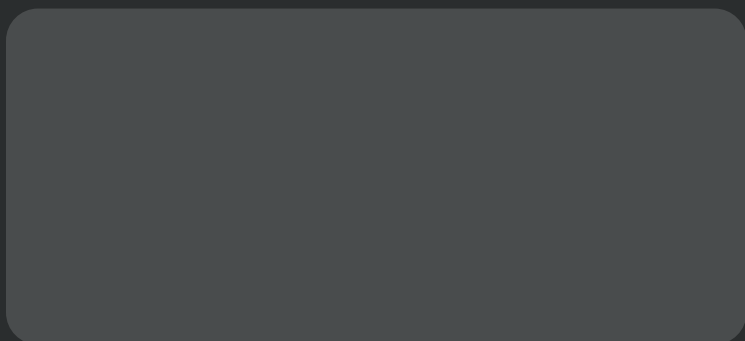




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# A moving target? Periodontally accelerated osteogenic orthodontics (PAOO) for rapid tooth movement

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| PUBLICATION DATE: | JANUARY 2024  |
| EXPIRATION DATE:  | DECEMBER 2027 |

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## Abstract

It is well established that adjunctive surgical activation can increase the rapidity of orthodontic tooth movement and utilization of preorthodontic surgical intervention, as well as reduce rates of root resorption and the need for orthognathic surgery. Orthodontic tooth movement induces bone resorption at the compression side of the tooth and bone deposition at the tension side of the tooth, ultimately resulting in tooth movement in the direction of the compression.

Periodontally accelerated osteogenic orthodontics (PAOO) leverages regional acceleratory phenomenon (RAP) to allow for an increase in sustained, rapid tooth movement. Without tooth movement, the effects of RAP phenomenon generally begin within a few days of injury and typically peak at one to four months. This upregulation of tooth movement can be sustained with ongoing tooth movement from six to 24 months. After completion of orthodontic tooth movement, reestablishment of normal histologic structures and remineralization occur. This course will review the underlying principles of PAOO, ideal case selection, typical case outcomes with PAOO, and the steps and armamentarium for PAOO surgery.

## Educational objectives

Upon completion of this course, the dental professional should be able to:

1. Develop an understanding of the history and rationale for PAOO to accelerate orthodontic therapy.
2. Assess the underlying biological mechanisms that allow for PAOO to improve orthodontic outcomes.
3. Critically evaluate the indications and contraindications for PAOO as an adjunct to traditional orthodontic therapy.
4. Establish an understanding of the surgical and orthodontic protocols for PAOO and potential innovations and treatment alterations.

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## Introduction

Orthodontic therapy enhances facial and dental esthetics, masticatory function, oral airway function, and oral and overall health. Orthodontic tooth movement involves moving teeth through differential pressure and tension on the periodontal ligament with a hyaline layer and subsequent bony resorption occurring on the pressure side and new bone formation occurring on the tension side.<sup>1-3</sup> Dental professionals performing orthodontic tooth movement are consistently assessing techniques to accelerate orthodontic tooth movement and reduce treatment complications.<sup>1-4</sup>

In young patients, orthodontic tooth movement can harness the ongoing growth that they are experiencing, but once significant growth of the alveolar processes ceases in adult patients, other techniques must be considered to enhance orthodontic tooth movement. These may include direct anchorage through temporary anchorage devices (TADs), orthognathic surgery in conjunction with orthodontic tooth movement, and/or surgically assisted orthodontic tooth movement.<sup>5-8</sup>

Currently, approximately one in four patients seeking orthodontic tooth movement are adults who have completed growth.<sup>9</sup> Such adult patients experience an increased chance of hyalinization and subsequent impaired tooth movement during treatment as a result of slower precursor cell recruitment and collagen turnover.<sup>10,11</sup> Due to such challenges in treating adults, including suture fusion and lack of ongoing growth, an interest in surgical therapies to accelerate orthodontic tooth movement has been increasing. The use of surgically assisted orthodontic therapy can reduce treatment time, risk of root resorption, and the need for orthognathic surgery.

