REVIEW ARTICLE

Innovations in Flapless Corticotomy to Accelerate Orthodontic Tooth Movement: A Review Focusing on the Different Techniques, Limitations and Future Possibilities

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ABSTRACT

The aim of this narrative review is to discuss on different approaches of the flapless corticotomy techniques to accelerate orthodontic tooth movement. There was limited understanding about the effect of the surgical procedures because of the great variations in the procedures between the flapless corticotomy techniques. Hence, no specific technique can be claimed to be superior to another. Eleven clinical trials have been reviewed from PubMed, Science Direct, and Google Scholar using the keywords such as accelerated, orthodontic tooth movement (OTM), minimally invasive corticotomy, RAP, corticision, piezocision, lasercision/laser assisted flapless corticotomy (LAFC), micro-osteoperforations (MOPs), discision and their combinations in the last 10 years. Early reports showed that Piezocision, MOPs and LAFC procedures are comparatively less aggressive flapless corticotomy procedure to accelerate OTM and more comfortable to the patient.

Keywords: Accelerated orthodontic tooth movement, Corticision, Piezocision, MOPs, LAFC, Discision

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INTRODUCTION

Orthodontic treatment usually requires between 18-30 months to complete depending on the types of malocclusion and severity of individual cases (1). Because of the lengthy period, innovations that could shorten the treatment time would be preferred and welcomed by both orthodontists and patients. Over the past decade, there has been a growing number of research related to intentional surgical intervention to accelerate orthodontic tooth movement (OTM) such as selective alveolar decortication and periodontally accelerated osteogenic orthodontics (2). The term corticotomy was first used in OTM by Wilcko et al. and was has been generally referred to as a surgical procedure where both labial and lingual full thickness mucoperiosteal flaps are reflected and only the cortical bone is cut, perforated, or mechanically altered through the medullary bone (1,2).

There has been some evidence that open flap techniques shorten the orthodontic treatment time (1,3-5). However, the procedures are quite invasive and associated with several adverse effects (2,6). It involves a full mucoperiosteal flap reflection at both buccal and lingual side which extends beyond the apices. This is followed by selective decortications using a diamond round bur or piezoelectric blade of the teeth. These are vertical cuts at 0.5mm depth between the roots of the teeth that needs to be moved that are connected by scalloped horizontal cuts at the apices of the teeth. Several perforations are also made at selective areas all over the alveolar bone around the tooth (1). The resulting trauma increases the risk of post-operative pain, swelling, infection, scarring, attached gingiva loss, pulp vitality loss, root damage and interdental bone loss (2,6). This, possibly explain the lack of enthusiasm from both patient and orthodontist to adopt the techniques.

To overcome this morbidity, flapless corticotomy techniques that are less invasive, do not inhibit healing response and more acceptable to the patients during and post-operatively have been introduced. The new techniques are flapless and performed using different devices; chisel and mallet, piezoelectric blade, hard tissue laser, disposable propel device and disc saw and subsequently named as corticision, piezocision, lasercision/laser assisted flapless corticotomy (LAFC), micro-osteoperforations (MOPs) and discision respectively. The research into corticotomy is developed based on the understanding of the regional acceleratory phenomenon (RAP) (1,2,7-15).

Regional acceleratory phenomenon

The RAP is a collection of a physiological healing process that is characterized by tissue remodeling and recuperating events; manifested as transient bursts of osteoclastic and osteoblastic activities, increased levels of local and systemic inflammatory markers which then causes an accelerated bone turnover and decreased bone density (16). The biological mechanism was first described by Dr. Harold Frost in 1983 after he observed in a human autopsy, an increased bone turnover in bone rib that underwent thoracotomy. He claimed that intentional surgical trauma induces the RAP response, which varies according to the extent of surgery, type of tissues, duration, size, intensity and magnitude of the stimulus. In humans, the RAP initiates within a few days of the trauma and most noticeable at 1-2 months and subsides after 6-24 months (18,19). The application of this understanding in OTM had been investigated in animal studies and the results showed that alveolar decortication by intentional surgery with or without reflecting the full thickness of mucoperiosteal flap induces the RAP response, produce a more extensive and diffused demineralization and increases remineralization in the alveolar bone (7,8,10,19-23). The RAP also cause an extensive direct resorption of the bundle bone and shortened the lag phase of tooth movement by stimulating the removal of hyalinized tissue. This condition allows a tooth to move rapidly through the demineralized bone matrix before the alveolar bone remineralizes without any pathological changes and root resorption of a tooth (7,20-25).

