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Surgically-based methods to modify orthodontic tooth movement: A literature review

María Cadenas de Llano-Pérula, Alejandro Iglesias-Linares

ABSTRACT

Aim: Reducing treatment time in orthodontics is a matter of strong interest for clinicians and patients. Many procedures have been reported in literature in the last years intending to accelerate orthodontic tooth movement by modifying its biological substrate. Among them, surgical techniques are becoming increasingly popular. The aim of the present article is to review these surgical techniques, offering a clear idea of the scientific evidence available in literature and the possible implications of these techniques in the future. Methods: A literature search was performed in the databases MedLine and Scopus, including all article types focused on surgically-based methods to modify tooth movement in combination with orthodontic or orthopedic force. Results: Osteotomy, corticotomy and piezocision are the most representative of the so-called 'surgically facilitated orthodontic techniques (SFOTs)'. Corticotomy and piezocision share the same biological background (Regional acceleratory phenomena or RAP) while osteotomy is based on osteogenic distraction. A historical overview and a description of the techniques are included in the text. Conclusion: Although clinical results are promising, most of the articles concerning SFOTs are studies performed on animals or case reports. There is a need for evidence-based reports and standardized protocols in order to clarify the process behind tooth movement secondary to surgery, biologically speaking. Side effects of the surgeries and stability of the orthodontic treatment on mid to long-term are yet insufficiently reported.

Keywords: Corticotomy, Orthodontic tooth movement, Piezocision, (SFOTs) Surgically-facilitated orthodontic techniques

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INTRODUCTION

In orthodontics, duration of the treatment is a key point for both the patient and the professional. In the last years, a number of techniques have been published in scientific literature focused on biological acceleration of orthodontic tooth movement (OTM). Low-level laser therapy, pharmacological and surgical procedures or gene therapy [1–6] are some of these techniques. The procedures are varied, and in most of the cases, the molecular base lying underneath remains yet unclear.

In particular, surgical methods or SFOTs (surgically-facilitated orthodontic techniques) have recently achieved increasing interest. Corticotomy [1, 7, 8], osteotomy [9, 10] and piezocision [11, 12] have been the most frequently reported procedures and different processes, (regional acceleratory phenomenon (RAP) [13] or bone distraction [14]) have been suggested to be the base underlying the clinical acceleration of OTM observed. In this review, we will go through them, in order to draw a clear sketch of the 'state of the art' that could be useful for clinicians and researchers with an interest in this area. We will review as well the risks and benefits and possible implications of these techniques in the future.

MATERIALS AND METHODS

A literature review was performed on databases MedLine and Scopus. All article types in human or animals focused on surgically-based methods to modify tooth movement in combination with orthodontic/ orthopedic force were included. Classical articles were selected in order to add certain historical background.

The review was updated until February 2015. Articles were initially selected by two reviewers (M.C.LL. and A.I.L.), on the basis of the title and abstract, with the complete article being reviewed whenever there was doubt as to whether it should be included or not.

RESULTS

Corticotomy

Historical overview and description of the technique

Alveolar corticotomy is not exactly a new procedure. Already in 1898, Guilford [15], published the first reports in English language regarding this technique, and Köle [16] provided the first detailed description of the surgical intervention applied to increasing OTM. He suggested that cortical bone was responsible for slowing down orthodontic tooth movement, reason why, according to him, once breaking its continuity, OTM would be increased. With his technique, interdental cuts were made, together with a horizontal cut above the apex, although in the upper maxilla, the procedure resembled more an osteotomy, sometimes even reaching Schneider's sinus membrane. However, on the lower arch, this horizontal incision was not so deep and more corticotomy-like, in order to avoid damaging the surrounding nervous structures. According to Köle, [16] if the bone marrow remained intact, periodontal damage was prevented, and pulpal vitality was kept, also avoiding root resorption, because there were 'bone units' moving instead of the teeth. Once the surgical technique was finished, orthodontic appliances were placed, and the treatment was completed in 12 weeks, using 6–12 months retention devices only, because of the 'extra support' that bone healing would add to the teeth. Nevertheless, Köle's technique required such an extensive surgery that it was not well accepted at the time.