## History of surgically assisted orthodontic tooth movement

Surgically assisted orthodontic tooth movement was initially introduced to dental practice in the 1800s. Corticotomies and mobilization of individual teeth within the dental arch was first described by L. C. Bryan in 1893, and this technique was then combined with orthodontic appliances for an increased rapidity of tooth movement in 1959.<sup>12</sup> At that time,

it was believed that the cortical alveolar bone caused the primary resistance to orthodontic tooth movement within the alveolar housing. To reduce this resistance, elevation of full-thickness mucoperiosteal flaps and interradicular cuts through the dense cortical bone and just into the cancellous bone (corticotomies) with subapical osteotomy cuts were proposed.<sup>12,13</sup>

While this technique was effective in increasing the rapidity of tooth movement, it was also very invasive, and this limited its adoption. In 1995, Wilcko et al. introduced a strategy to improve on the previous techniques and combined corticotomies and particulate alveolar grafting.<sup>14-16</sup> They called this technique “accelerated osteogenic orthodontics” (AOO), which later was adapted into “periodontally accelerated osteogenic orthodontics” (PAOO) and “surgically facilitated orthodontic treatment” (SFOT).<sup>2,7,8,14-16</sup>

## Biological mechanisms underlying PAOO

While there are subtle differences between AOO, PAOO, and SFOT techniques, notably with an evolution toward less and less

| Tension side     | Othodontics only                                                                                                                                              | PAOO                                                                                                                                                                                                                                                 |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Week 1-2         | Newly formed woven bone is observed. No collagen fiber degeneration was seen near the bone surface.                                                           | PDL is widened with dilated blood vessels. Newly formed bone with numerous osteocytes and wide marrow spaces are observed. This bone is thicker and less regular than in the orthodontic only group. Collagen fiber degeneration is seen in the PDL. |
| Week 3-4         | Mature collagen fibers only.                                                                                                                                  | Haphazard arrangement of the mature collagen fiber bundles in the PDL interlaced with immature fibers, especially in the intermediate zone. Thicker bone formation is observed.                                                                      |
| Week 6+          | Normal collagen fiber bundles in both groups. Woven bone is observed with wide marrow spaces.                                                                 | Bone has greater bulk and is lamellar with many osteoblasts on the bone surface.                                                                                                                                                                     |
| Compression side | Othodontics only                                                                                                                                              | PAOO                                                                                                                                                                                                                                                 |
| Week 1-2         | PDL narrowed and the fiber bundles are haphazard and condensed. Thin interseptal bone is surrounded by a layer of osteoblasts.                                | PDL is widened and the interseptal bone resorbed with sporadic bone remaining scattered in the PDL. PDL joined the extraction site, which was filled with dilated blood vessels.                                                                     |
| Week 3-4         | PDL narrow and consisted of mature and immature collagen fiber bundles. The bone is near normal with wide marrow spaces.                                      | PDL is mature and arranged regularly. The extraction site consists of thick woven bone with many reversal lines. Continuation of PDL with the extraction site.                                                                                       |
| Week 6+          | Fewer osteoclasts are seen. PDL turnover is seen mainly in the intermediate zone with hyalinization observed. The bone in the extraction site is still woven. | Direct resorption of the bone surface is seen, with dilated blood vessels at the bone surface. Lamellar bone is present at the extraction site.                                                                                                      |

**FIGURE 1:** Comparison of histologic findings with conventional orthodontics and PAOO at various time frames

invasive treatment, the biology underlying these therapies is consistent. All of the currently utilized surgically facilitated orthodontic techniques harness a healing event called “regional acceleratory phenomenon” (RAP), which results in acceleration of regional healing processes after injury.<sup>17</sup> RAP was first described by Frost in 1983 and usually occurs after a fracture, arthrodesis, osteotomy, or bone-grafting procedure.<sup>18,19</sup> In the case of acute local injury, local inflammation and upregulation of pro-inflammatory markers are observed.<sup>17-19</sup> This inflammation then results in activation of tissue precursor cells necessary for wound healing, which is concentrated at the site of injury.<sup>17-20</sup>

RAP is not considered a separate healing event, but can expedite hard- and soft-tissue healing stages by between two and tenfold.<sup>21</sup> The bone resorption and deposition in all orthodontic tooth movement is mediated by the coupled receptor activator of NF- $\kappa$ B ligand (RANKL) activation of osteoblast/osteoclast precursor cells.<sup>22,23</sup> PAOO allows for an increase in this activation through acute inflammation after creation of a surgical wound within the bony structure utilizing RAP healing. Both the decreased regional bone density and accelerated bone turnover seen at RAP healing events are believed to facilitate orthodontic tooth movement.<sup>24,25</sup>

RAP begins within a few days of injury and typically peaks at 30 to 60 days. The duration of RAP after injury is typically between four and six months, although it may take more than 24 months to abate.<sup>14,17</sup> There is evidence that active orthodontic tooth movement can prolong RAP, and when RAP concludes, normal histologic bone structures are re-formed, including alveolar remineralization (**figure 1**).<sup>17,20</sup>

### Case selection for PAOO

PAOO has demonstrated success when used to accelerate tooth movement in many of the applications of orthodontic tooth movement. In particular, PAOO has shown efficacy when used to accelerate the treatment of moderate to severe dental crowding, in class II malocclusions requiring arch expansion, and in mild to moderate class III malocclusions.<sup>2,14,26,27</sup> PAOO has also been used with both standard brackets and orthodontic aligners and in both the maxillary and mandibular arches.