There are currently very few reports on flapless corticotomy techniques because they are relatively new. A recent systematic review and meta-analysis had concluded that there was limited and narrow quality evidence on the efficacy of all flapless corticotomy techniques to reduce the overall orthodontic treatment time and suggested that more research should be carried out before it can be fully recommended in clinical practice (26). Another systematic review that focused on piezocision concluded that it was a safe adjunct to accelerate OTM, but the evidences to support the method were weak (27). Besides the small number and low quality of the trial there were also a large variation in the techniques used in the studies. Currently, there was only one review that discussed about the corticotomy techniques but the focus on flapless techniques was limited (28). Hence, this paper was aimed to review the surgical procedures of flapless corticotomy techniques, and discuss the issues related to the research.

MATERIALS AND METHODS

To ensure that all the flapless corticotomy techniques were included in this review, a search was carried out in PubMed, Science Direct, Scopus, Google Scholar and Web of Science. The keywords used in the search included accelerated, rapid, speed, rate, orthodontic tooth movement, flapless, minimally invasive corticotomy, RAP, micro-incision, corticision, piezocision, lasercision, piezo-surgery, piezoelectric-corticision, piezo-electric corticotomies, laser corticision, laser corticotomies, piezopuncture, corticopuncture, piezo-perforation, laser-perforation, micro-osteoperforation and their combinations, or any surgical procedure which is not required raising gingival flap were included. The search was carried out until October 2019 and only published English language articles were included. The titles and the abstracts of the search results were examined to identify the relevant reports. Two reviewers (SS and BA) assessed independently eligibility of the trials, and in case of disagreement, the second author (NAR) was asked to resolve this. Five different techniques were identified: corticision, piezocision, lasercision/LAFC, MOPs and discision and are described next. The descriptions of the surgical procedures are based on the details provided in the reports and for latter techniques, they were very limited.

Corticision

The first flapless corticotomy technique was described by Kim and Park in 2009 (7), and the technique on orthodontic patients was described by Park in 2010 (29). The procedure is carried out on a bracket bonding appointment day and under local anesthesia. It starts with a vertical interradicular gingival incision about 5mm away from the papillary gingiva, to avoid bone loss at the alveolar crest, and extends to approximately 2/3rd of the root length using a reinforced scalpel that is positioned at an inclination of 45–60° to the long axis of the tooth to be moved. The scalpel blade is then positioned within the incision line and the holder was tapped gently using a surgical mallet to cut through the periosteum and cortical bone up to 10 mm deep or upon reaching the medullary bone. Then the scalpel is pulled out with a gentle swing motion and the procedure is repeated along the incision line. The procedure is repeated at each interradicular area of the teeth to be moved. At the end of the corticision procedure, the wound is left without any suture and, orthodontic force is applied immediately after the surgery (Figure 1a). Bleeding is controlled using high volume suction during the procedure and hemostasis is achieved by applying ice pack and pressure upon completion. Patients are prescribed with broad-spectrum antibiotics and appropriate analgesics to control postoperative pain and discomfort. Followed-up for review and adjustment of orthodontic appliance is carried out every 2 to 4 weeks during treatment.

Piezocision

Piezocision technique on human was first reported by Dibart et al. in 2009 (8). It uses a piezoelectric blade No.

