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# Periodontally accelerated osteogenic orthodontics (PAOO): Past to present

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**ABSTRACT**
Different methods have been proposed and practiced to date by authors to reduce the treatment time for conventional orthodontic therapy. One of the main interdisciplinary approach to accelerate the tooth movement is the periodontally accelerated osteogenic orthodontic procedure (PAOO) introduced by the Wilcko brothers in 2001. This treatment modality has shown to reduce the overall orthodontic treatment time and has improved the post treatment outcomes. Thus, this article attempts to discuss about the historical perspectives of the treatment modality, the rationale behind the accelerated tooth movement, indications, contraindications and the modifications of this treatment approach till date.

**Key words:** Corticotomy, PAOO, PRF, RAP



## INTRODUCTION

Malocclusion is one of the most common oral health problems encountered which can alter both the function and aesthetics, thereby affecting the psychosocial well-being of an individual. Improving the appearance of the smile is one of the main reasons patients seek orthodontic treatment. Understanding the components of an aesthetically attractive smile is essential to achieve patient satisfaction as well as successful treatment results. However the duration of the orthodontic treatment is one of the primary concerns of most patients. A recent systematic review showed the mean treatment time for fixed orthodontic treatment to be 14 to 33 months. [1] The long orthodontic treatment time possess various disadvantages like higher predisposition to dental caries, gingival recession and root resorption. To overcome these disadvantages, both surgical and non surgical interventions have been carried out by the researchers to accelerate orthodontic therapy. Periodontally accelerated osteogenic orthodontics (PAOO) or Wilckodontics is a corticotomy assisted surgical method employed to reduce the orthodontic treatment time. It helps in improving the post orthodontic outcomes with increased stability and patient acceptance. PAOO was introduced by the Wilcko brothers, Dr. Thomas Wilcko Agents.[5]

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(Periodontist) and Dr. William Wilcko (Orthodontist) in the year 2001. [2]They described 2 case reports of decrowding and were completed in approximately 6 months and 2 weeks from bracketing to debracketing**.** This innovative approach included a combination of selective alveolar decortications (SAD) and particulate bone grafting accompanied with orthodontic forces. Wilckodontics is theoretically based on a phenomenon termed as regional acceleratory phenomenon(RAP),a bone healing pattern that was introduced by Harold Frost, a distinguished orthopedist, who found out that there was a direct correlation between the degree of injuring a bone and the intensity of its healing response. [3,4] This phenomenon includes a temporary burst of localized soft and hard tissue remodeling (i.e. regeneration) which rebuilds the bone back to its normal state. PAOO has shown to move the teeth 2-3 times further when compared to conventional orthodontic therapy. Thus, the aim of this review is to discuss about the historical perspectives of accelerated treatment approaches, the rationale behind the accelerated tooth movement, indications, contraindications and the modifications of this treatment approach till date.

**Historical background**

Orthodontic tooth movement attained with surgery began in the 1800s**.** Elementary surgical procedures have been used for more than 100 years to accelerate the tooth movement and to affect the dento-alveolar housing.