Clinical judgment should also be applied when PAOO is considered for use. For instance, there may be more utility in using PAOO in adults versus children due to the reduced risk of hyalinization when PAOO is used and due to the difficulty of certain types of tooth movement in adults. Further, given the anticipated

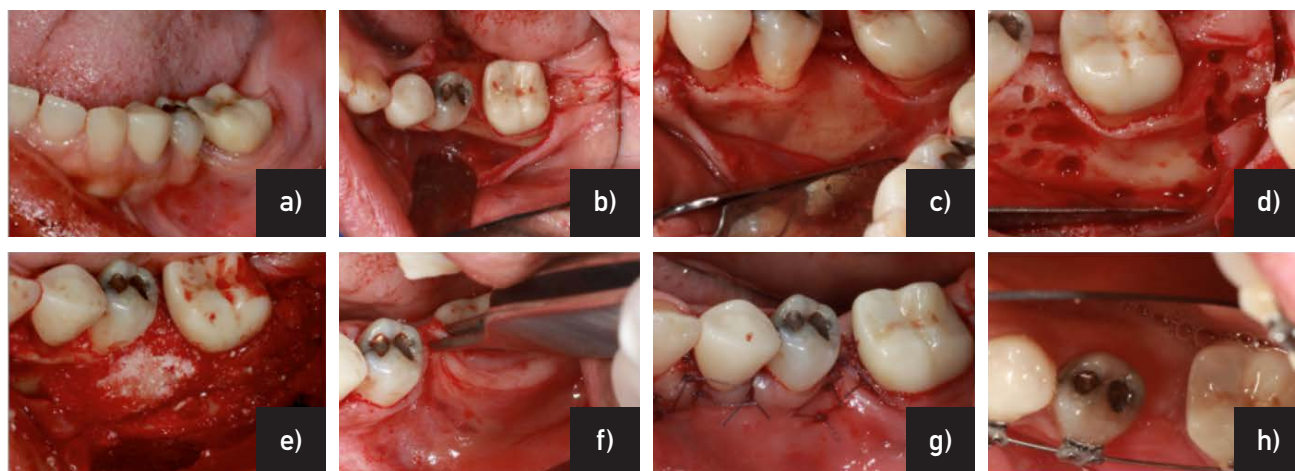
time frames for tooth movement, PAOO may be employed in one arch and omitted in the other.

For example, in a patient requiring both maxillary expansion and treatment of mild to moderate mandibular crowding, utilizing PAOO in the maxillary arch to accelerate treatment and align the treatment time frame between arches may be advantageous. Further, if molar uprighting and/or protraction are planned adjacent to an edentulous site where ridge augmentation is planned, coordination of treatment to harness RAP can allow application of PAOO and acceleration of tooth movement without any additional surgical therapy. PAOO may also be considered in cases where phenotype modification through dentoalveolar bone augmentation would be advantageous to promote postorthodontic stability. Additionally, PAOO may be used in combination with other orthodontic treatment devices and treatments, including orthognathic surgery and TADs.

### PAOO surgical technique

The surgical aspect of PAOO requires the precise execution of surgical technique, including flap design and elevation, cortical perforations, bone replacement grafting, and flap closure (**figure 2**).<sup>3,14,27,28</sup>

**Flap design and elevation:** Flap design must extend to allow access to all



**FIGURE 2:** Molar uprighting adjacent to an edentulous area allowed for combined treatment with lateral ridge augmentation and local PAOO harnessing RAP: **a)** Initial presentation with inadequate bone volume and mesio-distal space at no. 19 for implant placement with mesially inclined no. 18; **b)** Sulcular and crestal incisions made at surgical site nos. 18–21; **c)** Full-thickness flaps elevated at surgical site nos. 18–20; **d)** Cortical perforations accomplished with high-speed round bur; **e)** Treated sites with onlay hard-tissue graft materials (anorganic bovine bone matrix [ABBM] and freeze-dried bone allograft [FDBA]); **f)** Periosteal release performed to allow tension-free closure; **g)** Flaps reapproximated and sutured with polygalactin sutures; **h)** Six months postoperative and postorthodontic tooth movement

