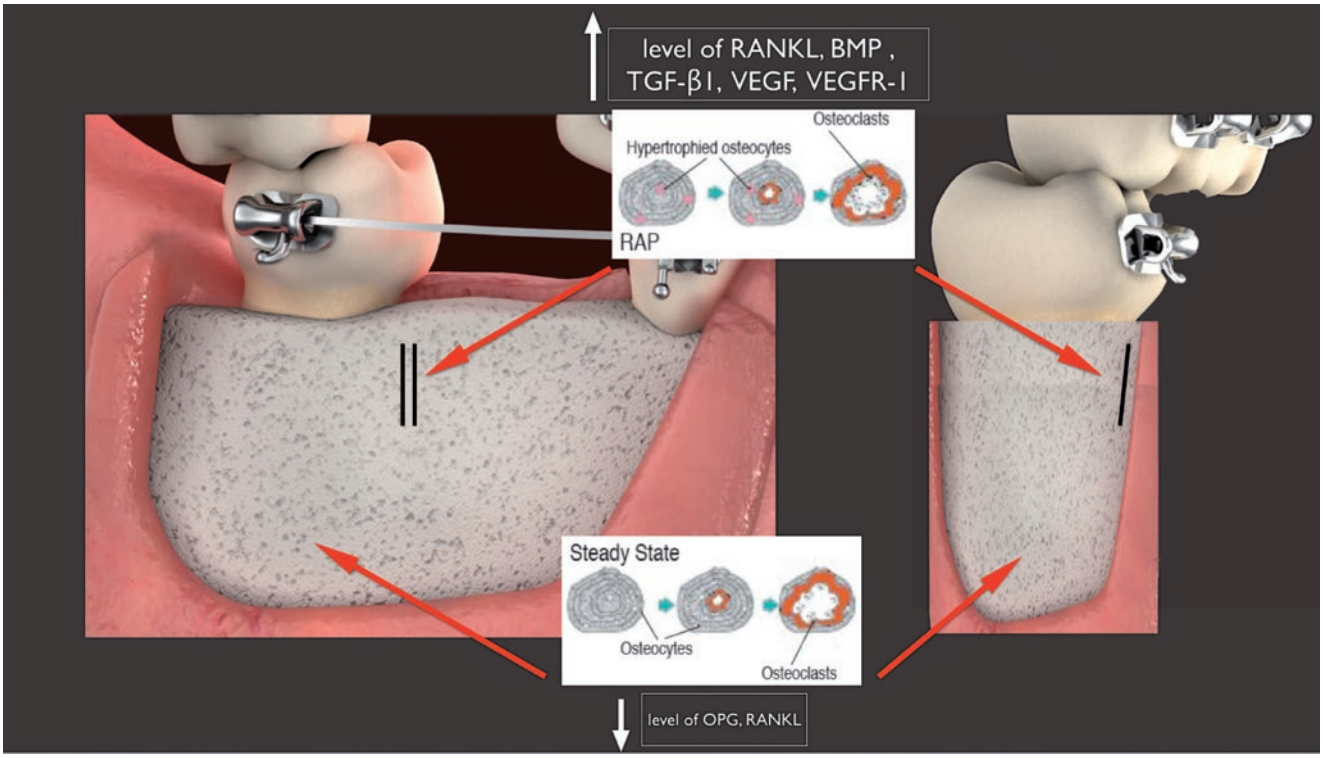


Figure 6. *Limited alveolar corticotomy and limited RAP reaction.*

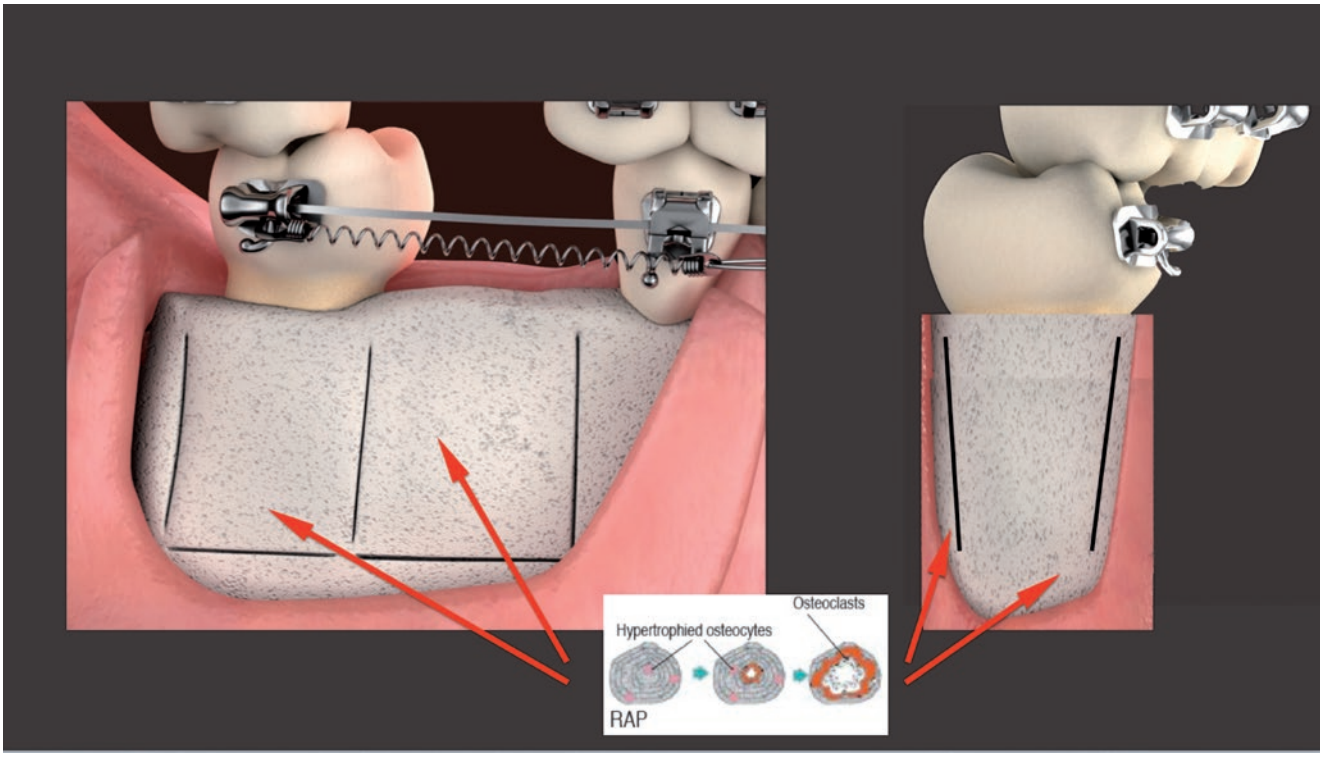


Figure 7. *Extended alveolar corticotomy and extended RAP reaction.*

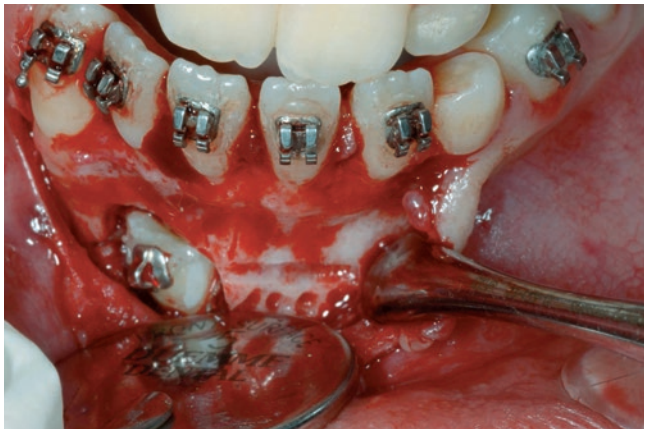


Figure 8. *Alveolar corticotomy in the direction of the tooth movement.*

Several surgical protocols of AC have been described. They may be quite different in execution, level of invasivity and morbidity, and cost. Most of them have been tried by the author in the past 15 years on several patients. These surgeries may be divided into two groups: the open flap and the flapless (Table 1).

The surgery

The original corticotomies were performed raising a flap. The open flap surgery is still preferred when an extended or critical area of decortication has to be managed and when an extended grafting is planned. The flap can be designed according to the periodontal characteristics of the site and has to be full thickness in the area of decortication and split thickness below this area to keep a good blood supply. Interproximal and sub-apical cuts of 1-2 mm in the cortical bone (Fig. 11 A-B) are created together a light scraping of the external cortex in between the cuts.

This extended surgical insult will produce a wide RAP reaction and prepare a bleeding bed for any grafting material eventually associated to the decortication. The piezosurgical calibrated microsaws are preferred to the rotating surgical burs because of their selective safer cuts, micrometric more precise cuts, better irrigation/cooling effect from cavitation, better comfort for the surgeon and the patient, and better healing[49-53].

The open flap corticotomy procedure is indicated and routinely used during orthognathic surgery, exposure of impacted teeth, transverse maxillary deficiencies, periodontally involved cases, and all those cases that need hard and/or soft tissue grafting.

Flapless surgery is an alternative way of producing corticotomy. Park with the corticision[54,55] and Dibart with the piezocision[56] have tried to reduce the invasiveness of the

Table 1. Open flap and Flapless surgical protocols

Open flap corticotomies	Flapless corticotomies
PAOO surgery	Fiberotomy
Segmental Corticotomy	Corticision
Any corticotomy performed during an open flap surgery	Piezocision
	MOPs

MOPs: micro-osteoperforations.

Figure 11. A: *Vertical interproximal cut performed with calibrated piezoblades.*

Figure 11. B: *Horizontal sub-apical cut performed with calibrated piezoblades.*