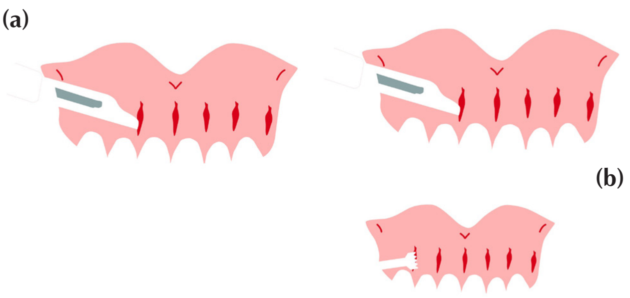

Figure 1: (a) Corticision procedure and (b) Piezocision procedure

BS1, which has a saw like cutting tip, is attached to an ultrasonic piezoelectric device (Piezotome TM Satelec Acteon Group) commonly used in soft and hard tissue cutting, hence the name. The procedure is done 1 week after bracket bonding appointment day, under local anesthesia. It started with 5mm vertical interradicular incision using a scalpel blade No. 15, starting at about 2–3 mm away from the base of the interproximal papillae of attached gingiva, cutting through the soft tissues and the underlying periosteum. Then, the ultrasonic piezoelectric blade is inserted through the incision at 450-600 to the long axis of the tooth to cut the alveolar bone up to 3mm depth or upon reaching the medullary bone (Figure 1b). The steps are repeated at every interradicular area of the teeth to be moved. Bleeding is controlled in a similar manner to corticision during the procedure and hemostasis is achieved by applying iodoform gauze. No suture is required after surgery except in areas where a bone or tissue graft is intended, in which cases a subperiosteal tunneling is performed by using a small periosteal elevator to create pouches that will accommodate the bone graft. This tunneling procedure could also be used to correct a pre-existing mucogingival defect (i.e. gingival recession) by placing soft tissue graft into the pouch instead of bone. In cases where extractions are required, two extra vertical buccal cortical incisions that corresponds to the extraction socket can be made to facilitate rapid closure of the space. Postoperative treatment with ice packs for the first 2 hours after surgery and mouth rinses with chlorhexidine gluconate 0.12% for the first week are recommended. Antibiotics are prescribed if bone grafting was performed and nonsteroidal anti-inflammatory drugs for pain control. A patient is followed-up for review and adjustment of orthodontic appliance every 2 weeks during treatment.

There were several modifications to the technique reported in other studies but none had provide justification for the changes. The critical differences were the dimensions of the length x depth cuts that were diverse between the studies (Table I) (15,30-35). Other variation included the surgical day - few studies had performed the procedure on a bracket bonding appointment day (30) and another, on activation day of clear aligner therapy (31). Some studies used surgical guidance to help with the location of the cuts, placed sutures after the surgery, and had shorter or longer follow up visits.

Table I: Summary of flapless corticotomy characteristics

	Corticision	Piezocision	Lasercision	MOP	Discision
Under local anaesthesia	✓	✓	✓	✓	✓
Site: interradicular	✓	✓	✓	Over extraction socket	✓
Distance from papillary gingiva (mm)	5mm[29]	2-3mm[8,31,32,34], 1mm[15], 4mm[30], 5mm[33]	5mm[11]	ND	1mm[15]
Type	cut	cut	hole	hole	cut
Dimension	2/3 of root x 10[29]	5x3[8], 7x3[15], 4x1[30], 5-8x3[32], 10x3[33], root length x 3[34]	1.5 (diameter) x 2-3[11]	1.5 (diameter) x 2-3[12] 1.6 (diameter) x 3[13]	7x3[15]
Sutures	×	Used[30,33-35] Not used[8,14,30,32]	×	×	×
Follow-up frequency	2-4 weeks[29]	2 weeks,[8, 32-34] 2-3 weeks,[15] 2-4 weeks,[35] 4-6 weeks,[30] For aligner-every 5 days[31]	ND	4 weeks[12,13]	2-3 weeks[15]
Guided assistance	Radiograph[28]	Radiograph[8,15,30,32-35] 3D STL[31]	Radiograph and loop archwire[11]	Radiograph[12] Rubber stopper[13]	Radiograph[15]
Number of case reports	2	>4	×	×	1
Number of clinical trials	0	7	1	2	1