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| 1893 | A presentation by Cunningham titled *"*Luxation, or the immediate method in the treatment of irregular teeth" at the International Dental Congress, Chicago led to the evolution of accelerated treatment approaches in orthodontic therapy.[5] | |
| 1893 | LC Bryan described firstly about the corticotomy facilitated tooth movement published in a textbook called 'Orthodontia': Malposition of the Human Teeth, Its Prevention and Remedy.[6] | |
| 1900s | Distraction Osteogenesis was one of the first methods used in orthopedic medicine,but not widely employed initially. | |
| 1931 | A surgical technique was introduced by Bichlmayr for the rapid correction of the severe maxillary protrusion with orthodontic appliances. He removed wedges of bone to reduce the volume of bone through which the roots of the maxillary anterior teeth would need to be retracted.[7] | |
| 1950s | Russian orthopedic surgeon Dr. Gabriel Ilizarov guided a breakthrough perfecting Distraction Osteogenesis. He often performed bone surgeries to correct deformities and defects in arms and legs.[5] | |
| 1959 | Heinrich Köle set the stage for the subsequent evolution of refining decortication-facilitated orthodontics.[8] Major tooth movements were corrected in 6 to 12 weeks without significant apical root resorption. The term "bony block" was given based on Kole's work, which describes the suspected mode of movement following corticotomy surgery. However, the sub-apical horizontal cuts explained by Kole, penetrating the full thickness of alveolus was eventually put down by many of the dentists due to its aggressive and invasive nature.[9] | |
| 1972 | Bell and Levy in the year 1972 conducted the first experimental animal study of alveolar corticotomy in 49 monkeys.[10] | |
| 1975 | Duker carried out a study on beagle dogs and demonstrated that rapid tooth movement could be achieved by orthodontic appliance by weakening the bone with corticotomy. He also studied the effect of the vitality of the tooth which was moved and concluded that the marginal bone must be preserved and interdental cuts should be made 2 mm apical to level of alveolar crest.[9,11] | |
| 1978 | Generson *et al.* [12] | Modified the supra-apical horizontal cut with labial and lingual corticotomy cuts. |
| 1986 | Anholm *et al.*[13] | |
| 1990 | Gantes *et al.*[14] | |
| 1991 | Suya[15] | |

The first description of a surgical attempt to enhance orthodontic treatment by only corticotomies was termed as SAD. Kole and Suya attributed the accelerated tooth movement by selective corticotomy to moving "blocks of bone". Both believed that teeth were embedded and moved in "blocks of bone" connected to each other by medullary bone only, instead of today's understanding of how teeth move through alveolar bone. As early as the 1950s, periodontists began using a corticotomy technique to increase the rate of tooth movement. Wilcko and co-workers[2] reported that the rapid tooth movement occurred due to a transient localized demineralization-remineralization phenomenon in the alveolar bone housing and was not as a result of bony block movement with the help of surface computed tomographic (CT) scan. This was consistent with the wound healing pattern of the RAP developed by Frost. Yaffe and coworkers have also described RAP in the periodontal literature following periodontal flap surgery. [16]

**Regional acceleratory phenomenon (RAP)**

Orthopedist Harold Frost in 1983 recognized that surgical wounding of osseous hard tissue results in striking reorganizing activity adjacent to the site of

injury in osseous and/or soft tissue surgery. He collectively termed this cascade of physiologic healing events as the Regional Acceleratory Phenomenon (RAP).Once a surgical wound is created in the cortical bone, RAP potentiates tissue reorganization and healing by way of a transient burst of localized hard and soft tissue remodeling.[17] Authors have suggested that RAP in humans would begin within a few days following surgery which would typically peak at 1-2 months and would continue from 6-24 months.The initial phase of RAP was characterized by an increase in cortical bone porosity as a result of increased osteoclastic activity. The RAP is a local response of tissues to noxious stimuli by which tissue regenerates faster than normal in a regional regeneration /remodeling process. It varies directly in size, duration, and intensity with the magnitude of the stimulus.RAP causes the bone to heal 10-50 times faster than the normal bone turnover. [18] Healing phases of RAP in rat tibia have been carried out. Initially, the woven bone is formed in the periosteal area and then extended to the medullary bone. It reaches its maximum thickness on the 7th day. This cortical bridge of woven bone formed is an elemental component of RAP, providing mechanical stability of bone after an injury. The woven bone in the cortical area begins to undergo remodeling to lamellar bone from the 7th day. The medullary woven bone undergoes resorption depicting the transient local osteopenia. Medullary bone gets reorganized and rebuilt after the establishment of the new cortical bone.It gets adapted to the mature cortical bone around 3 weeks in rats. RAP is maximized when tooth movement is combined with selective decortication. RAP explains how damaged bone can repair itself in a timely fashion through increased cellular activity, initially manifesting with demineralization but resolving with remineralization.

**Principle of PAOO surgery**

The main principle of PAOO is that, the corticotomy procedure peformed does not just cut into the alveolar bone but rather decorticates it (some of the external surfaces of the bone are removed).The bone then goes through a phase known as osteopenia, where its mineral content is temporarily decreased. The cells of the alveolar bone release abundant deposits of calcium and the new bone remineralize in about 20-55days. The alveolar bone during this transient state offers less resistance to the orthodontic forces and being softer, permits the teeth to move faster.