areas planned for treatment so that cortical perforations can be accomplished to initiate RAP. Typically, the flap design is a combination of full thickness and partial thickness.<sup>28</sup> The coronal aspect of the flap, from the gingival margin to the apical extent of the planned decortifications, is a full-thickness flap. The more apical portion of the flap is a partial-thickness dissection to provide the release necessary to allow for placement of graft materials and tension-free closure. Further, attention should be paid to the esthetic concerns with the interdental papilla between maxillary central incisors released via a tunneling technique, but not severed, which can allow for a reduced risk of papillary loss and esthetic compromise at this critical area. Consideration of periodontal and gingival phenotype may inform decision-making with regard to adjunctive hard- and/or soft-tissue augmentation. Cases with thin gingival phenotype (e.g., < 0.8 mm gingival thickness) may result in esthetic compromise, and phenotype modification should be considered.<sup>26,28</sup>

**Cortical perforations:** Cortical perforation, or decortication, references the injury and removal of the cortical bone. This is performed to induce the RAP healing effect and is not meant to result in mobilization of individual tooth segments or to allow for mechanical stability of the graft materials. For this reason, such perforations should be limited to what is needed to achieve local traumatic injury and induce regional inflammation and local osteopenia. After flap elevation, decortication of the bone adjacent to the malpositioned teeth of interest can be performed with low- or high-speed handpieces, piezoelectric saws, hard-tissue cutting lasers, and/or specialized perforation instruments.<sup>14,26,28,29</sup> Care should be taken to just enter the cancellous bone and avoid critical oral structures, including tooth roots, the maxillary sinus, and the mandibular canal. Such cortical penetrations may be placed on the buccal and/or lingual aspects of the alveolar bone based upon the directionality of the planned tooth movement, overall alveolar bone architecture, and periodontal phenotype.

**Bone replacement grafting:** While bone grafting is not necessary to harness

RAP healing and accelerate tooth movement, the addition of bone replacement graft materials can allow for orthodontic tooth movement with a reduced risk of gingival recession. This may be especially important in the case of orthodontic tooth movement in patients with a thin periodontal phenotype.<sup>30-33</sup> It is well established that a thin periodontal phenotype is a risk factor for subsequent gingival recession.<sup>32,33</sup> In such patients in particular, labial tooth movements can result in bony dehiscences and, in turn, increase the risk for gingival recession.<sup>2,32,33</sup>

The materials most commonly used for such bone replacement grafting include xenograft materials, such as anorganic bovine bone matrix, autogenous bone, and both mineralized and demineralized allograft materials.<sup>28</sup> Composite grafts using a combination of these materials are also commonly employed.<sup>28</sup> When grafting is used, graft materials are placed at all areas of cortical perforations. The volume of graft materials may vary based upon the anticipated direction and amount of tooth movement and facial contours and desired final labial support. A typical volume of graft materials used may range from 0.25 mL to 0.5 mL of graft per tooth to be treated.<sup>28</sup>

**Flap closure:** Tension-free flap closure should be achieved with flap eversion. Practitioners may use a double-layer suturing technique with mattress sutures to approximate flaps and then closure sutures (e.g., interrupted sutures) to ensure primary closure. Nonresorbable sutures that can remain in place with low levels of plaque accumulation for up to 14 days are ideal for such an application.<sup>28</sup>

### Timing of orthodontic treatment after PAOO surgical therapy

Activation of orthodontic tooth movement that allows harnessing of the initial inflammatory response is critical to maximizing the benefits from PAOO. Generally, orthodontic bracket placement and activation of orthodontic arch wires occur approximately one week prior to surgical intervention. This may be delayed, however. For example, if fixed orthodontic appliances will interfere with surgical access and/or adjunctive mucogingival

procedures, the placement of orthodontic appliances may be delayed until after surgical treatments.

After completion of surgical therapies, activation of heavy orthodontic forces can be immediately initiated. It is advisable that activation is not delayed more than two weeks after surgery, as a longer delay will not allow practitioners to take full advantage of the period of most acute inflammation during the time frame that RAP is occurring. Significantly accelerated orthodontic tooth movement can generally be accomplished for approximately four to six months, so it is imperative that major movements are done during this period.<sup>28</sup> After six months, finishing movements will generally occur at a similar speed as movements without surgical intervention. Given that the opportunity for accelerated movement is limited, arch wire sizes should be advanced rapidly, and the initial arch wire engaged should be the largest arch wire possible. Further, arch wire changes should likely occur more frequently throughout the period of accelerated tooth movement.