Bell and Levy [17] used Rhesus Monkeys in order to check if the vascularization was interrupted with Köle's technique, finding that in central incisors particularly, after some weeks, ischemia and change in coloring happened. As an explanation, they argued that because of the closer roots and denser, less spongy bone on that area, after the incisions were made, blood supply to the apex was interrupted. However, Köle's technique was not strictly performed; all cuts were corticotomy-like together with a bone distractor appliance, and it was the movement of the sectors that stopped normal blood circulation.

Later, in 1975, Duker [18] investigated the effects of corticotomy over periodontal and pulpal tissue. In general, he followed Köle's technique, with one difference only: interdental cuts were at least 2 mm away from the alveolar crease, because that would avoid nervous and soft tissue damage, a fact that was proven afterwards by his results. From the 70s until the 90s, Besides Mossaz [19], several authors continued performing and developing this technique, making it easier for daily practice and immediately using high forces in order to clear out the impact over periodontal tissues, not finding it in any case. According to Kerdvongbundit [20], this could be due to the short treatment time. However, the histological processes responsible for tooth movement were still unknown. In 1998 Liou and Huang [21], changed the original technique performing, instead of deeper cuts, perforations or lines on the bone. This ended up being equally effective, plus enormously simplifying the surgery.

In 2001, Thomas and William Wilcko [7] patented their technique '*Accelerated Osteogenic Orthodontics*'. The main difference with the previous techniques was the addition of synthetic bone graft on the alveolar region. Their technique consisted on the performance of a full thickness flap, perforations or longitudinal incisions on the cortical bone and addition of bone grafting composed by deproteinized bovine bone, autogenous bone, decalcified freeze-dried bone allograft, or a combination of the three of them [7, 22]. This bone graft aimed to avoid height loss on the bone crease, protecting the periodontal tissues (gingival recessions, inadequate adherence of the soft tissue to the bone, etc.) and inducing bone formation, a fact proved by them through CT scan.

The CT scans were repeated even two years after the ending of the treatment (that can be solved between four and six months according to their reports) and they showed the existence of remineralized bone tissue in different levels (more remineralization in younger patients) surrounding the dental roots, which proved that

OTM was not due to the movement of segmented bone. On the contrary, they argued that the small perforations on the cortical bone performed in corticotomy trigger an inflammatory response, raising the activity of several cytokines and therefore accelerating tooth movement [7]. This effect can be explained through the Regional Acceleratory Phenomena or RAP named by Frost [13] in 1983 in which demineralization of the bone surrounding the dental roots would occur for a short time, while OTM can be enhanced, right before remineralization happens again. Frost claimed it to be an 'alarm system', designed in order to boost local bone healing as a response from the tissues to external aggression. Once tissue damage has happened, it widely triggers processes such as bone cell renovation and remodeling in the areas surrounding the trauma.

Shih and Norrdin [23] studied in animal model the healing of bone defects, inflicting surgical wounds in long bones to observe the remodeling process happening in the bone afterwards. This way, they managed to prove that RAP enhances tissue reorganization around that wound and it increases healing through temporary formation of mineralized and non-mineralized tissue after cortical damage. Bolander [24] on the other hand, argued that RAP starts right after bone damage and is influenced by mechanical, genetic, immunological and hormonal factors, whose specific behavior is still unknown, although it is considered a fact that bone goes through several healing steps until its complete calcification. This study suggested low levels of calcium and reduced bone density during RAP as conditions that may lie under OTM enhancement generated after corticotomy.

Most of the literature regarding corticotomy (or corticision as it has also been named) is based on case reports [22] and very few has been published about the cellular basis behind the procedure. The papers published by Wang [25] and Lee [26] support the theory that corticotomy behaves as proposed by Frost: it is a local response where inflammation created by trauma leads to transient bone demineralization that increases cytokines and ease OTM. As most local inflammatory processes it is transitory, and accelerated tooth movement decreases. Three phases of bone healing have been observed in rats [25]: resorptive phase at third day, replacement phase at day-21, and mineralization phase at day-60. Therefore, between days 20 and 30, another surgery needs to be done if the desired amount of tooth movement has not been achieved. However, Sanjideh [27] performed a second surgery after 28 days in foxhounds, finding no relevant differences.