**Indications**

- To increase alveolar bone volume and enhance the periodontium (i.e., correction of dehiscence and fenestrations)
- To accelerate the orthodontic treatment
- To provide greater stability of clinical outcomes and less orthodontic relapse
- To enhance the scope of malocclusion treatment (i.e., avoiding orthognathic surgery and extractions in selected cases)
- Enhancement of the patient's profile when indicated
- Rapid recovery of impacted teeth (i.e., canines)
- Treating moderate to severe crowding
- Class II malocclusions requiring expansion or extractions
- Mild Class III malocclusions

**Contraindications**

- Ankylosed teeth
- PAOO is not recommended in patients having Rheumatoid Arthritis who require regular doses of nonsteroidal anti-inflammatory drugs (NSAIDs).
  - NSAIDs interfere with the production of prostaglandin hormone in the body and slow down the bone growth process which is vital to PAOO.
  - Corticotomy facilitated tooth movement is a periodontal ligament mediated sterile inflammatory process, so the use of NSAIDs will reduce the inflammatory response and therefore tend to counteract the RAP effect.[19]
- Patient having active periodontal disease.
- PAOO should not be considered in patients having alveolar bone loss, root damage or poor root form.
- Bimaxillary protrusion accompanied with a gummy smile is usually contraindicated Seg-mental osteotomy is preferred.
- In severe crossbite cases, which require surgically assisted palatal expansion.

PAOO is unsuitable in Class III malocclusion wherein the lower jaw is too long relative to the rest of the face and the chin has many physical constrains. [20]

**Technique of PAOO procedure**

Dr. Wilcko has said, "PAOO is not as invasive as taking out teeth. There is some swelling and very little bleeding involved".Prior to the periodontal surgical procedure, a complete medical checkup of the patient is done to rule out any systemic conditions interfering with the surgery. Radiographic interpretation helps in evaluating the periodontal status of the patient. Phase I therapy is done and then the periodontal surgery is scheduled.

The surgical procedure involves the following steps-

- Full thickness flaps are reflected both labially and palatally/lingually using a crevicular incision.
- The interdental papillae can be reflected with the flaps or left in place. The interdental papillae with full thickness flap is generally avoided between

the upper central incisors considering the esthetic purpose.

- Herethe lingual portion of the interdental papilla is not reflected because the nasopalatine foramen precludes the need for bone activation in this area.
- The flaps are reflected until the accessibility is reached.
- Vertical releasing incisions can be used but should be positioned at least 1 tooth beyond the bone activation if the bone grafting is more in amount.
- Alveolar decortications are performed with the use of a no.1 or no.2 round bur both on the labial and lingual side. Decortications initiate RAP response.
- Vertical grooves are placed in the inter-radicular space stopping 2-3 mm below the crest of the bone and to a point 2mm beyond the apices of the roots.
- Vertical corticotomies are then connected with a horizontal corticotomy, circular in shape. Solitary perforations can be given in the alveolar bone over the radicular surface if the alveolar bone has sufficient thickness. [Figure 1a]
- If the bone is estimated to have a thickness of lesser than 1-2 mm, then the perforations are avoided to prevent injury to the radicular surface. The corticotomy cuts should be approximated until the entire thickness of the cortical bone and barely into the medullary bone.

**Particulate bone grafting**

Alveolar augmentation is then followed with the application of resorbable particulate bone grafting material. [Figure 1b] The bone graft is first wet with a clindamycin phosphate/bacteriostatic water solution of approximately 5mg/ml. This is done to facilitate the ease of placement. Platelet rich plasma can also be used for wetting the material as it does not inhibit tooth movement. Resorbable grafts are preferred in PAOO. The grafting material can be 100% demineralized freeze dried bone allograft (DFDBA), a mixture of DFDBA and bovine bone, or a mixture of DFDBA and mineralized FDBA and also alloplast bone graft. Resorbable membranes can be used to increase the resulting bone volume.[21]Care is taken not to place an excessive amount of bone graft material as it interferes with the replacement of the flaps.

