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Review Article

Update on surgical approach in accelerating orthodontic tooth movement: A concise review

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Abstract

The orthodontic treatment is a time-consuming procedure. Fixed orthodontic treatment usually takes 2-3 years, with several regular follow up appointments, depending on various factors such as severity of the malocclusion, treatment planning, and patient compliance. The prolong treatment could increase more complications such as caries and root resorptions. A patient burnout also could happen because of this long term exhausted procedure. Thus, to be able to shorten the orthodontic treatment duration will be highly desirable for both patients and orthodontists. Up to now, several treatment modalities have been reported to accelerate orthodontic tooth movement including biomechanical, biological, physical/mechanical, and surgical approaches. This review describes current surgical procedures used for accelerating orthodontic tooth movement. The regional acceleratory phenomenon (RAP) phenomenon, surgical techniques including dental distraction, corticotomy/osteotomy-assisted orthodontic tooth movement, piezocision, and micro-osteoperforation are summarized and discussed.

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Keywords: RAP, dental distraction, corticotomy, piezocision, micro-osteoperforation

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Introduction

One of the unfortunate downsides of orthodontics is lengthy treatment time. The treatment normally takes 2-3 years depending on several factors such as case severity, treatment plan, and patient compliance (Fisher, et al., 2010). With this time-consuming treatment, many complications, including root resorption, dental caries and periodontal diseases (Geiger, et al.,1992, Pandis, et al.,2008) can be problematic and patients may even decline the treatment. The method to shorten the treatment duration is highly desirable as it not only reduces the possibility of the side effects mentioned above but it also offers convenience and aesthetics to the patients(Yi, et al., 2017a).

To date, various methods have been suggested to accelerate orthodontic tooth movement such as less friction brackets, low-intensity laser irradiation and pharmacological approach. However, the surgical methods have been reported to be the most clinically applied and the most examined with the potentially significantly decreasing treatment time (Nimeri, et al., 2013). The acceleratory effect of corticotomies was attributed to the altered physiologic response called regional accelerated phenomena (RAP) (Wilcko, et al., 2001).

The term "regional acceleratory phenomenon (RAP)" was suggested by Frost *as "It is a complex reaction of mammalian tissues to diverse noxious stimuli. The phenomenon occurs regionally in the anatomical sense, involves both soft and hard tissues, and is characterised by an acceleration and domination of most ongoing normal vital tissue processes. It may represent an "SOS" mechanism which evolved to potentiate tissue healing and local tissue defensive reactions. When a RAP is obtunded, retarded healing and lowered resistance to infection and mechanical abuse may ensue." (Frost, 1983).* According to Frost, any regional noxious stimulus (e.g. fracture, burns, infections, and even bone operations) of sufficient magnitude seems to evoke a RAP in a normal body, the size and intensity of which varies directly with the magnitude of the stimulus. Once evoked by the stimulus, many ongoing regional soft and hard tissue vital processes, including for example perfusion, growth of skin and bone, turnover of bone and connective tissue, soft tissue and bone healing, and cellular metabolism, accelerate above normal values. It is these accelerated processes which collectively form the RAP (Frost, 1981, Frost, 1983, Frost, 1989). In a healthy human the RAP following a single stimulus such as a fracture would typically last 4 months, compared to 6 months to 2 years following a stimulus such as a severe burn (Frost, 1989).

The corticotomy has been reported to be effective in accelerating tooth movement, however, it is a high morbidity and invasive procedure. It requires full mucoperiosteal flap and the post-operative adverse effects such as pain and swelling can occur. This might have been the reason why it is not widespread acceptance among orthodontists and patients (Dibart, et al., 2009). Therefore, more conservative flapless corticotomy techniques have been proposed recently, such as piezocision and micro-osteoperforations.

This review focuses on updated information, expected outcomes and potential complications of the current surgical procedures include intraseptal alveolar surgery or distraction osteogenesis, corticotomy or osteotomy-assisted orthodontic tooth movement, piezocision and micro-osteoperforations. The clinical considerations and benefits of these recent surgical methods are also summarized and discussed.

Surgical methods

a. Dental distraction:

Distraction osteogenesis is a process of growing new bone by mechanical stretching of the pre-existing bone tissue. The most common technique is mechanical stretching of the reparative bone tissue by a distraction device through an osteotomy or corticotomy site

(Ilizarov, et al.,1969, McCarthy, et al., 1992, Polley and Figueroa,1997, Snyder, et al.,1973). With this technique, new bone is generated in the gap of osteotomy or corticotomy at the approximate rate of 1 mm per day. Another well-known modality of distraction osteogenesis is through a suture, such as in rapid palatal expansion where the hard palate is distracted transversely through the mid-palatal suture 1 mm per day (Liou and Huang, 1998b).