Rate of OTM acceleration

Most of the studies using corticotomy have been performed in animal model, mainly rats and dogs. Iino [28] in 2007, Mostafa [29] in 2009, Sanjideh [27] Texeira [30] in 2010 and Baloul [31] in 2011 studied corticotomy results over OTM with experiments in dogs and rats respectively, and although force ranges were different (200–50 g) they show similar data: OTM double increases when it's corticotomy-assisted. Iglesias-Linares et al [32] reported a 21,63% increase in OTM with corticotomy in rats and a 1.64% increase when comparing it with Bone Morphogenetic Protein-2 (BMP-2), but showed not significantly relevant results when combining both techniques.

In human, we can mainly find case reports. In the ones from Wilcko et al. [7, 22], three to four times more OTM is reported. Fischer [8] and Aboul-Ela [1] published RCTs in human in 2007 and 2011 respectively. The first author found in six patients with bilaterally impacted canines that the use of corticotomy diminished treatment time in a 28–33%. Aboul-Ela [1] in 2011 found a double OTM rate when using corticotomy to bilaterally retract canines in 13 patients. More recently, a tendency has been observed on diminishing the surgical interventions, and studies such as the randomized clinical trial performed in 2013 by Alikhani [2], report a 2.3-fold more OTM after micro-osteoperforations made on the cortical bone without the need of a previous flap.

Piezocision

Historical overview and description of the technique

Piezocision is a minimally-invasive surgical technique designed to accelerate orthodontic tooth movement (OTM) in combination with orthodontic therapy [12]. With corticotomy, flaps are performed with two entry points, palatal and buccal, ending up in bigger aggression. Piezocision is made without the need of a flap and perforations on the cortical bone are performed with a piezoelectric knife instead of a bur [11, 12]. The vibrations of the piezotome are also claimed to contribute to a faster movement. Because of this, it represents a less aggressive surgical approach than corticotomy, although the molecular bases underneath have been suggested similar: both procedures have been described to be based on RAP. Histologically speaking, some authors [11, 12] found that after two weeks the process of demineralization is mostly completed while with corticotomy, after that period, there is still presence of transient bone.

Corticotomy has been well documented in literature with wide animal experimentation (rats and dogs mostly) [27–33] and several clinical trials in human [1, 2, 8]. Piezocision on the other hand, has been reported once in rats [34] and dogs [35] and there are only case reports available so far [36–41]. There is an obvious lack of clinical trials in human strictly using piezocision in combination with orthodontics.

Rate of OTM acceleration

Kim YS et al. [35] reported 3.26 and 2.45-fold more OTM in the maxilla and mandible of dogs, respectively, when treated with piezocision, or cortical perforations through the soft tissues, no need of a flap either. Dibart et al. [34] reported in 2014 more than two-fold TM increase with piezocision in rats (0.6 mm after 28 days compared to 0.25 mm without piezocision). In some case reports available in human [11, 36, 38], cases with moderate to light crowding are reported to be solved in 5 to 6 months. Again, these are not RCTs, reason why results need to be taken cautiously.

Osteotomy

Historical overview and description of the technique

Osteotomy, differently than corticotomy and piezocision, is based on osteogenic distraction, where a bone segment is completely separated, leading to callus formation. This technique involves the complete resection of the cortical bone leaving 0.5–1 mm of the alveolar bone adjacent to the teeth to move, using a bone distractor device screwed on both sides to the bone.

Osteotomy was first described in literature by Codivilla [42] in 1905 and was thoroughly developed afterwards by Ilizarov [43] in 1988. As an OTM accelerator, this technique was first proposed by Liou et al. [9] in 2000. According to them, tooth movement could be easier when done through fibrous new bone created by distraction.