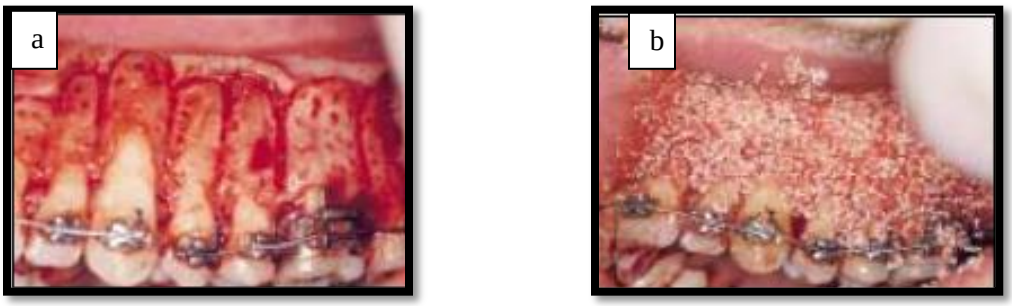


**Figure 1: (a) Corticotomy cuts placed (b) Bone graft placed in the corticotomy cuts**

**Flap closure**

The full thickness flaps are sutured with interrupted loop 4-0 non-resorbable sutures (Gortex), being careful to preserve the interdental papillae. The suture removal is done after 2 weeks. Sufficient time is allowed for the epithelial attachment to re-establish. Periodontal pack may or may not be placed.

**Post-operative management**

- Antibiotics and analgesics (Acetaminophen is the drug of choice) are prescribed based on the operator's preference.
- Long term uses of NSAIDs are discouraged as they interfere with RAP.[19]
- The application of icepacks on the surgical area helps in decreasing the severity of any postoperative swelling or edema.
- The follow-up has to be done weekly for 1 month and then monthly thereafter.

**Orthodontic adjustments**

Complete recovery takes about 10-14days and the orthodontist adjusts the braces about every 2 weeks during the active phase. The adjustments should not be delayed for more than 2 weeks. Orthodontic braces are put for 3-9 months and once the braces are removed, retainers are fixed for at least 6 months. [22]

**Technique modification**

Gingival augmentation procedures can be combined with PAOO.[23] This is mainly applicable in adult patients who have gingival recession and in such situations, a subepithelial connective tissue graft is placed over the recessed surface in addition to alveolar augmentation. The graft is procured by removing 1-2mm thickness of gingival connective tissue from the elevated palatal flap.

**Advantages of PAOO**

- Alveolar augmentation benefits the patient by repairing bony dehiscences and fenestrations.
- Rapid tooth movement, reduced treatment time, lesser relapse than conventional orthodontic therapy.
- Additional bone support and improved periodontal status.
- A hospital visit is not required and cost-effective when compared to orthognathic surgery.[23]
- No root resorption reported till date - Ren et al. stated the rapid tooth movement in beagles without any associated root resorption or irreversible pulp injury [24]less furcation invasion, less chance of gingival recession and cervical abrasion following orthodontic therapy.[9]
- PAOO has no effect on the vitality of the pulps of the corticotomized teeth.[24]
- The facial profile does not change or get affected by PAOO.
- The need for appliances and headgear is limited depending on the case.
- Metal and ceramic brackets can be used for orthodontic adjustment.
- PAOO can be done together with temporary anchorage devices to aid in tooth movement.
- In the ten years since PAOO was first applied, the patient's outcomes are good.

**Disadvantages**

- Mildly invasive surgical procedure.
- Risk of pain, swelling, and possibility of infection.
- Patients on long term intake of NSAIDs or who have chronic health problems cannot be treated with PAOO technique.
- PAOO technique cannot be applied in class III malocclusion cases wherein the chin is protruded.