The concept of dental distraction was coined by Liou and Huang (1998b), who introduced this procedure to demonstrate rapid canine retraction through distraction of the PDL. The premise of this technique is based on the concept that orthodontic force induces a resorptive pressure side and an appositional tension side within the PDL (Reitan, 1964). On the tension side the PDL is stretched (distracted) followed by alveolar bone deposition (osteogenesis), thus the PDL acts a "suture" between alveolar bone and tooth (Bilodeau, 2005). The process of osteogenesis in the periodontal ligament during orthodontic tooth movement is similar to that in the midpalatal suture during rapid palatal expansion (Liou and Huang, 1998b).

The procedure was performed on patients requiring premolar extraction and canine retraction. At the time of premolar extraction, the interseptal bone distal to the canine was undermined with a bone bur, grooving vertically inside the extraction socket along the buccal and lingual sides and extending obliquely toward the socket base. A tooth-borne, custom made, intraoral distraction device was then placed and activated 0.5-1.0 mm/day immediately after extraction to distract the canine distally into the extraction space (Liou and Huang, 1998b). Liou and Huang found the canines were distracted 6.5 mm within 3 weeks, with minimal movement of the anchorage teeth (due to hyalinisation which takes 2-3 weeks to be removed), minimal root resorption (resorption is initiated 2-3 weeks after force application), and no periodontal or endodontic complications.

The canine can be distracted so quickly because orthodontic tooth movement is faster and root surface resorption is less in alveolar bone with loose bone trabeculae and less bone resistance (Ashcraft, et al., 1992, Collins and Sinclair, 1988, Goldie and King, 1984, Midgett, et al., 1981). The canine was distracted into an extraction socket that had not been refilled by solid bone tissue. After extraction, regenerative bone tissue will refill the socket in 3 weeks and become resistant and solid in 3 months. If the canine is not retracted within the first 3 weeks, the rate of tooth movement will slow down, root surface resorption will increase, and the anchor unit will start to move forward (Liou and Huang, 1998b).

This surgical technique found to accelerate tooth movement with no evidence of significant root resorption, ankylosis, and root fracture in all studies (Hoogeveen, et al., 2014, Iseri, et al., 2005, Liou and Huang, 1998a, Sukurica, et al., 2007). However, regarding for the electrical vitality test of the retracted canines, Liou reported 9 out of 26 teeth had positive vitality response, while Sukurica et al., (2007) reported that 7 out of 20 showed positive vitality after retraction for sixth months. Thus, there are still some variable results regarding this technique found in this aspect (Hoogeveen, et al., 2014).

b. Corticotomy/Osteotomy-assisted orthodontic tooth movement:

Osteotomy or corticotomy have been combined with tooth movement to facilitate difficult tooth movement, reshape the alveolar arch, and accelerate tooth movement (Iseri, et al., 2005, Sukurica, et al., 2007, Wilcko, et al., 2001, Yen, et al., 2001, Yen, et al., 2005). An osteotomy can free a bony segment to be distracted with tooth-borne distracters or aligned with orthodontic wires and springs (Lee, et al., 2008).

Corticotomy started in orthopaedics in the early 1900s (Hassan, et al., 2010). It was first defined as a linear cutting technique in the cortical plates surrounding the teeth to produce mobilization of the teeth for immediate movement (Fitzpatrick, 1980). Köle (1959) introduced a surgical procedure involving both osteotomy and corticotomy to accelerate orthodontic tooth movement based on the concept that teeth move faster when the resistance exerted by the surrounding cortical bone is reduced via a surgical procedure (Hassan, et al., 2010). Disrupting the continuity of this cortical layer reduces the bony resistance and enhances an en bloc movement of the entire alveolar cortical segment (including the confined teeth) which is connected by softer medullary bone (Kole, 1959, Lee, et al., 2008).

The conventional corticotomy procedure started with the full thickness flap elevation then the blocks of bone were outlined using vertical interradicular corticotomy cuts both facially and lingually and these were joined 10 mm supra-apically with an osteotomy cut through the entire thickness of the alveolus. The graft material then can also be placed after wherever needed to augment the thickness of the bone. Köle reported that the major active tooth movements were accomplished in 6 to 12 weeks (Kole, 1959).

In 1991 Suya reported an improved surgical procedure that he referred to as "corticotomy-facilitated orthodontics." This technique differed from Köle's with the substitution of a supra-apical horizontal corticotomy cut in place of the horizontal osteotomy cut beyond the apices of the teeth. Most cases were completed in less than 12 months, some completed in 6 months (Suya, 1991).