open flap decortication, the potential periodontal damage, and post-operative discomfort. Even if attractive, they have shown surgical and biomechanical limitations[57]. The surgical limitations include risks when performed in crowded arches, limited visibility when producing the cuts, limitation of the cuts to the interproximal areas and the middle third of the roots, difficult control of the grafting in the apico-coronal direction, need of an optimal extension of the attached gingiva in the area of decortication. The biomechanical limitations are related to the fact that the cuts are

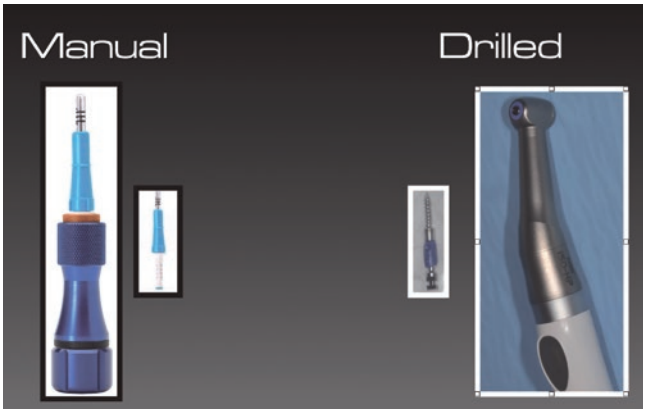


Figure 12. *On the left, the Propel Excellerator for manual osteoperforations and, on the right, a handpiece and the proper bur for drilled perforations.*

usually made only on the buccal side and middle third of the roots. They are certainly not minimally invasive surgeries as claimed by the authors and are quite expensive for the patient since only a well-trained periodontist/oral surgeon can perform them and often need complex planning with 3D digitally fabricated surgical guides[58].

A much more effective and very low invasive way of producing insult to the cortical alveolar bone are the MOPs described by Alikhani et al.[59] and Teixeira et al.[60] The MOPs may be created in two ways: with manual instruments (excellerator by propel) or with dedicated burs on a reduced speed electric handpiece (Fig. 12).

MOPs are made with penetration into the cortex of maximum 1-2 mm. Instead of the traditional local anesthesia with needles, a strong anesthetic gel placed on the mucose for 3 min is enough to control patient's pain and discomfort. As said before, the effect of corticotomy does not extend much in space. For this reason, it is advisable to produce at least 2-3 MOPs in each interproximal area of the teeth and both buccally and lingually (Fig. 13) to be sure that the metabolic changes are extended around the entire radicular alveolar bone of the tooth to move.

The procedure and the precautions are similar to the insertion of miniscrews. The tip of the bur should be inserted and removed perpendicular to the bone surface at a careful distance from dental roots. This way, manual MOPs are usually made in the frontal areas whereas drilled MOPs are usually made in the posterior and lingual areas (Figs. 14 A-C).

Orthodontists can easily made MOPs at the chairside; they can easily repeat them during treatment if additional «bone stimulation» is needed, and the cost is a lot more affordable for the patient. No packing, no sutures are necessary after MOPs. The limit is that no grafting can be associated.