**Modifications in corticotomy**

1. Corticotomy Modification 1 [Figure 2] - Here a monocortical piezosurgery is done. The muco-periosteal flaps are reflected (Redline) followed by the corticotomy cuts given with the help of ultrasonic bone saw (Blackline). "Y" shaped cuts are given in the interdental crest to preserve the alveolar crest (Blackline at the crest).[25]

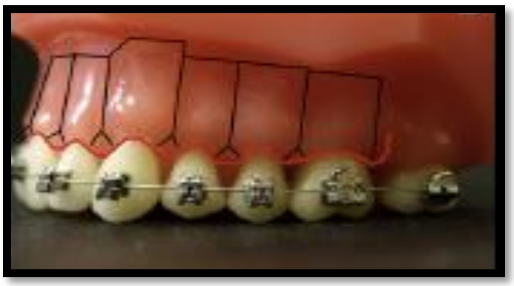

**Figure 2 : Monocortical piezosurgery**

2. Corticotomy modification 2 [Figure 3]-Here monocortical perforations (Black dots) are made in the areas where tooth movement is intended.[25]


**Figure 3 : Monocortical perforations**

3. Corticotomy modification 3 [Figure 4]-Piezocision is a minimally invasive procedure wherein small vertical incisions (Redline) and vertical cuts (Blackline) are given. Bone augmentation is limited (White dot) and is possible through subperiosteal tunneling and injection of graft paste.[25]

**Figure 4: Piezocision**

**Novel approaches**

**Modified corticotomy technique**

Germec and his colleagues in the year 2006 introduced a more conservative approach to accelerate the tooth movement during lower incisors retraction. This approach involved corticotomy cuts that were only given on the buccal aspect and not on the lingual side. This technique was in support of RAP as most of the orthodontic movements explained by RAP involved the labial movement of the teeth.[26]

**Advantages**

- Elimination of the lingual cuts and flap.
- Reduction of surgery time.
- Minimum discomfort to the patient.
- Balanced occlusion and facial esthetics were achieved.

➢ **Lasers**

Laser assisted flapless corticotomy is a novel approach introduced in PAOO as a useful noninvasive procedure. Erbium, Chromium doped Yttrium Scandium Gallium Garnet (Er-Cr: YSGG) laser irradiation, (Waterlase, Biolase, USA) was used to deliver an energy range about 300 mJ at pulse rates of 20 Hz. It helps in reducing treatment time and damage to the periodontium. It activates the tooth movement by reducing the cortical bone layer following Er-Cr: YSGG irradiation without flap reflection. Massoud Seifi in 2012 reported the flapless laser assisted corticotomy to enhance orthodontic tooth movement. [27]

➢ **Monocortical tooth dislocation and ligament distraction (MTDLD) technique**

It works separately on two opposite root surfaces simultaneously. A piezosurgical micro saw is used to perform both horizontal and vertical microsurgical corticotomies as to eliminate the resistance from the cortical bone. Rapid dislocation of the roots and bone is caused by immediate application of strong biomechanical forces.On the root surface the dislocation force produces rapid distraction of ligament fibers opposite the direction of movement. The involvement of periodontal tissue fibers is avoided thereby preventing periodontal and bone resorption. MTDLD technique results in the greatest amount of tooth movement that occurs approximately in the first 30% of total treatment time. [28-30]