### Indications and contraindications for PAOO

#### Patient selection/case evaluation:

While patients of any age with planned orthodontic tooth movement and a healthy periodontium may be candidates for PAOO, the use of surgical treatment to accelerate and facilitate orthodontic tooth movement may be particularly impactful in adult patients due to the increased risk of hyalinization during orthodontic tooth movement, which can arrest and/or slow treatment.<sup>33-36</sup> Careful patient assessment is necessary to select optimal cases for PAOO. Patients who will derive the most benefit from PAOO are those in whom conventional orthodontic therapy has significant limitations, including extended treatment duration, difficulty in facilitation of tooth movement, thin periodontal phenotype in cases where grafting may be indicated, and in patients who may be prone to root resorption.<sup>33-36</sup> Examples of cases in which PAOO may provide significant benefit include those with:

- Angle's class I malocclusion with moderate to severe crowding

- Angle's class II malocclusion cases planned for extraction therapy
- Mild Angle's class III cases
- Aid in eruption and positioning of impacted teeth
- Molar intrusion and open-bite correction
- Accelerate slow orthodontic arch expansion
- Molar uprighting and/or distalization

PAOO may be used adjunctively in palatal expansion cases after suture fusion with surgical palatal suture treatment and/or in conjunction with orthodontic anchorage devices in this and other cases.<sup>37</sup> However, not all patients are ideal candidates for PAOO. Orthodontic tooth movement should not be undertaken in individuals with active periodontal disease and/or suboptimal plaque control. PAOO is also contraindicated in individuals with severe Angle's class III malocclusion, and it should not be considered in cases with bimaxillary protrusion and excessive gingival display in which segmental osteotomy may provide greater benefit.<sup>5,38</sup> Additionally, in cases of severe discrepancies between the jaws, orthognathic surgery may be required for optimal occlusal relationships.

Further, PAOO is contraindicated in patients with uncontrolled systemic conditions that can compromise healing, including diabetes mellitus, osteoporosis, compromised immune function, and bone metabolic diseases. Finally, chronic use of some systemic medications that impair bone metabolism may limit the efficacy of PAOO. Such medications include anti-inflammatory and antirheumatic medications, corticosteroids, bisphosphonates, and NSAIDs.<sup>5</sup> Clinical judgment should be used to select patients for whom PAOO will provide the best risk-benefit ratio.

Currently, the Commission on Dental Accreditation (CODA) for both orthodontic and periodontal residency training includes interdisciplinary training (and in most instances, understanding of the principles of PAOO).<sup>39,40</sup> Referral patterns often involve identification of malocclusion by the treating general dentist and evaluation of treatment concerns and goals prior to referral to an orthodontist for a primary evaluation. Further interdisciplinary treatment would likely involve the general

dentist, orthodontist, and a periodontist or oral surgeon. Coordination of care and interdisciplinary treatment planning are critical for optimal outcomes.

**Potential treatment complications and side effects:** PAOO has many advantages, but there are potential pitfalls and complications that may be experienced.<sup>5,38</sup> PAOO adds costs associated with the surgical procedures and grafting. While PAOO may be less invasive than orthognathic surgery and/or surgically assisted expansion, since it still involves surgical treatment, postoperative edema, discomfort, and/or hematoma may be experienced. Further, any elevation of a full-thickness mucoperiosteal flap can result in a small amount of bone resorption and/or gingival recession, particularly without adjunctive hard- and soft-tissue grafting during the surgical procedures. If cortical perforations are particularly aggressive, the subsequent local inflammation and osteopenia could result in increased bone resorption and uncoupling of bone resorption and deposition.<sup>5,38</sup> This uncoupling may be particularly deleterious in cases with high levels of gingival inflammation and/or undiagnosed active periodontal disease.

Animal studies have demonstrated maintenance of pulp vitality and no increase in rates of root resorption when PAOO is performed when compared to standard orthodontic tooth movement.<sup>41</sup> In human studies, PAOO-associated rapid maxillary molar intrusion resulted in a mean of 3.0 mm intrusion in two months without root resorption.<sup>42</sup> Increased root resorption has been associated with the duration of orthodontic tooth movement, and it may be that shortened treatment times associated with PAOO therapy reduces the risk of root resorption.<sup>43</sup> Finally, the accelerated tooth movement associated with PAOO requires more frequent dental visits for patients, which may not be desirable to some patients and/or practice locations.

### Indications for alterations to PAOO protocols

When PAOO was developed, the vast majority of orthodontic tooth movement was accomplished with fixed orthodontic

brackets and wires, but the evolution of clear aligner tooth movement has meant a large increase in the number of cases of orthodontic tooth movement performed with clear aligners annually. In fact, the global clear orthodontic aligner market is projected to grow nearly 20% between 2021 and 2028.<sup>44,45</sup> Clear aligners may be preferred by patients due to their esthetic appearance and the increased access for delivery of oral hygiene, but orthodontic tooth movement is reliant on patient compliance with aligner use.