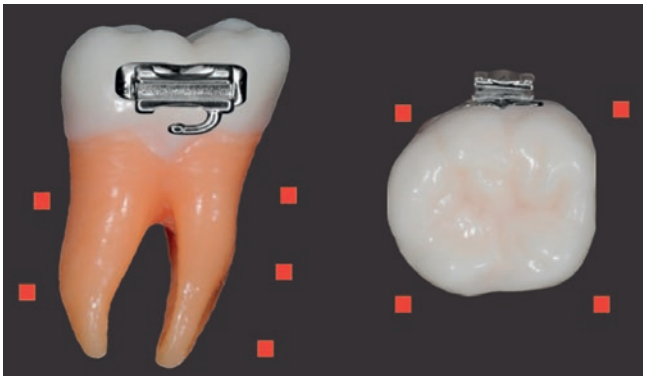


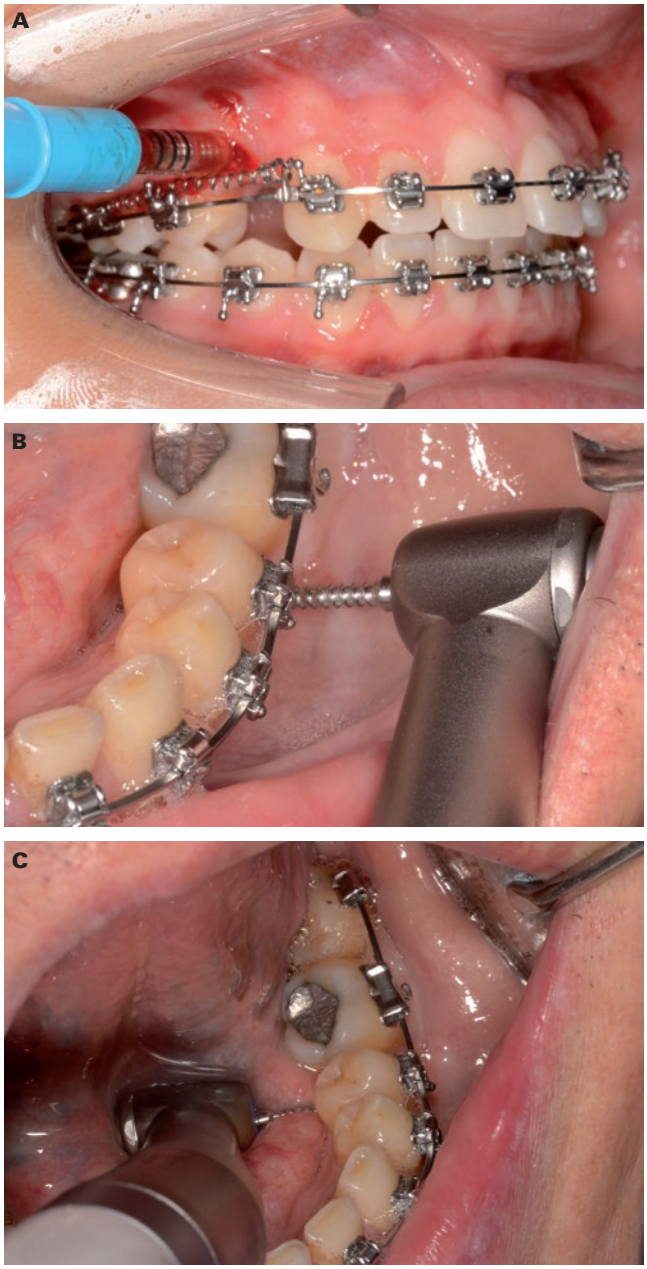
Figure 13. *Recommended areas where to perform osteoperforations.*

The grafting

Whenever possible and desirable, grafting may be associated to AC. The grafting is usually planned before surgery based on initial clinical and radiological evaluation, desired OTM, short- and long-term periodontal considerations. In situations of thin bone and thin gingival biotype, when risky movements such as expansion, labial proclination, or anteroposterior movements in reduced bone volumes are planned, grafting may be indicated to reduce/eliminate fenestrations and dehiscences, produce additional support for the roots, improve final aesthetics and stability. Grafting may include hard tissue, soft tissue, and autologous growth factors[61-63]. Quality and quantity may be modulated at the surgery depending on the clinical conditions of the surgical site. As a general rule, composite bone grafts are preferred. In this mix, allogenic bone (from human cadavers that are freeze-dried to reduce antigenicity and demineralized to expose the underlying collagen and its growth factors like BMP) with osteoinductive properties is combined to xenogenic bone (bone usually from bovine animals that provide a physical matrix or scaffold suitable for deposition of new bone and that prevents its rapid resorption) with osteoconductive properties (Fig. 16 A).

Soft tissue grafts are added to bone graft when a thin biotype or gingival recessions are present. Autologous connective tissue graft is the gold standard procedure when the area to regenerate is small. Allogenic human acellular dermal matrices, available in different sizes and thicknesses, may be used instead when large areas need to be managed (Fig. 16 B). Soft-tissue grafts are sutured with resorbable sutures.

Both bone and soft tissue grafts may be coupled with autologous growth factors. With aging, the number of stem cells rapidly decreases. These cells are important in healing processes. Studies[63] have shown that growth factors from



Figures 15 A-C. *Manual and drilled perforations.*

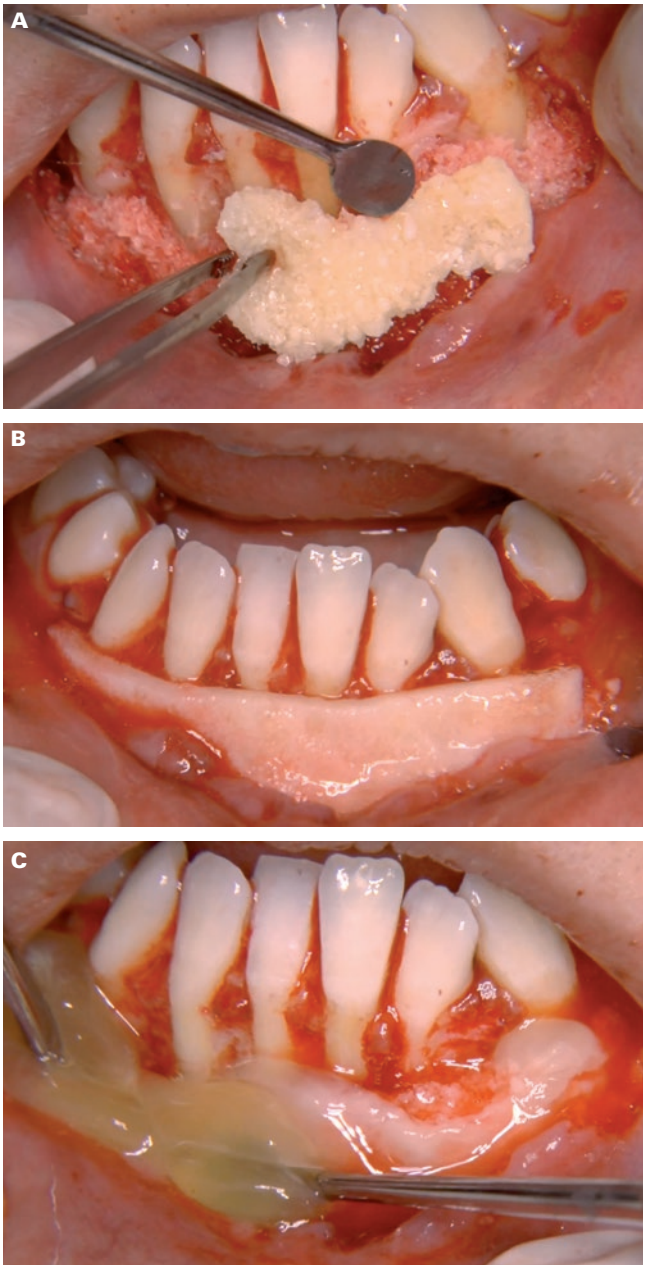


Figure 16. A: *Bone graft and PRGF. Note the stability of the grafting.* ***B:*** *Soft-tissue grafts before being stabilized with resorbable sutures.* ***C:*** *The membrane of PRGF placed on top of the bone graft.*