Lee and co-workers in their animal study found the bony response was dependent upon the type of surgical intervention. For example, if a corticotomy was used, then RAP resulted, but if an osteotomy was used, then either normal fracture healing or distraction osteogenesis occurred, depending on whether tooth movement was added to provide a distraction force to the bony segment (Lee, et al., 2008).

Recently, the Drs Wilcko developed a patented technique called Accelerated Osteogenic Orthodontics (AOO) (Wilcko, et al., 2001) or Periodontally Accelerated Osteogenic Orthodontics (PAOO) (Wilcko, et al., 2008) which is similar to conventional corticotomy except that selective de-cortication in the form of lines and points is performed over all of the teeth that are to be moved (Ferguson, et al., 2006, Ferguson, et al., 2001, Hassan, et al., 2010). A resorbable bone graft is placed over the surgical sites to augment the confining bone during tooth movement, and after a healing period of one or two weeks, orthodontic tooth movement is started. A faster rate of activation, of two week intervals, is used (Wilcko, et al., 2008, Wilcko, et al., 2001). Using this technique, Wilcko and co-workers (Ferguson, et al., 2006, Wilcko, et al., 2008, Wilcko, et al., 2003, Wilcko, et al., 2001) reported rapid tooth movement at a rate of 3 to 4 times greater than conventional orthodontic movement. They attributed this rapid movement to a state of reduced mineralization (reversible osteopenia) of the alveolar bone surrounding the involved teeth during the orthodontic movement and not to bony block movement, as claimed by Köle (Wilcko, et al., 2008, Wilcko, et al., 2003, Wilcko, et al., 2001). The concept of reversible osteopenia was explained by Wilcko and colleagues in a study using computed tomographic imaging (Wilcko, et al., 2003). After corticotomy, demineralization of the alveolar bone occurs and the remaining collagenous matrix of the bone is transported with the tooth during its movement. Remineralisation then occurs following tooth movement (Hassan, et al., 2010).

Corticotomy has been shown from many studies to accelerate the tooth movement, however this procedure also has disadvantages such as it is high morbidity and invasive procedure, the adjacent vital structures can be damaged, post-operative adverse

effects (pain, swelling, chance of infection, avascular necrosis) and the patient's acceptance is low (Dibart, et al., 2009).

c. Piezocision

In 2009 Dibart et al introduced Piezocision, a flapless method of corticotomy using piezosurgery, to reduce the morbidity from the conventional corticotomy. The procedure is performed 1 week after orthodontic appliances placement under local anaesthesia. The vertical gingival incisions are made on the buccal side only in the attached gingiva and cut through contact a cortical bone. Then use the piezoelectric knife to perform the corticotomy cuts in the depth of 3 mm. The tunnelling is performed using the elevator insert between the incisions in the area where bone augmentation is required to create sufficient space for the graft material. There is no need for suturing unless in the area that need to hold the graft material. This initiates RAP and accelerate the tooth movement. It is important to pay attention to perform the incisions only around the teeth that want to be moved so the anchorage value of the other teeth is still high while the anchorage value of the teeth adjacent to the incisions is low. It is also critical to see patient and perform orthodontic adjustment every 2 weeks (Dibart, et al., 2009). The piezocision procedure is reported to be a less invasive and has better acceptance from patients. However, there is risk of root damage from incisions and cortocotomies as they are blindly done (Shenava, et al., 2014).

Mehr et al (2013), a randomized controlled clinical trial, found that the piezocision had 1.6 time faster correction in only the first 4-5 weeks compared to the conventional group then the acceleration declined resulted in no significant difference in the total time to correct the mandibular crowding between the piezocision and the conventional group. On the other hand, the piezocision was reported to reduce to overall treatment time by 43% compared with the control group in the randomized controlled trial study by Charavet et al. (2016).

A systematic review of the efficacy of Piezocision by Yi et al. in 2017 found a weak evidence to support that piezocision could accelerate orthodontic tooth movement without adverse effects on periodontal tissue and pain perceptions at least in the short-term duration. The authors suggested to have more information from high-quality RCTs assessing long-term effects and optimal protocol of piezocision before recommendation to use definitively in orthodontic clinical practise (Yi, et al., 2017b).

d. Micro-Osteoperforation (MOP)

A device called Propel was introduced by Propel Orthodontics to lessen the invasive nature of surgical irritation of bone. This is a ready-to-use sterile disposable device with an adjustable depth dial and an indicating arrow on the driver body. The tip depth can be adjusted to 0, 3, 5, and 7 mm depend on the area of the operation.