A similar report was made by Hässler [44] in 1999, comparing canine retraction right after extraction of the premolar with retraction on healed side. He found a significant increase when canines were retracted on recent extraction alveolus. This could also be caused by the fibres of recently created bone, and the undesired inclination suffered by the canines could be a combination between the low calcification of the new bone and the orthodontic technique used. (Gjessing canine retraction spring activated to create 100 g force). No histological records were shown. According to Liou [9], a latency period of seven days is needed, and after that, it can be activated 1 mm a day. In the studies consulted [10, 14, 45] activation was done on patients immediately, 2 and 3 days after device placement respectively, with 0.5 and 0.8 mm/day.

Long-term effects of bone distraction are yet unknown, and in the studies consulted, certain side effects which need to be further researched are described, such as extrusion of the molar, anchorage loss, mesial tip of the canine crown. The resistance of interseptal bone and the existence of bony interferences at the apical region of the socket that can be encountered during tooth movement have been proposed as reasons for this tipping. The differences between time treatment between the studies can be explained by variations in the surgical technique or the rigidity or the retractors. Although no pulpal damage has been described, as the tooth tips forward when moving, the entering of blood vessels to the apex can be stretched, causing pulp alterations that need long-term following.

Lee [26] in 2008 compared both corticotomy and osteotomy techniques by using a 100 g Niti spring combined with corticotomy and osteotomy, finding this last one as faster but with no statistically relevant differences between groups. He clearly stated by serial microCTs that both procedures where based in two different phenomena, such as RAP and distraction. Those findings where confirmed by Wang [25] in 2009 in a similar experiment: corticotomy produced bone resorption around the dental roots under tension that was replaced by fibrous tissue after 21 days and by bone after 60 days, while osteotomy, on the other hand, resembled distraction osteogenesis and did not pass through a stage of regional bone resorption.

Rate of OTM acceleration

Liou et al. [9] found four times more OTM when it was started after distraction than when done simultaneously. Iseri, Kumar and Kharkhar [10, 14, 45] performed bone distractions to enhance canine retraction in extraction cases in humans, with 10, 8 and 6 patients each. Iseri [10] stated that movement was 50% faster than in the control side, with a full canine retraction in 8–14 days. Kumar [14] completed retraction in 20 days and Kharkhar [45] in 12 days. Neither of them describes pulp vitality loss, gingival damage or root resorption.

DISCUSSION

In the last decades, many different techniques have emerged in literature with the same objective: accelerating OTM and therefore reducing treatment time in orthodontics. However, as we saw before, very few can be actually stated about biologically modified OTM. Most of the reports cannot be compared because of the big differences in techniques, animal models, absence of force range consensus, control over the appliances, etc. Among those investigations made in humans, there is also a general lack of randomized clinical trials and no blinding measures are being used in general terms. In addition, the small sample size commonly used in the studies should make us take the results cautiously.

Surgery methods, particularly corticotomy, seem to be popular in recent literature and it is become widely accepted that surgical aggression to the bone speeds up tooth movement [8, 27]. In general, acceleratory effects are observed to be substantially different because of the absence of standardization in this research field about this type of experiment. For example, the rate of OTM acceleration using a surgical technique has been reported to oscillate between a 16% increase [46] to more than 100% [1].

The biological explanation for the tooth movement acceleration observed in most studies was associated with an increased number of osteoclasts and bone resorption [47, 48]. In this respect, surgically-based modulatory mechanisms are related to the regional acceleratory phenomenon (RAP) [13] or to an increase in catabolic/ anabolic activity on bone [49, 50].

At the same time, there is no consensus whatsoever regarding the magnitude or type of force. Although closed coil springs (Niti or Sentalloy) seem to be the most popular devices, other appliances like bone distractors are also used. The magnitude of the force varies dramatically from one study to the other and there is little attention to the direction of the force; sometimes its executed mesially and some others distally. It ranges from 60 g [8] to 150 g [1] in humans and from 400 g [29] to 50 g [28] in other animals like dogs.

Despite the differences in procedures, magnitude of force and taking into account that animal and human model are mixed, based on the studies consulted and included in this review, corticotomy has been claimed to increase tooth movement on a range between 30 and 50% [28, 30]. A tendency on simplifying the surgical interventions can be observed [2] and the appearance of techniques such as piezocision confirms the interest of the orthodontic community on easier procedures.