a light compression of the centrifuged fraction. Differently, PRGF allows the separation of three fractions with different concentrations of platelets. They may be mixed with bone grafts (increasing its viscosity and adherence to the surgical site thus facilitating its application) and soft-tissue grafts. Activating and heating the PRGF fraction produces clots/membranes of fibrin that are placed on the bone grafts stabilizing their position (Fig. 16 C).

Last but not least, when adding grafts to AC, a tension-free platelet-concentrated plasma (platelet-derived growth factor, vascular endothelial growth factor, transforming growth factor [TGF-b1], and TGF-b2) may rapidly increase the number of the available stem cells, stimulate their activity as well as reduce inflammation and pain during the healing processes. The platelet-rich fibrin (PRF)[64,65] and the platelet-rich in growth factors (PRGF)[66,67] are two different protocols where blood centrifugations allow separation of the plasma platelets from the white and red cells. PRF contains also leukocytes and allows production of membranes with

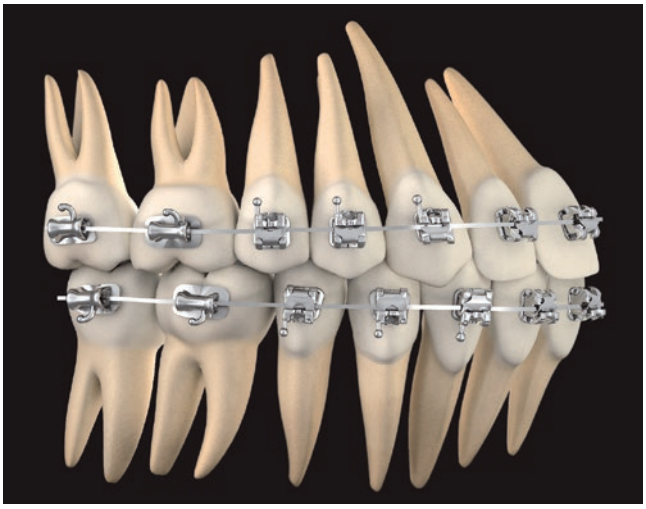


Figure 17. *Schematic picture of the CCO System with new molar tubes and new prescriptions for active SLB.*

flap closure must be achieved at the end of the surgery to provide optimal coverage of the decorticated area with the grafted material and to enhance final soft-tissue healing. Non-resorbable sutures are left for at least 14-21 days.

FOLLOW A PROPER ORTHODONTIC MANAGEMENT AFTER CORTICOTOMY

Any orthodontic treatment carried out with either fixed or removable appliances may be associated to AC. It is the choice of the author to combine decortication procedures with fixed active self-ligating appliances (In-OvationÓ) with the new prescription of the CCO system (Fig. 17)[68,69].

The management and wire changes are similar to an orthodontic case. No initial heavy force is necessary: AC has dento-alveolar not orthopedic effects. There is no rule as far as timing of the bonding: in some cases, appliances are placed a week after the surgery while in other several months before corticotomy (for example, when distalizing upper molars or repositioning impacted teeth). The enhanced tooth movement deriving from the RAP reaction is obtained when needed. As already mentioned, timing of the surgical decortication must be carefully planned.

After the periodontal surgery and until tooth movement is clearly enhanced, the visits for wire activations or wire changes are planned every 2 weeks instead of the usual 6-8 weeks. When corticotomy is associated with treatments with aligners, the frequency of appliance changes is every 3-4 days.

AC may be easily associated to skeletal anchorage devices. The TADs are to increase anchorage, while the corticotomies are to reduce anchorage. High biomechanical effectiveness may be reached in complex cases or tooth movements when AC is combined to skeletal anchorage and efficient bracket/wire systems.

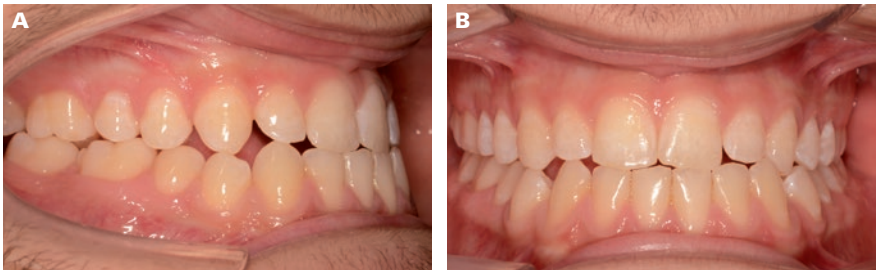
PROPER CASE SELECTION

Contrary to what is often read in literature, AC is not for every patient and should not be used on a routine basis in clinical practice. The main indication is in clinical cases with complex OTMs. Open flap surgery is indicated in impacted teeth, orthognathic surgery first with extraction, orthognathic surgery with major post-operative OTMs, complex space closures with reduced supporting tissues, and maxillomandibular transverse, or labial expansion in periodontally compromised cases. MOPs are indicated in treatments with aligners, complex OTMs without periodontal problems, patients with economical limitations. Two cases treated with open flap corticotomy and two cases treated with MOPs will be shown to elucidate the concepts described in this article.

Case 1

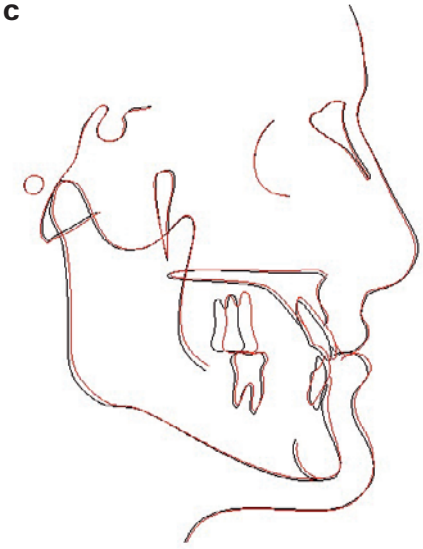
A 19 years-old-male patient with a Class III dental malocclusion with anterior midline discrepancy, wanted to be treated only with aligners (Figs. 18 A-B).