Alikhani et al. came with a hypothesis that controlled micro-trauma in the form of micro-osteoperforations (MOPs) will amplify the expression of inflammatory markers that are normally expressed during orthodontic treatment and this amplified response will accelerate both bone resorption and tooth movement. They tested their hypothesis in animal models and found that in adult rats, MOPs treatment increased molar protraction rate significantly accompanied by the increase in inflammatory cytokine expression, osteoclastogenesis, and alveolar bone remodeling (Teixeira, et al., 2010). Later, Alikhani et al. (2013) performed a human clinical trial to test their hypothesis. They performed a first single blinded study to investigate the MOPs on humans. Maxillary first premolar was extracted then used Ni-Ti closed coil spring, which attached to canine with power arm and connected to a temporary anchorage device (TAD) placed distal

to second premolar, to distalize the canine into the extraction space using a constant force of 100 g. The gingival crevicular fluid (GCF) then were collected from the distobuccal crevices of the maxillary canine of each subject to evaluate the level of inflammatory response. GCF was collected before orthodontic treatment, immediately before canine retraction, and at each following appointment between 10 AM and 12 noon. Cytokine levels (CCL-2 (MCP1), CCL-3, CCL-5(RANTES), IL-8 (CXCL8), IL-1a, IL-1b, IL-6, and TNF-a) were then measured using custom protein array. To assess rate of tooth movement, the authors used digital caliper measured the distance between the canine and the lateral incisors from the study casts (the alginate impressions were taken at the beginning of the study, immediately before canine retraction, and 28 days after canine retraction started and then poured with plaster). They found MOPs increased the rate of canine retraction significantly by 2.3-time compared with the control group together with a significantly increased of the inflammatory markers. Patients reported only mild discomfort locally at the time of the MOPs was done. At days 14 and 28, little or no pain was experienced and there was no additional pain medications or additional care required. They concluded that MOPs are an effective, comfortable, and safe procedure to accelerate tooth movement during orthodontic treatment and it could reduce orthodontic treatment time by 62%. For the clinical application, they suggested to repeat the procedure every other month since the increase in cytokine activity decreases after 2 months of MOPs (Alikhani, et al., 2015). From the result acquired from both animal and human studies, the authors concluded that "MOPs can be incorporated into routine orthodontic mechanics and at different stages of treatment, facilitating alignment and root movement, reducing the possibility of root resorption, stimulating bone remodeling in areas of deficient alveolar bone, and reducing the stress on anchor units. Therefore, MOPs offers a practical, minimally invasive and safe procedure that can be repeated as needed to maximize the biological response to orthodontic forces" (Alikhani, et al., 2015).

The study by Alikhani et al was the first study to investigate the MOP method, however some certain points, for example, root resorption, the amount of perforations needed and long-term effect were not addressed in the study (Shenava, et al., 2014).

The summary of the results of each surgical technique is shown in Table 1.

Discussion

The systematic review and meta-analysis in 2016 by Alfawal et al (2016) was performed to assess the effectiveness of minimally invasive surgical procedure in the acceleration of tooth movement. Four studies and nine ongoing studies had met the criteria and were included in this review. There were both extraction (were performed in 3 studies) and non-extraction treatments (was performed in only 1 study) and the surgical procedure in the studies included piezocision, micro-osteoperforation and interseptal bone reduction. They reported that the surgical procedure had a higher rate of tooth movement in the first two months (a weight mean difference of 0.65 mm for 1 month and 1.41 mm for 2 months of canine retraction) compared to the conventional treatment. There were no serious adverse effects found after the procedures however there was still no scientific evidence to confirm whether there had post-operative infection, bleeding, swelling, root resorption, loss of tooth vitality and possible morbidity or not. Since there haven't have enough concrete scientific evidence to support the claim, the evidence was limited and low-quality, therefore the authors concluded that these minimally invasive surgical procedures currently still cannot be recommended to use in routine clinical practise even though it significantly speed up the canine retraction rate in the first 2 months and further study in this field should be performed.

Another systematic review by Braydon et al. (2016) also found significantly temporary increase in rate of tooth movement compared to control group in all corticotomy techniques assessed. The acceleration of tooth movement seemed to last only short-term, and the rate of tooth movement decreased close to baseline after a few months. The procedures seemed not to increase risk of adverse effects on the periodontal tissue, root resorption, and tooth vitality compared to conventional orthodontic treatment. They found that the quality of evidence to support this claim was low due to the presence of multiple methodologic issues, high risk of bias, and heterogeneity in the articles. It was also impossible to decide which corticotomy techniquewas more desirable than another. The authors suggested to have additional high-quality randomized clinical trials before making a definitive conclusion.