Given how common the use of clear aligners to accomplish orthodontic tooth movement has become and that we anticipate that their use will continue to be prevalent, understanding how PAOO may be altered for clear aligner-assisted tooth movement is critical. PAOO has been successfully used with both fixed orthodontic appliances and removable clear aligners. Since the underlying forces used for orthodontic tooth movement are the same regardless of the method of orthodontic appliances used, harnessing RAP healing can be used to accelerate tooth movement in both situations. Further, clear aligners may allow for improved surgical access for PAOO when compared to fixed orthodontic appliances.

There are alterations that need to be made when clear aligners are planned. Since clear aligners cannot use heavy wires, they must be designed with an increased amount of activation forces during the initial postsurgical period. Patients must also move through aligners more rapidly, and for such patients, more frequent dental visits once tooth movement is initiated may be required to determine the proper amount of time for aligner wear and the number of aligners that should be used to accomplish the planned tooth movement.<sup>44-46</sup> It has also been suggested that, in some patients, particularly in those with a history of periodontal disease and/or high potential for plaque retention, clear aligners may allow for improved access for home care and more optimal plaque control. In such cases, aligners should be designed to reduce gingival stimulation and irritation and allow access for oral hygiene measures.<sup>46</sup>

While PAOO includes the use of particulate bone grafting, adjunctive soft-tissue grafting has also been proposed in cases where the preexisting periodontal phenotype and planned tooth movement may predispose patients and/or sites to gingival recession. The use of concurrent hard- and soft-tissue grafting has been demonstrated to limit and/or avoid gingival recession after completion of orthodontic tooth movement and allow for a healthier long-term result.<sup>33,46</sup> In a recent report, adjunctive hard- and soft-tissue grafting with PAOO improved both the gingival thickness and gingival recession as well as radiographic buccal bone thickness on cone beam computed tomography (CBCT).<sup>30,31,33</sup>

Harnessing RAP during healing may be particularly advantageous in adults, but these patients present with higher likelihoods of periodontitis and more complex medical histories, which may require staged dental treatment to establish periodontal health prior to active tooth movement and more frequent maintenance visits during treatment. Additionally, it is well established that if PAOO is used to enhance treatment, accelerated tooth movement occurs in the initial four to six months. It is also important to consider that many adults may have a more truncated period of RAP effectiveness and thus require more than one PAOO surgery in complex cases and/or cases that require extended or phased tooth movement.

### Clinical decision-making for the use of PAOO

When considering cases to be treated with PAOO, clinicians should always begin therapy with a comprehensive dental examination to determine any other active dental diseases or conditions, such as periodontitis, that may need to be addressed prior to initiation of active tooth movement. Further, assessment of the overall dental treatment plan as well as the need for orthodontic tooth movement should be undertaken prior to determining the advantages of PAOO. This is particularly critical if surgical treatment may be required to treat other dental needs and/or to develop sites for tooth replacement. In these cases, combining

PAOO procedures with other surgical procedures may limit disadvantages and side effects associated with surgical access required for PAOO.<sup>33,46</sup>

PAOO may also be advantageous for enhancing the effectiveness of tooth movements where incomplete or compromised results are expected. Review of the time frames and directions of tooth movement to determine the most advantageous areas to be treated in conjunction with PAOO should be performed during the initial treatment planning phase. Such considerations may include PAOO treatment in only one arch, if that arch requires more extensive tooth movement to allow for simultaneous leveling and aligning of both arches and overall reduction in treatment time. It is also important to determine the need for potential adjunctive hard- and soft-tissue grafting, especially in individuals with a thin periodontal phenotype.

### Conclusion

The role of the periodontal ligament and inflammation in bone remodeling associated with orthodontic tooth movement allows for the potential of accelerated tooth movement when a healing phenomenon, RAP, is initiated through surgical injury to the alveolar bone. Periodontally accelerated osteogenic orthodontics or other similar procedures that utilize RAP during tooth movement can result in shortened treatment time, accelerated and/or enhanced tooth movement, phenotype enhancement, and reduced rates of root resorption. While PAOO has been employed to augment many forms of orthodontic treatment, optimal clinical case types and long-term advantages and disadvantages may require further study in the future.