Even with the efforts in making these techniques simpler, we must not forget that every surgical procedure implies certain side effects and hazards. Results are technique sensitive, and in bigger surgeries such as osteotomy, an exhaustive evaluation of the real benefit for the patient must be previously done.

Another controversial point is the real biological base of the OTM acceleration observed clinically. In a recent 2013 review, Wilcko and Wilcko [51] stated that corticotomy produces an aggression to the bone that induces exaggerate local inflammatory response, increasing the presence of cells to facilitate healing. These authors defend that OTM happens during this process, first, due to the demineralization of the bone surrounding the teeth and second, because of changes in the PDL, being the demineralization/remineralization processes able to be seen in surface CT scan [52].

However, proof of demineralization has only been found in animal studies, more concretely in rats [53], while dogs have not shown evidence of that process, [27] reason why we cannot safely state that it happens in humans. Mathews and Kokich [54], in their 2013 counterpoint review about corticotomy, wonder if surface CT scan has sufficient resolution to denote this mineralization differences in bone.

It has also been reported that on initial stages of OTM, due to compressive forces, hyalinization of the PDL takes place, and as long as it is present, OTM is not able to begin [55]. Histologically, it has been seen that this hyalinization is generally removed in four weeks, [28] but inflammation triggered by corticotomy accelerate the presence of macrophages that remove the hyaline in approximately 1 week. Because of this, there is earlier bone resorption that results in faster OTM.

Nevertheless, studies show that fast OTM induced by corticotomy peaks around days 22 to 25, [1] moving than twice as fast as controls, and then it decelerates, coming back to normal OTM rates. According to Mathews and Kokich, [54]. RAP can last until 4 months, and it is only for this period of time that we will find faster OTM induced by corticotomy. Besides, there is no evidence in literature that bone grafting would improve stability of the orthodontic results, because there is a lack of long-term studies that would compare the retention outcome with or without bone grafting secondary to corticotomy.

It is difficult to generalize surgery into general orthodontic practice, as there is an important group of patients which may not be eligible for it. Age, or existence of base pathology, could be factors excluding them, and as a matter of fact, in most of the articles where corticotomy was used, inclusion and exclusion factors were set for the individuals finally accepted in the studies [2, 14]. Younger age groups (18-30 years old) with good quality of bone are preferred, and long-term effects of interdental/ periodontal ligament distraction are unknown [10, 44].

As advancements in Biomolecular sciences have reached our field, we can also find in literature other techniques that could constitute an alternative for corticotomy [33, 56]. Articles proposing the use of gene-based techniques or stem cells are becoming increasingly numerous [6, 57, 58]. Now, it is up to the orthodontic community to decide if these techniques are suitable for their application to orthodontics and whether or not they have advantages over pre-existing techniques such as corticotomy. For accurately doing that, knowledge over the molecular signalling pathways and the map of genes implied on the process of physiological tooth movement should be sufficiently clarified.

CONCLUSION

Surgical techniques, particularly corticotomy, are an increasingly popular method to accelerate orthodontic tooth movement (OTM). It is generally considered in literature that they enhance tooth movement by an average of two-fold. However, there is still a lack of randomized clinical trials, as most of the published articles are animal studies or case reports. Range of force, design of the appliances or times of study are too varied to establish fair comparisons between them. Scientific innovation in this field needs to standardize the procedures used, in order to optimize the efficiency in the advancements obtained. Methods based on higher scientific consistency need to generalize their designs to be able to compare the results. Although a tendency can be observed on making the surgeries less aggressive, the risks and benefits must be evaluated when it comes to speed up OTM, such as the decay on the rate of acceleration after four months.

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Author Contributions

Maria Cadenas de LLano-Perula – Substantial contributions to conception and design, Acquisition of data, Analysis and interpretation of data, Drafting the article, Revising it critically for important intellectual content, Final approval of the version to be published
Alejandro Iglesias-Linares – Substantial contributions to conception and design, Acquisition of data, Analysis and interpretation of data, Drafting the article, Revising it critically for important intellectual content, Final approval of the version to be published

Guarantor

The corresponding author is the guarantor of submission.

Conflict of Interest

Authors declare no conflict of interest.

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