Treatment was carried out with 71 aligners and two MOPs performed at the 2nd month and the 5th month of treatment only on the premolar-molar maxillary dentition (Fig. 19).



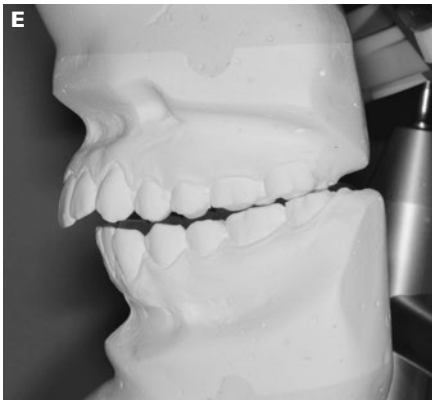
Figures 18 A-B. *Adult patient at the beginning of treatment with a Class III malocclusion.*

Figure 19. *Osteoperforations performed in the upper arch on both buccal segments. Aligners in place with Class III elastics*



Figures 20 A-C. *Final dental result and superimposition. Note the inclinations of upper and lower incisors.*

Figures 21 A-C. *Patient at the beginning of treatment.*



Figures 21 D-E. *Mounted casts show the CR-CO discrepancy and how the Class II relationship is worse than the one in habitual occlusion.*

Figure 21 F. *Initial lateral cephalogram.*

Class III elastics were prescribed throughout the therapy. Treatment was completed in 7 months with an acceptable intercuspation in the buccal segments and correction of the midlines (Figs. 20 A-B) and with a good anchorage control in the lower arch (Fig. 20 C).

Case 2

A 22-year-old female patient with a Class II, division 1 malocclusion in a skeletal pattern with vertical excess and mandibular retrusion (Figs. 21 A-F).

Treatment plan was to treat her with surgery first protocol and extraction of second premolars and all four wisdom teeth (Figs. 21 G). Corticotomy was performed during the orthognathic surgery (Figs. 22).

Active orthodontic treatment started a week after the surgery and was completed in 11 months (Fig. 23 A-D).

Case 3

A 30 years-old male patient, with two previous

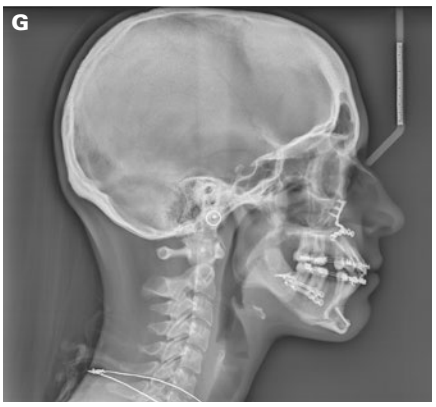


Figure 21 G. *Lateral cephalogram after surgery.*

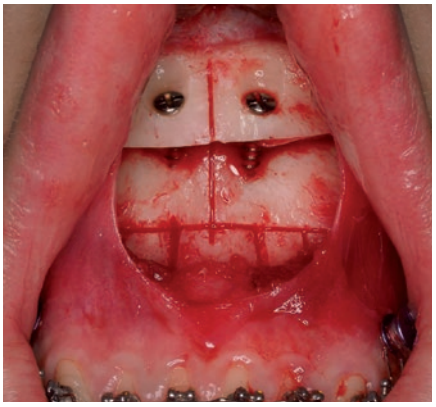
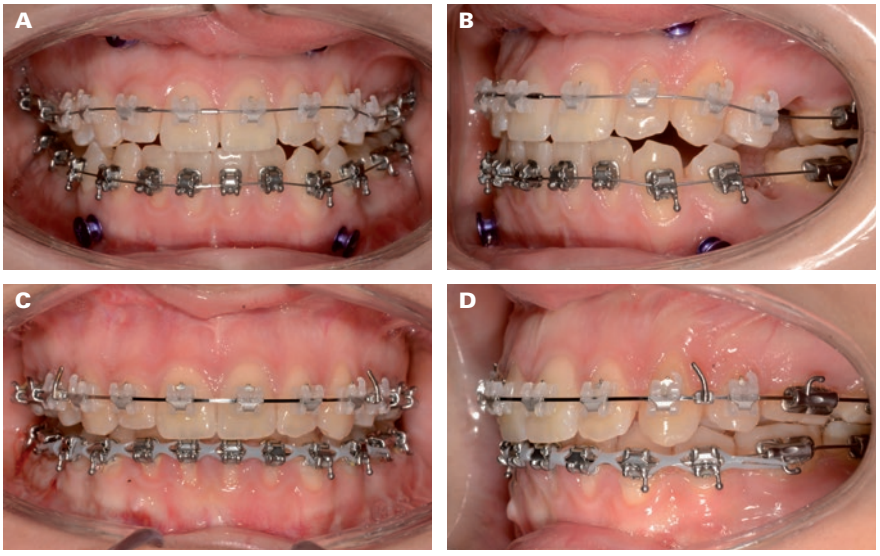


Figure 22. *Alveolar corticotomy peformed during the orthognathic surgery* (Courtesy of Dr. Federico Hernandez-Alfaro).



Figures 23 A-D. *Treatment started a week after the surgery and at the end after only 8 months.*

unsuccessful orthodontic treatments, shows a Class I malocclusion with anterior crowding and missing upper lateral incisor. Transverse and anteroposterior dental compensations are evident. Patient showed a slight skeletally constricted upper arch that needed expansion. The ideal treatment included surgical assisted maxillary expansion. Patient refused this treatment. Patient accepted an alternative treatment with open flap corticotomy extended from molar to molar and generous hard and soft tissue grafting. Treatment started a week after the surgery and continued with visits every 2-3 weeks. The CBCT images before and after treatment reveal the increased volume of the maxillary alveolar bone that allowed the successful expansion of the upper arch despite the age of the patient. Stability is still present after 5 years (Figs. 24-28).

CONCLUSIONS

AC (or PFO as we prefer) is an effective procedure where alveolar decortication is associated to orthodontic treatments with the primary goal of enhancing OTM and reducing anchorage needs. Accelerating the rate of OTM and reducing the complexity of a clinical case, bone decortication may reduce treatment time. However, this effect is considered a side effect and not the primary reason for using this periodontal surgery. According to patient's needs, it may be performed with an open flap or a flapless procedure and may be associated with hard and soft tissue grafting. Further studies are still needed to evaluate indications, contraindications, and risks. The procedures here described will certainly evolve and improve with the improvement of the materials, the devices and appliances utilized.