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## QUESTIONS

1. Approximately what percentage of current orthodontic patients are adults?
  - A. 10%
  - B. 25%
  - C. 40%
  - D. 55%
2. What does the acronym "RAP" stand for?
  - A. Rapid acceleration protocol
  - B. Rapid accumulation phenotype
  - C. Regional acceleratory phenomenon
  - D. Regional application protocol
3. Which of the following statements is not true about RAP?
  - A. RAP was first described by Frost in 1965.
  - B. RAP usually occurs after a fracture, arthrodesis, osteotomy, or bone-grafting procedure.
  - C. After acute local injury, RAP is initiated through local inflammation, and upregulation of pro-inflammatory markers are observed.
  - D. Local inflammation due to RAP results in activation of tissue precursor cells necessary for wound healing, which is concentrated at the site of injury.
4. RAP can expedite hard- and soft-tissue healing stages by between \_\_\_\_-fold.
  - A. 1.5 and 2
  - B. 2 and 10
  - C. 5 and 12
  - D. 18 and 20
5. RAP begins within a few days of injury and typically peaks at \_\_\_\_ days.
  - A. 7–10
  - B. 14–28
  - C. 21–30
  - D. 30–60
6. The duration of RAP after injury is typically between four and six months. It may take more than 24 months to abate.
  - A. Both statements are true.
  - B. The first statement is true; the second statement is false.
  - C. The first statement is false; the second statement is true.
  - D. Both statements are false.
7. PAOO can be employed with both standard brackets and orthodontic aligners. PAOO should only be used in the maxillary arch.
  - A. Both statements are true.
  - B. The first statement is true; the second statement is false.
  - C. The first statement is false; the second statement is true.
  - D. Both statements are false.
8. When dental professionals are considering the utility of PAOO in individual patients, in those patients with \_\_\_\_ anticipated time frames for tooth movement for both arches, utilization of PAOO in the \_\_\_\_ arch may align the treatment times between arches.
  - A. Similar; maxillary
  - B. Different; shorter treatment time
  - C. Different; longer treatment time
  - D. Similar; mandibular
9. PAOO requires surgical flap elevation, and the flap design must extend to allow access to all areas planned for treatment because:
  - A. Access must be gained to all teeth to allow for segmental corticotomies and mobilization of teeth.
  - B. PAOO requires apical flap positioning to result in exposure of more tooth structure.
  - C. Exposure of bone is required for the placement of TADs.
  - D. Access to the alveolar process allows for cortical perforations to initiate RAP.
10. Flap elevation for PAOO generally employs both full- and partial-thickness flaps. The coronal aspect of the flap is a partial-thickness flap while the more apical portion of the flap is full thickness.
  - A. Both statements are true.
  - B. The first statement is true; the second statement is false.
  - C. The first statement is false; the second statement is true.
  - D. Both statements are false.
11. After flap elevation, which of the following cannot be routinely used to perform decortication of the bone adjacent to the malpositioned teeth of interest for PAOO?
  - A. Low- or high-speed handpieces
  - B. Bone chisel hand instruments
  - C. Piezoelectric saws
  - D. Hard-tissue cutting lasers
12. Which of the following is not true about the performance of cortical perforation for PAOO?
  - A. Cortical perforation should just enter the cancellous bone.
  - B. Cortical perforation should be positioned to avoid critical oral structures.
  - C. Cortical perforation should be positioned on the lingual aspects of the alveolar bone only.
  - D. Cortical perforation should be placed on alveolar bone surfaces based upon the directionality of planned tooth movement.
13. Bone grafting after cortical perforation is \_\_\_\_ to induce RAP healing and accelerate tooth movement.
  - A. Preferred
  - B. Necessary
  - C. Not necessary
  - D. Disadvantageous
14. A typical volume of graft materials used may range between \_\_\_\_ mL of graft per tooth to be treated.
  - A. 0.25 and 0.5
  - B. 0.5 and 0.75
  - C. 0.75 and 1.0
  - D. 1.0 and 2.0
15. Placement of orthodontic brackets and activation of orthodontic arch wires ideally would occur:
  - A. Approximately one week prior to PAOO surgery
  - B. Simultaneous with PAOO surgery
  - C. Approximately two weeks after PAOO surgery
  - D. Approximately 30 days after PAOO surgery
16. After PAOO surgery, arch wire sizes should be advanced rapidly, and the initial arch wire engaged should be the smallest arch wire possible. Arch wire changes should occur more frequently throughout the period of accelerated tooth movement.
  - A. Both statements are true.
  - B. The first statement is true; the second statement is false.
  - C. The first statement is false; the second statement is true.
  - D. Both statements are false.