*vertical (mm) x depth (mm)
**not described

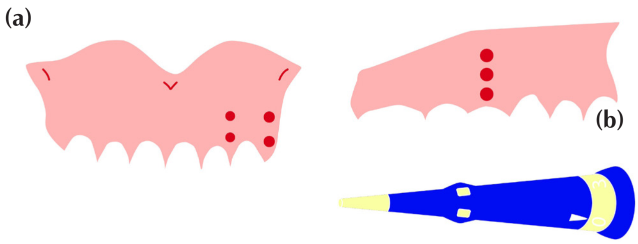

Figure 2: (a) 1 LAFC procedure and (b) MOPs procedure

Laser assisted flapless corticotomy

The use of laser in OTM was first introduced by Seifi et al. in 2012 in an animal study using Er,Cr:YSGG (10). The laser procedure differs from previous techniques in that it burns the alveolar cortical bone to make perforation holes. The first human trial report had used the erbium family laser Er:YAG and was reported by Salman et al. (2014) (11). However, the report did not provide a detailed description of the surgical procedure. The surgery can be performed under local anesthesia either by topical or infiltration. A patient is instructed to use chlorhexidine mouthwash just before surgical intervention. The location of the perforation holes is pre-determined with the help of radiographs and a temporary archwire (0.018-inch S.S), which is designed to have two indicator U-loops at the interradicular area of the tooth to be moved. The perforations are made within the loops. Each perforation site should be at 5 mm from the base of the interproximal papillae and 2-3mm apart from each other. The surgical procedure is carried out in two stages. First, a soft tissue ablation is made using a soft tissue laser device at the identified sites. Then a hard tissue laser is used to make perforations at the sites in a non-contact mode with constant water spray irrigation. Each perforation is about 1.5 mm in diameter and 2 to 3 mm deep. (Figure 2a). The surgical site is covered with an iodoform gauze and surgical pack without the need for a suture. Orthodontic appliance activation starts immediately following the intervention. There is usually no need for pain or antibiotic medication.

Micro-osteoperforations

Propel device assisted MOPs

MOPs has a similar principal to lasercision in that it creates holes in the alveolar cortical bone. The technique was introduced by a company that invented the propel orthodontics (Ossining, NY) based on alveocentesis process; which is similar to puncturing the bone (12). The device has an adjustable length and automatically detects and give a light signal when the desired depth is achieved (Figure 2b). So far, there is only one clinical trial report on MOPs by using a propel device but the description of the technique was not very clear (12). The researchers had intended to retract the canine after extracting the first premolar and opted to perform the corticotomy holes over the extraction socket and at equal distances from the canine and the second premolar. The procedure is carried out under local anesthesia. Three vertically aligned puncture sites are pre-determined with the help of a radiograph. However, the distance between the puncture sites is not mentioned. Puncture holes with the size of 1.5 mm diameter and 2 to 3 mm deep are made. No suture is needed after the surgery and orthodontic appliance activation can be started immediately after the procedure. Patient follow-up and orthodontic appliance adjustment is carried out every 4 weeks. Antibiotic and pain medication is also not needed.

Mini implant assisted MOPs

A current split-mouth study investigated MOP using mini-implant supported canine retraction of both maxilla and mandible in first premolar extraction cases. The researchers performed MOPs by creating three holes directly through the buccal mucosa adjacent to the extraction site in a vertical direction 2 mm apart from each other and 3 mm in depth by using an orlus screw with 1.6 mm in diameter and 6 mm in length. The depth of each hole has adjusted by using a rubber stopper in the mini-implant screw. The procedure is carried out under local anesthesia. The study observation period is 16 weeks and patient follow up for canine retraction and orthodontic appliance adjustment is carried out every 4 weeks. Paracetamol (1000 mg) is prescribed for post-operative care (13).

Discision

Discision is a technique that uses a 0.3mm thick and 3.5mm radius disc saw bur (Osstem Implant, Esset KIT-Saw, Seoul, Korea) to create alveolar bone cuts similar to corticision and piezocision. The technique was described in a recently published case report by Buyuk et al. (2018) (14) and a single-center clinical trial by Yavuz et al. (2018) (15). The procedure is done 1 week after the bracket bonding appointment day. Under local anesthesia, a scalpel blade is used to make a vertical interradicular gingival micro-incisions starting at 1 mm below from the free gingival sulcus and cuts across the mucogingival line to the intended length. Then, a disc saw bur was used to make a 7mm length x 3mm depth cut within the incision line. Constant and proper irrigation is carried out throughout the procedure to clean the working area from tissue residuals. The suture is not required and analgesics are prescribed postoperatively to be taken when necessary. A patient is followed-up for review and adjustment of orthodontic appliance every 2-3 weeks during treatment.