REFERENCES

1. Long H, Pyakurel U, Wang Y, Liao L, Zhou Y, Lai W. Interventions for accelerating orthodontic tooth movement. A systematic review. Angle Orthod. 2013;83:164-71.

Figure 24 A-C. *Patient at the beginning of treatment. 12 is missing and upper arch is constricted and shows previous compensations.*

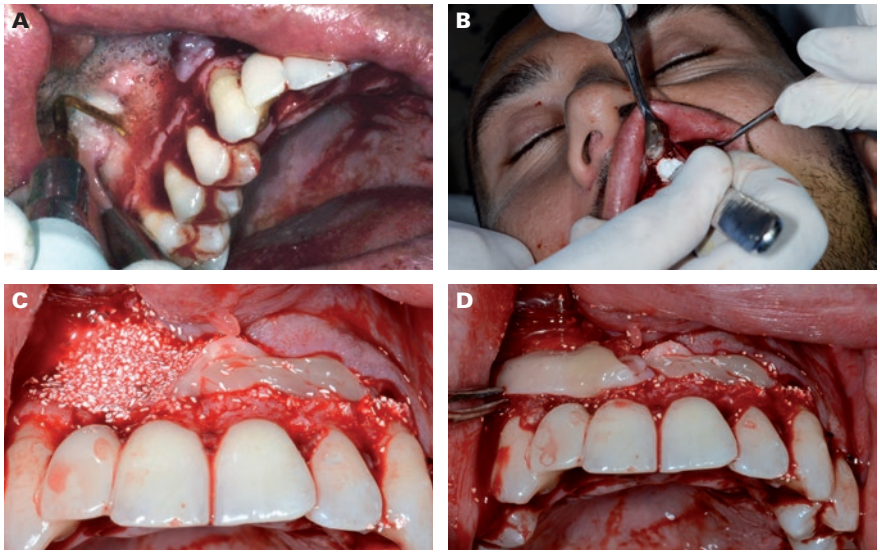


Figure 25 A-D. *Alveolar corticotomy performed with piezosurgery from molar to molar. Bone grafting with PRF membranes added on the decorticated bone.*

2. Hoogeveen EJ, Jansma J, Ren Y. Surgically facilitated orthodontic treatment: a systematic review. Am J Orthod Dentofacial Orthop. 2014;145:S51-64.
3. KOLE H. Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surg Oral Med Oral Pathol. 1959;12:515-29.
4. Suya H. Corticotomy in orthodontics. In: Hosl E, Baldauf A, editors. Mechanical and Biological Basics in Orthodontic Therapy. Germany: Huthig Buch Verlag, Heidelberg; 1991. p. 207-26.
5. Wilcko WM, Wilcko T, Bouquot JE, Ferguson DJ. Rapid orthodontics with alveolar reshaping: two case reports of decrowding. Int J Periodontics Restorative Dent. 2001;21:9-19.
6. Frost HM The regional accelerated phenomenon. Orthop Clin North Am. 1981;12:725-6.
7. Frost HM. The regional accelerated Phenomenon: A review. Henry Ford Hosp Med J. 1983;31:3-9.
8. Frost HM. The biology of fracture healing. An overview for clinicians. Part I. Clin Orthop Relat Res. 1989;246:283-93.
9. Frost MH. The biology of fracture healing: an overview for clinicians. Part II. Clin Orthop. 1989;248:294-309.
10. Wilcko MT, Wilcko WM, Pulver JJ, Bissada NF, Bouquot JE. Accelerated osteogenic orthodontics technique: a 1-stage surgically facilitated rapid orthodontic technique with alveolar augmentation. J Oral Maxillofac Surg. 2009;67:2149-59.
11. Wilcko MT, Wilcko WM, Omniewski KB, Bouquot JE, Wilcko JM. The periodontally accelerated osteogenic ORTHODONTICS (PAOO) technique: efficient space closing with either orthopedic or orthodontic forces. J Implant Adv Clin Dent. 2009;1:45-61.
12. Wilcko MT, Wilcko WM, Bissada NF. An evidence-base analysis of periodontally accelerated orthodontic and osteogenic techniques: a synthesis of scientific perspectives Semin Orthod. 2008;14:305-16.
13. Vig PS, Weintraub JA, Brown C, Kowalski CJ. The duration of orthodontic treatment with and without extractions: a pilot study of five selected practices. Am J Orthod Dentofacial Orthop. 1990;97:45-51.
14. Beckwith FR, Ackermann RJ, Cobb CM, Tira DE. An evaluation of factors affecting duration of orthodontic treatment. Am J Orthod Dentofac Orthop. 1999;115:439-47.
15. Skidmore KJ, Brook KJ, Thomson WM, Harding WJ. Factors influencing treatment time in orthodontic patients. Am J Orthod Dentofacial Orthop. 2006;129:230-8.
16. Mavreas D, Athanasiou AE. Factors affecting the duration of orthodontic treatment: a systematic review. Eur J Orthod. 2008;30:386-95.
17. Gil APS, Haas OL Jr., Méndez-Manjón I, et al. Alveolar corticotomies for accelerated orthodontics: a systematic review. J Craniomaxillofac Surg. 2018;46:438-45.
18. Gantes B, Rathbun E, Anholm M. Effects on the periodontium following corticotomy-facilitated orthodontics. Case reports. J Periodontol. 1990;61:234-8.
19. Akay MC, Aras A, Günbay T, Akyalçin S, Koyuncue BO. Enhanced effect of combined treatment with corticotomy and skeletal anchorage in open bite correction. J Oral Maxillofac Surg. 2009;67:563-9.
20. 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.
21. Ahn HW, Lee DY, Park YG, et al. Accelerated decompensation of mandibular incisors in surgical skeletal class III patients by using augmented corticotomy: a preliminary study. Am J Orthod Dentofacial Orthop. 2012;142:199-206.
22. Coscia G, Coscia V, Peluso V, Addabbo F. Augmented corticotomy combined with accelerated orthodontic forces in class III orthognathic patients: morphologic aspects of the mandibular anterior ridge with cone-beam computed tomography. J Oral Maxillofac Surg. 2013;71:1760.e1-9.
23. Hernández-Alfaro F, Guijarro-Martínez R. Endoscopically assisted tunnel approach for minimally invasive corticotomies: a preliminary report. J Periodontol. 2012;83:574-80.
24. Ma ZG, Yang C, Xie QY, et al. A novel surgical technique for augmented corticotomy-assisted orthodontics: bone grafting with periosteum. J Oral Maxillofac Surg. 2016;74:170-80.
25. 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.
26. Aboul-Ela SM, El-Beialy AR, El-Sayed KM, et al. Miniscrew implant-supported maxillary canine retraction with and without corticotomy-facilitated orthodontics. Am J Orthod Dentofacial Orthop. 2011;139:252-9.
27. Shoreibah EA, Salama AE, Attia MS, Abu-Seida SM. Corticotomy-facilitated orthodontics in adults using a further modified technique. J Int Acad Periodontol. 2012;14:97-104.
28. 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.