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## QUESTIONS

17. PAOO contraindications include all of the following except:
  - A. Severe Angle's class III malocclusion
  - B. Patients with severe discrepancies between the jaws where orthognathic surgery may be required for optimal occlusal relationships
  - C. Patients with bimaxillary protrusion and excessive gingival display in whom segmental osteotomy may provide greater benefit
  - D. Molar uprighting and/or distalization
18. Chronic use of some systemic medications that impair bone metabolism may limit the efficacy of PAOO. Such medications include:
  - A. Anti-inflammatory and antirheumatic medications
  - B. Corticosteroids
  - C. Bisphosphonates
  - D. All of the above may impair the benefits of PAOO.
19. Which of the following is not an adverse postoperative event associated with PAOO?
  - A. Postoperative edema
  - B. Postoperative discomfort
  - C. Hematoma formation
  - D. All of the above are potential postoperative adverse events.
20. Overly aggressive cortical perforations can result in:
  - A. No changes
  - B. Increased bone resorption due to uncoupling of bone resorption and deposition
  - C. More rapid onset of RAP and early acceleration of tooth movement
  - D. An extended period of RAP and longer duration of tooth movement
21. Animal studies have demonstrated \_\_\_\_ pulp vitality and \_\_\_\_ rates of root resorption when PAOO is performed compared to standard orthodontic tooth movement.
  - A. Decreased; increased
  - B. No changes in; decreased
  - C. No changes in; similar
  - D. Decreased; decreased
22. In human studies, PAOO-associated rapid maxillary molar intrusion resulted in a mean of \_\_\_\_ mm intrusion in two months and \_\_\_\_ root resorption.
  - A. 1.0; increased
  - B. 3.0; no noted
  - C. 3.0; increased
  - D. 5.0; no noted
23. The global clear orthodontic aligner market is projected to grow nearly \_\_\_\_ between 2021 and 2028.
  - A. 20%
  - B. 40%
  - C. 50%
  - D. 100%
24. Benefits of using clear aligners for orthodontic tooth movement include:
  - A. Increased esthetics
  - B. Improved access for delivery of oral home care procedures
  - C. No fixed brackets that can limit surgical access for delivery of PAOO
  - D. All of the above
25. Which of the following is not a necessary alteration in PAOO protocols when clear aligners are to be used?
  - A. Clear aligners must be designed with an increased amount of activation forces during the initial postsurgical period.
  - B. Patients must move through aligners more rapidly.
  - C. Surgical procedures should be altered to eliminate cortical perforations.
  - D. For patients with a high propensity for plaque accumulation and/or gingival inflammation, aligners should be designed to reduce gingival stimulation and allow oral hygiene access.
26. Simultaneous adjunctive use of soft-tissue grafting with other PAOO procedures has been proposed to reduce the risks of gingival recession after orthodontic tooth movement. In a recent report, adjunctive hard- and soft-tissue grafting with PAOO improved both the gingival thickness and gingival recession as well as radiographic buccal bone thickness on cone beam computed tomography (CBCT).
  - A. Both statements are true.
  - B. The first statement is true; the second statement is false.
  - C. The first statement is false; the second statement is true.
  - D. Both statements are false.
27. Considerations for utilization of PAOO in adult patients include:
  - A. Harnessing ongoing growth during orthodontic interventions
  - B. Increased likelihood of significant medical history and/or periodontitis
  - C. PAOO may induce an extended period of RAP in adults compared to younger patients
  - D. All of the above
28. Utilization of a multidisciplinary treatment plan to allow for clinical decision-making for PAOO includes:
  - A. Understanding the expected time frames for planned orthodontic tooth movement
  - B. Additional dental/surgical needs
  - C. Medical history that may impact bone turnover and RAP
  - D. All of the above
29. Adjunctive hard- and/or soft-tissue grafting performed with surgical access may be particularly impactful in which of the following types of patients?
  - A. Younger patients
  - B. Patients with a thin periodontal phenotype
  - C. Patients in whom incomplete or prolonged tooth movement may be expected
  - D. Patients with active periodontitis
30. Which of the following is not a potential advantage of PAOO or other similar interventions using RAP to augment orthodontic tooth movement?
  - A. Shortened treatment time
  - B. Phenotype enhancement
  - C. Improved gingival and periodontal health
  - D. Reduced rates of root resorption

# A moving target? Periodontally accelerated osteogenic orthodontics (PAOO) for rapid tooth movement

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## Educational Objectives

- Develop an understanding of the history and rationale for PAOO to accelerate orthodontic therapy.
- Assess the underlying biological mechanisms that allow for PAOO to improve orthodontic outcomes.
- Critically evaluate the indications and contraindications for PAOO as an adjunct to traditional orthodontic therapy.
- Establish an understanding of the surgical and orthodontic protocols for PAOO and potential innovations and treatment alterations.

## Course Evaluation

- Were the individual course objectives met?  
Objective #1: Yes No      Objective #3: Yes No  
Objective #2: Yes No      Objective #4: Yes No

Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

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