DISCUSSION

The understanding of RAP and its potential to accelerate orthodontic tooth movement had driven the innovations in the corticotomy techniques. A number of evidence from animal studies had demonstrated that these techniques induce the RAP response (7,8,10,19-23,36-38). However, the practice of these techniques in orthodontic clinics is still limited particularly for the flapless corticotomy techniques; possibly because they are relatively new and evidence is still limited. Also, the clinical procedures were inadequately described in the literature to allow a reader to follow the protocol clearly, least to emulate it. The present review discussed two main concerns over the researches into the flapless corticotomy techniques: the diversity and developmental pathway of the techniques.

The present review found more than 6 case reports and 11 clinical trials to describe five different flapless techniques in the last 10 years (Table 1). These numbers are rather small and the quality of evidence was also limited to convince clinicians to adopt them as an evidence based practice (26,27). Another concern is that the evidence for the flapless technique is currently diverse in the procedures. Corticision, piezocision and discision are flapless techniques that adopted a 'cut' in the bone to induce the RAP. The dimensions of the cut vary not only between the techniques but also within a technique; wherein the case of piezocision, there were 6 different length x depth dimensions reported in 7 different trials and two of them did not significantly shorten the orthodontic treatment time (30,35). It is unclear why the researchers had selected a particular dimension in their studies and if there was any evidence to justify the choice. At present there is no evidence in the literature on the optimum depth x length dimensions that would produce the maximum RAP effect in OTM. It is also not known how variation of length and depth would affect RAP and treatment time. To prevent alveolar crest bone loss the cut was made at a distance from the papillary gingiva but this has also varied between and within studies (Table 1). Evidence on this is also limited and the optimum distance is still not clear.

The advancement in technology and availability allowed researchers to experiment with new instruments. Instead of a cut, the use of laser, propel and mini-implant instrument resulted in a total change in the surgical dimension where they create small perforations or 'holes' in the bone to trigger the RAP. Adoption of small perforations was innovative and advantageous as it has a smaller surgical area and although the current evidence support it potential to shorten treatment time, the evidence is lacking to show whether it is superior to a cut. And similar to the cut techniques, the questions over the variation in characteristics of the holes between the two techniques: the number, distances between them, the diameter and the depth, how these would affects treatment time are still unknown. Nevertheless, the perforations or holes technique is simpler as it requires no initial soft tissue incision, less traumatic, less messy due to controlled bleeding, lesser skill requirement and can be completed in a shorter time. While laser for hard tissue have been around for quite a while, the MOP was a new instrument specifically designed and developed for flapless corticotomy. The diameter and depth of the holes can be fixed by adjusting the propel device (12) and mini-implant device (13). Both of these innovation are less aggressive to operate, allows the intended trauma to be carried out under better manual control, hence a more localized and less severe tissue injury compared to corticotomy cut techniques. The latter were highly dependent on the dexterity skill of the operator to achieve the required depth and length of the cut and, the bone thickness of the patients. The application of 3D STL, CAD/CAM and radiograph had also been adapted in the piezocision and lasercision which allows the site of corticotomy to be precisely determined to reduces the risk of unnecessary tissue damage (31). However, these instruments are costly and may not be widely available, particularly the hard tissue laser and propel device; and how the outcome would differ from the cut techniques have not been studied.

Besides the difference in the surgical procedures, the follow-up visit for appliance activation also varied, from 2 weeks to 6 weeks between the studies. In one exceptional case, a piezocision study that used a clear aligner therapy had the appliance replaced at every 5 days instead of 15 days based on treatment need (31). Due to the transient nature of the RAP response which remains active up to 28 days (37,38), activation of the orthodontic appliance at a regular interval within 2-6 weeks after bone trauma is indicated if the tooth movement during the diffused demineralization phase period is to be optimized. It may also be possible to repeat the corticotomy procedure more than once in the same area to re-activate the RAP after 5-6 months and keep the area less mineralized over the required period of treatment (8). Thus, a shorter and more frequent follow-up could, in theory, shortened treatment time (14, 30-35) and should also be investigated. But currently, the reports did not indicate whether their choice of follow up period are based on these understanding and how much this would contribute towards the overall treatment time is still not known.