Figure 26 A-L. *Treatment with the CCO System to coordinate arches and align teeth. Space for the implant in the 12 area nicely created. Arches were nicely decompensated in both anteroposterior and transverse dimensions.*

29. Wang B, Shen G, Fang B, Yu H, Wu Y. Augmented corticotomy-assisted presurgical orthodontics of class III malocclusions: a cephalometric and cone-beam computed tomography study. J Craniofac Surg. 2013;24:1886-90.
30. Bhattacharya P, Bhattacharya H, Anjum 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.
31. Pilon JJ, Kuijpers-Jagtman AM, Maltha JC. Magnitude of orthodontic forces and rate of bodily tooth movement. An experimental study. Am J Orthod Dentofacial Orthop. 1996;110:16-23.
32. Von Böhl M, Maltha J, Von den Hoff H, Kuijpers-Jagtman AM. Changes in the periodontal ligament after experimental tooth movement using high and low continuous forces in beagle dogs. Angle Orthod. 2004;74:16-25.
33. von Böhl M, Maltha JC, Von Den Hoff JW, Kuijpers-Jagtman AM. Focal hyalinization during experimental tooth movement in beagle dogs. Am J Orthod Dentofacial Orthop. 2004;125:615-23.
34. Verna C, Cattaneo PM, Dalstra M. Corticotomy affects both the modus and magnitude of orthodontic tooth movement. Eur J Orthod. 2018;40:107-12.
35. Glenn RW, Weimer AD, Wentz FM, Krejci RF. The effect of gingival fiberotomy on orthodontic cuspid retraction in cats. Angle Orthod. 1983;53:320-8.
36. Tuncay OC, Killiany DM. The effect of gingival fiberotomy on the rate of tooth movement. Am J Orthod. 1986;89:212-5.
37. Binderman I, Gadban N, Bahar H, Herman A, Yaffe A. Commentary on: periodontally accelerated osteogenic orthodontics (PAOO) - A clinical dilemma. Int Orthod. 2010;8:268-77.
38. Spena R, Caiazzo A, Gracco A, Siciliani G. The use of segmental corticotomy to enhance molar distalization. J Clin Orthod. 2007;41:693-9.
39. Spena R, Turatti G. Distalizaciòn molar superior y ortodoncia accelerada periodontalmente. Rev Esp Ortod. 2011;41:167-74.
40. Oliveira DD, de Oliveira BF, de Araújo Brito HH, de Souza MM, Medeiros PJ. Selective alveolar corticotomy to intrude overerupted molars. Am J Orthod Dentofacial Orthop. 2008;133:902-8.
41. Baloul SS, Gerstenfeld LC, Morgan EF, et al. Mechanism of action and morphologic changes in the alveolar bone in response to selective alveolar decortication-facilitated tooth movement. Am J Orthod Dentofacial Orthop. 2011;139:S83-101.
42. Sanjideh PA, Rossouw PE, Campbell PM, Opperman LA, Buschang PH. Tooth movements in foxhounds after one or two alveolar corticotomies. Eur J Orthod. 2010;32:106-13.
43. Fischer TJ. Orthodontic treatment acceleration with corticotomy-assisted exposure of palatally impacted canines. Angle Orthod. 2007;77:417-20.
44. Murphy KG, Wilcko MT, Wilcko WM, Ferguson DJ. Periodontal accelerated osteogenic orthodontics: a description of the surgical technique. J Oral Maxillofac Surg. 2009;67:2160-6.
45. Murphy NC. In vivo tissue engineering for the orthodontists: a modest first step. In: Davidovitch Z, Mah J, Suthanarak S, editors. Biological Mechanisms of Tooth Eruption, Resorption and Movement. Boston: Harvard Society for the Advancement of Orthodontics; 2006. p. 385-410.
46. Dibart S, Yee C, Surmenian J, et al. Tissue response during piezocision-assisted tooth movement: a histological study in rats. Eur J Orthod. 2014;36:457-64.
47. Keser EI, Dibart S. Sequential piezocision: a novel approach to accelerated orthodontic treatment. Am J Orthod Dentofacial Orthop. 2013;144:879-89.
48. Buschang PH, Campbell PM, Ruso S. Accelerating tooth movement with corticotomies: is it possible and desirable? Sem Orthod. 2012;18:286-94.
49. Yu H, Jiao F, Wang B, Shen SG. Piezoelectric decortication applied in periodontally accelerated osteogenic orthodontics. J Craniofac Surg. 2013;24:1750-2.
50. Horton JE, Tarpley TM Jr., Wood LD. The healing of surgical defects in alveolar bone produced with ultrasonic instrumentation, chisel, and rotary bur. Oral Surg Oral Med Oral Pathol. 1975;39:536-46.
51. Stübinger S, Kuttenberger J, Filippi A, Sader R, Zeilhofer HF. Intraoral piezosurgery: preliminary results of a new technique. J Oral Maxillofac Surg. 2005;63:1283-7.
52. Vercellotti T, Nevins ML, Kim DM, et al. Osseous response following resective therapy with piezosurgery. Int J Periodontics Restorative Dent. 2005;25:543-9.
53. Preti G, Martinasso G, Peirone B, et al. Cytokines and growth factors involved in the osseointegration of oral titanium implants positioned using piezoelectric bone surgery versus a drill technique: a pilot study in minipigs. J Periodontol. 2007;78:716-22.
54. Park YG, Kang SG, Kim SJ. Accelerated tooth movement by corticision as an aosseous orthodontic paradigm. Kinki Tokai Kyosei Shika Gakkai Gakujyutsu Takai Sokai. 2006;48:6.