Same finding also reported from a recent systematic review by Yi et al. in 2017. Finding from the review supported the effectiveness and safety of corticotomy in increasing the rate of tooth movement. However, they found that "the evidence quality was rated as low and very low and was downgraded for an unclear risk of bias, inconsistency and imprecision". Highly significant difference found in primary studies including tooth movement types (space closure, canine retraction, and alignment) and surgical technique procedures (traditional corticotomy, interseptal bone reduction, and micro-osteoperforations). The authors recommended to interpret the present evidences with caution due to the limit number of studies and high degree of heterogeneity. The further prospective clinical trials addressing on the differences between the corticotomy procedures with longer follow-up duration were also suggested to verify this conclusion (Yi, et al., 2017a).

At the present, there is still a conflict finding whether the surgical approach has truly accelerate orthodontic tooth movement and hence reduce the orthodontic treatment time. This is because we still lack of a high-quality evidence. Most of the previous evidences found to be in a low-quality level due the lack of a control group, large attrition of the sample, unclear diagnosis and end points or poorly defined patient material. The further studies with a well-designed set up, such as prospective clinical trials focusing on the differences among the surgical procedures with a long-term follow up, having an appropriate sample size, clearly identified clinical indications and treatment plans, are still needed to draw a valid conclusion.

Conclusion

To be able to fasten the orthodontic treatment with no adverse effect is highly desirable for both patients and orthodontists. A surgical approach (with various techniques e.g. dental distraction, corticotomy, piezocision, and micro-osteoperforation) is one of the methods that has been reported to be able to accelerate tooth movement. However, at present, it seems to be too early to make a definitive conclusion due to the low-quality of evidence available. Unless there is further higher-quality evidence from well-conducted researches, using the surgical approach to accelerate orthodontic tooth movement should not be recommended as a routine orthodontic clinical practice.

Table 1: The summary of the results of each surgical technique

Surgical methods	Author, year	Results
a. Dental distraction	Hoogeveen, et al., 2014: systematic review Iseri, et al., 2005 Liou and Huang, 1998 Sukurica, et al., 2007	Found the canine can be distracted quickly with no significant of root resorption, ankyloses, and root fractures. However, there are still some variable results regarding the vitality of the retracted canine.
b. Corticotomy/Osteotomy-assisted orthodontic tooth movement	Kole, 1959	Reported major active tooth movements were accomplished in 6-12 weeks with conventional corticotomy.
	Suya, 1991	Reported an improved surgical procedure called corticotomy-facilitated orthodontics. With this technique, most cases were completed in less than 12 months, some completed in 6 months.
	Lee, et al., 2008	Found the bony response was dependent upon the type of surgical intervention (corticotomy - RAP occurred whereas osteotomy - normal fracture healing / distraction osteogenesis occurred).
	Wilcko, et al., 2001 Wilcko, et al., 2003 Wilcko, et al., 2006 Wilcko, et al., 2008	Developed a patented technique called Accelerated Osteogenic Orthodotnics (AOO) or Periodontally Accelerated Osteogenic Orthodontics (PAOO).Using this technique, they reported rapid tooth movement at a rate of 3 to 4 times greater than conventional orthodontic movement.
c. Piezocision	Dibart, et al., 2009	Introduced Piezocision, a flapless method of corticotomy using piezosurgery, to reduce the morbidity from the conventional corticotomy.
	Mehr, et al., 2013	Found that the piezocision had 1.6 times faster correction in only the first 4-5 weeks and there was no significant difference in the total time to correct the mandibular crowding between the piezocision and the conventional group.
	Charavet, et al., 2016	Found that piezocision reduces overall treatment time by 43% compared with the control group.
	Yi, et al., 2017: systematic review	Found weak evidence to support that piezocision could accelerate orthodontic tooth movement without adverse effects on periodontal tissue and pain perceptions at least in the short-term duration.
d. Micro-Osteoperforation (MOP)	Teixeira, et al., 2010	Found that in adult rats, MOPs treatment increased molar protraction rate significantly accompanied by the increase in inflammatory cytokine expression, osteoclastogenesis, and alveolar bone remodeling
	Alikhani, et al., 2013	With their human clinical trial, they found MOPs increased the rate of canine retraction significantly by 2.3-time compared with the control group together with a significantly increased of the inflammatory markers. Patients reported only mild discomfort locally at the time of the MOPs was done.

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