The effects of flapless corticotomy were also investigated at different stages of OTM; at the alignment leveling, canine retraction or enmass retraction stages (11,12, 13, 30-35) in mixed types of extraction and non-extraction cases. Three different outcome measures were used: the overall number of days to complete a stage (30,33,35), the percentage of days to complete overall treatment or stage in experimental group compared to the control group (11,32), and the average of tooth movement (30,31,33,34). Because of these heterogeneities, the results of the studies were not directly comparable to each other. Despite the lack of evidence from clinical trial on safety and potential efficacy, there were no adverse effects reported on gingival recession, pocket depth, alveolar crest bone resorption, root resorption, unexpected tooth movement or rotation, molar anchorage loss and pulp vitality loss (11, 12,15,30-35). Nevertheless, there are possible risks of accidental bone fracture, loss of tooth vitality and dizziness to the patients after the surgery due to highly aggressive use of the blade and surgical mallet in corticision technique (40,41). Piezocision and MOPs were found to be less painful or discomfort and had better patient satisfaction (12,15,31,32) although a current study showed that mini-implant assisted MOPs to create postoperative moderate to severe pain during chewing and speech (13). None of the studies reported about the cost and clinical time of the surgical procedure which is also important for patient and clinician considerations.

The development of the flapless techniques seemed to focus on the potential result – that it would shorten treatment time. Based on the published literature, there is a concern that less focus was given on the progression of developmental pathway of each technique. The flapless techniques were innovations from the more traumatic corticotomy which had been shown in a number of trials to have the potential to accelerate tooth movement. The present review found that not all techniques provide sequential supporting evidence before moving to a clinical trial. According to the IDEAL framework, a surgical innovation should develop in stages from idea, development, exploration, assessment, and long term study described by McCulloch et al. (39). Evidence for a particular technique should be sufficient enough before going to the next stage in trial. Hence, innovation should be investigated and, all parameters and outcomes are reported as case studies to show its potential. Based on that evidence, a technique can be goes into a developmental stage of clinical trial for further investigation into the efficacy and safety. And once this has been satisfactory, then a randomized controlled trial at a larger scale can be initialized. In general this developmental progression is not observed in all flapless corticotomy techniques presented; particularly in lasercision and MOP techniques where there was no case report on idea development and safety issues. Nevertheless, it is plausible that because the instruments were developed by specific manufacturers, in-house studies could had been carried out but was not been published. For the other techniques, the case reports for the corticision, peizocision and discision were available, the number was limited. Details about the idea development stage that explain a particular surgical procedure was not available in for any of the technique. This probably contributed to the diversity of the procedures raised earlier,the evidence was lacking and there were gaps in the understanding of the effects of, for example, cuts, holes, dimensions, and follow up periods. Nevertheless, the whole flapless corticotomy idea has been supported by previous open flap corticotomy and animal studies in relation to RAP. The first-in-human translation of the corticision techniques was not followed up by clinical trials; perhaps because the procedure was too traumatic and not favorable to many researchers and clinicians, hence no further investigation into it.

CONCLUSION

Previous reviews had concluded that there was little evidence to support the use of flapless corticotomy to acceleration OTM. This review found that piezocision, discision, MOPs and LAFC procedures are comparatively less aggressive and more comfortable to the patient than corticision technique. The MOP and LAFC were the least traumatic procedures but may incur higher cost. There are concerns over the evidence because of the great variations in the procedures between the flapless corticotomy techniques and that they are not directly comparable for efficacy. Also, there was limited understanding about the effect of the surgical procedures such as the cut, holes number, and dimensions on treatment outcome because of the variation in the procedures between studies. Hence, no specific technique can be claimed to be superior to another. Having a standardized procedure would allow a better understanding of the effects on RAP and is essential during evaluation of the efficacy. It is recommended that the IDEAL collaboration guideline should be considered when developing the techniques. Future trials should consider including short and long term outcomes, standardizing the outcome measures, standardize follow-up observation periods in their study design and cost-benefit analyses.

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