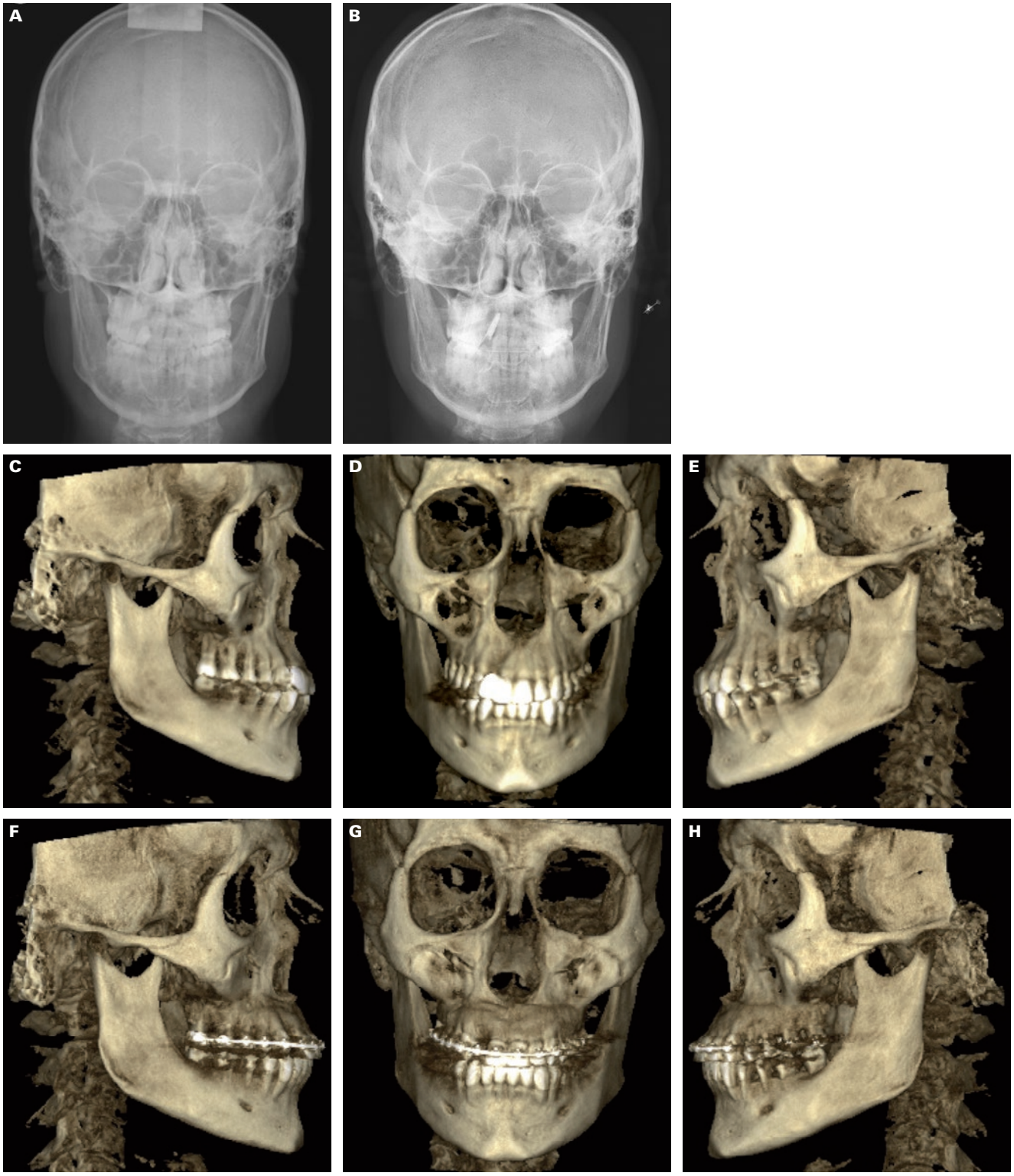


Figura 27 A-H. *Posteroanterior Cephalograms before and after treatment to show the transverse changes in both upper and lower arches. The CBCT images at the beginning of treatment and right before debonding show the amount of alveolar bone created in the upper arch with the alveolar corticotomy and the bone graft.*

Figure 28 A-C. *Patient 5 years after the end of treatment. Note the good stability.*

55. Kim SJ, Park YG, Kang SG. Effect of corticision on paradental remodeling in orthodontic tooth movement. Angle Orthod. 2009;79:284-91.
56. Dibart S, Sebaoun JD, Surmenian J. Piezocision: a minimally invasive, periodontally accelerated orthodontic tooth movement procedure. Compend Contin Educ Dent. 2009;30:342-4, 346, 348-50.
57. Patterson BM, Dalci O, Papadopoulou AK, et al. Effect of piezocision on root resorption associated with orthodontic force: a microcomputed tomography study. Am J Orthod Dentofacial Orthop. 2017;151:53-62.
58. Milano F, Dibart S, Montesani L, Guerra L. Computer-guided surgery using the piezocision technique. Int J Periodontics Restorative Dent. 2014;34:523-9.
59. Alikhani M, Raptis M, Zoldan B, et al. Effect of micro-osteoperforations on the rate of tooth movement. Am J Orthod Dentofac Orthop. 2013;144:639-48.
60. Teixeira CC, Khoo E, Tran J, et al. Cytokine expression and accelerated tooth movement. J Dent Res. 2010;89:1135-41. Wang I, Lee W, Lei DI, Liu YP, Yamashita DD, Yen SL. Tissue responses in corticotomy-and osteotomy-asssisted tooth movements in rats: histology and immunostaining. Am J Orthod Dentofac Orthop. 2009;136:770.e1-770.e11.
61. Nowzari H, Yorita FK, Chang HC. Periodontally accelerated osteogenic orthodontics combined with autogenous bone grafting. Compend Cont Edu Dent. 2008;29:200-6.
62. Gapski R, Parks CA, Wang HL. Acellular dermal matrix for mucogingival surgery: a meta-analysis. J Periodontol. 2005;76:1814-22.
63. Marx RE, Carlson ER, Eichstaedt RM, et al. Growth factor enhancement for bone grafts. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1998;85:638-46.
64. Dohan DM, Choukroun J, Diss A, et al. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part 1: technological concepts and evolution. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006;101:E37-44.
65. Choukroun J, Diss A, Simonpieri A, et al. Platelet-rich fibrin (PRF): a second-generation platelet concentrate. Part 4: clinical effects on tissue healing. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006;101:E56-60.
66. Anitua E. The use of plasma-rich growth factors (PRGF)in oral surgery. Pract Proced Aesthet Dent. 2001;13:487-93.
67. Anitua E, Sanchez M, Orive G, Andia I. Delivering growth factors for therapeutics. Trends Pharmacolog Sci. 2008;29:37-41.
68. Secchi AG. Complete Clinical Orthodontics. The Course Manual. DoctorOs, Ariesdue, March; 2012.
69. Spena R. Upper and lower incisor torque and the straight-wire appliance. Eur J Clin Orthod. 2014;1:21-32.
70. Wilcko W, Wilcko MT. Accelerating tooth movement: the case for corticotomy-induced orthodontics. Am J Orthod Dentofac Orthop. 2013;144:4-12.
71. Mattews DP, Kokich VG. Accelerating tooth movement: the case against corticotomy-induced orthodontics. Am J Orthod Dentofac Orthop. 2013;144: 5-13.