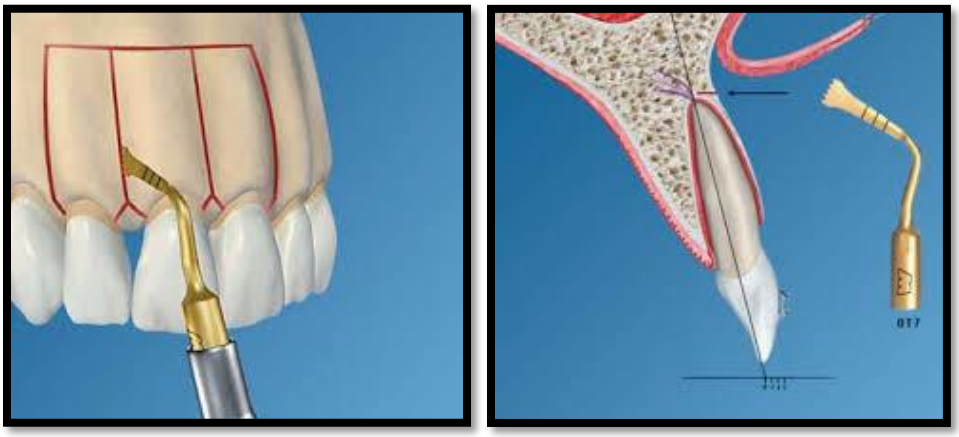

**Figure 5 : Microcorticotomy performed around each tooth and after healing, there is no change in the crestal bone level**

- **Piezocision** –Vercellotti & Podesta (2007) [28] introduced the use of Piezosurgery in conjunction with conventional flap elevations to create an environment conducive to rapid tooth movement. Dibart *et al* (2009) [31] introduced a procedure known as Piezocision (Figure 5), minimally invasive procedure combining micro-incisions, minimal piezoelectric vertical osseous cuts (corticotomies)to buccal cortex only and bone and soft tissue grafting concomitant with tunnel approach. He demonstrated the treatment approach to solve a mild crowding case within 17 weeks.

**Figure 6:Piezocision**

**Disadvantages and limitations**

- Since mucoperiosteal flaps are not reflected, cortical incisions may present a risk of root damage particularly in areas of close root proximity.
- Gingival incisions are to be given with the utmost care. It is very important to keep at least 2 mm from the gingival margin to avoid the formation of the gingival cleft.
- Postoperative scar formation may occur in the case of gingival pigmentation.

- **Micro-Osteoperforations** -This method involves the use of a device called Propel (Figure 6) introduced by Propel Orthodontics. This device aims to reduce the invasive procedure of injury to the bone. Propel is used to create corticotomy cuts by giving micro-osteoperforations. Alikhani et.al. in 2013 studied the effect of tooth movement with micro-osteoperforations.[32]

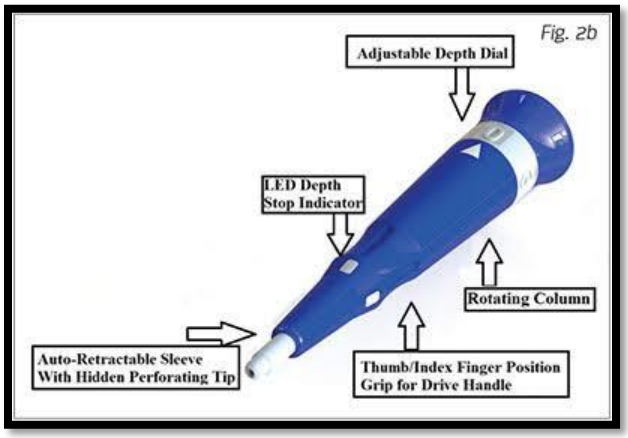


**Figure 7 : Propel device used for micro-osteoperforations**

- **PRF as an adjunct to PAOO**

PRF membranes have been used as an adjunct to PAOO for better postoperative outcomes. A study by Munoz *et al.* in 2016 used leukocyte rich platelet rich fibrin membrane in PAOO and the post-operative pain, inflammation and infection were recorded for 10 days.[33] Dukka in 2018, reported the use of PRF that was used alone without any bone graft in PAOO. He concluded the improvement seen in the soft tissue appearance and keratinized tissue width. [34] However more longitudinal randomized controlled studies are to be carried out to standardize the use of PRF in PAOO[Figure 7,8]

**Figure 8:PRF membrane placed on the surgical site**

## CONCLUSION

PAOO is a clinical procedure that combines selective alveolar corticotomy, particulate bone grafting and the application of orthodontic forces, which not only fastens the orthodontic tooth movement but also provides long term post orthodontic stability and prevents relapse. With the increase in the number of adults seeking orthodontic treatment, PAOO can be used as a treatment modality where it creates an environment conducive for rapid tooth movement. This technique requires a combination of periodontist and an orthodontist for its success. This approach has led to shorter orthodontic treatment duration and great patient acceptance.

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