CASE REPORT

Novel Application of Micro-Osteoperforations During Treatment of Severe Malocclusion

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ABSTRACT

Patients with extreme skeletal Class II Division 2 malocclusion suffer from excessive retroclination of maxillary and mandibular anterior teeth. In these cases, a severe deep bite can affect both the growth and position of the mandible and may cause significant gingival recession due to trauma. Because of the severity of the problem, treating these patients is a medical necessity that not only improves the patient's overall health, but also significantly impacts their appearance and social life. However, orthodontic treatment in these patients carries its own risk since intrusion and root movement of anterior teeth may make patients susceptible to severe root resorption. This resorption is affected by the density of the surrounding bone, which may slow the rate of tooth movement, thereby prolonging root exposure to orthodontic forces. In this report, we demonstrate for the first time the use of micro-osteoperforations (MOPs) as a preventive measure against root resorption in an adult male with a severe Class II Division 2 malocclusion. We hypothesize that the root protective effect of MOPs is due to the fact that MOPs increases the rate of bone remodeling and temporarily decreases the bone density around the teeth, thereby, facilitating root movement through less dense alveolar bone. In the case presented here, the patient required significant intrusion and root movement of the maxillary anterior teeth. MOPs were applied frequently to facilitate this difficult movement. Maxillary and mandibular anterior teeth underwent significant intrusion and proclination, yet no root shortening was measured from CBCT images. This case demonstrates a role for MOPs as a method to decrease the probability of root resorption when significant root movement through dense alveolar bone is necessary.

Background

During orthodontic tooth movement, activated osteoclasts and odontoclasts resorb bone and cementum, respectively, and produce small craters (lacunae) on the surface of the alveolar bone and dental roots. Most of the time these small craters are temporary and both bone and root structures are restored after removal of orthodontic forces. However, if odontoclast-mediated resorption is excessive, the changes in root structure may not be reversible and permanent damage in the form of root resorption may occur, jeopardizing the longevity of the tooth. This root resorption often appears as root shortening in radiographs.

Numerous patient- and treatment- related factors are potential etiologies of root resorption [1]. These factors may appear individually, sequentially or simultaneously, complicating the risk assessment for root resorption in any given orthodontics patient. For example, among the patient-related factors is high bone density that leads to slow tooth movement. This could potentially trigger two treatment-related factors [2, 3]: increased duration of dental root exposure to orthodontics forces, and increased force magnitude applied to the teeth by a frustrated clinician.

The effect of bone density can be especially appreciated in adults with higher bone density, when an orthodontist applies an orthodontic force to intrude anterior teeth [4, 5], or during root movement in dense alveolar bone, including mesial-distal movement, up-righting or torque movements [6-10]. The effect of bone density is even more evident in children, who show lower bone density, faster tooth movement [11] and less root resorption when compared to adults [12-14].

In addition to odontoclast-mediated resorption, root resorption in response to prolonged application of orthodontic forces in dense alveolar bone results from the formation of acellular necrotic regions (cell-free zones) in the periodontal ligament (PDL), which require osteoclast recruitment to clear the path for tooth movement. Any delay in clearing the necrotic area due to dense alveolar bone will prolong the presence of osteoclast and odontoclast in the area and increase the possibility of attack on adjacent root structure [15-18].

Based on the discussion above, one can reason that any procedure that decreases alveolar bone density should decrease the duration of treatment and prevent unnecessary exposure to lingering and high-magnitude orthodontics forces, and therefore, have a protective effect against root resorption. Micro-osteoperforations (MOPs) is a procedure that locally decreases alveolar bone density and increases the rate of tooth movement. While this procedure has been recommended for different purposes, such as accelerated orthodontics and biological anchorage [15], it is not clear if it can help decrease or prevent root resorption.

Here we present an adult male with a severe Class II Division 2 malocclusion. The severity of the problem has affected the position of the mandible and has caused significant recession of the gingiva around the mandibular anterior teeth, due to an impinging bite, with a negative impact on the patient's overall appearance. Treatment of this malocclusion required significant intrusion and root movement of the maxillary and mandibular anterior teeth, which could expose the patient to root resorption considering his age and quality of his alveolar bone. Personalized mechanics in this case was required to decrease unnecessary root movement. To achieve this, MOPs was recommended to increase the rate of bone remodeling, thereby facilitating the biological response to orthodontic forces and decreasing the probability of root resorption.

Patient Presentation, Etiology and Diagnosis

A healthy 35.11-year-old male presented to our clinic with a chief concern of unsatisfactory esthetic appearance due to misaligned teeth and retrusive chin. The patient reported muscular tenderness and TMJ pain associated with clicking on both joints during opening and closing. The patient had no history of trauma.

Extraoral examination and frontal portrait photographs (Figure 1) show a brachyfacial pattern and a decreased lower facial third. No facial asymmetry, mentalis strain or lip incompetence at rest were observed.

The lateral portrait photographs (Figure 1) show a convex profile with deficient maxillary and mandibular lips relative to the E-line. The nasolabial and chin-to-throat angle were obtuse (135.4^o and 142.3^o, respectively), but the labiomental angle was acute (55.1^o) (Table I). The patient's full smile was broad with increased buccal corridor width and 100% incisal display.

Intraoral examination (Figure 1) showed fair oral hygiene and normal frenum attachments. Severe retroclination of the maxillary anterior teeth and noticeable gingival recession around the mandibular anterior teeth was noted. The patient's third molars were previously extracted. The maxillary midline was deviated 1.5 mm toward the left with respect to the facial midline, while the mandibular midline coincided with the facial midline. Significant incisal plane cant was observed.

Digital cast analysis (Figure 2) showed a Class II molar and canine relationship on both sides. The overjet and overbite were 1.2 mm and 15.2 mm, respectively. The maxillary dental arch showed a reverse Curve of Spee and the mandibular dental arch showed a severe Curve of Spee. Both maxillary and mandibular dental arch widths were constricted (maxillary inter-canine and inter-molar width were 35.6 mm and 38 mm, respectively; mandibular inter-canine and inter-molar width were 25.5 mm and 33.3 mm, respectively). Severe crowding was found in both dental arches (dental arch space deficiency was 13.4 mm in the maxilla and 8.1 mm in the mandible). An anterior maxillary excess Bolton discrepancy of 2.1 mm was also measured. A buccal crossbite was observed at the maxillary right second molar. Measurements indicated that there was an 8.9^o upward cant from right to left in the incisal plane.

Figure 1: Pre-treatment portrait and intra-oral photographs. *Lateral profile photograph shows a convex profile, a decrease in the mandibular facial third, a retrusive chin, and deficient maxillary and mandibular lip position. Frontal portrait photographs show large dark buccal corridors, 100% incisal display upon smiling, maxillary dental midline deviated 1.5 mm to the left in relation to the facial midline, mandibular midline coincident with facial midline upon opening. Intraoral photographs reveal a constricted maxilla and mandible, crowding in the maxillary and mandibular arches, severe deep bite, retroinclined maxillary anterior teeth, buccal crossbite at the maxillary right second molar, gingival recession on mandibular anterior teeth, and missing third molars.*

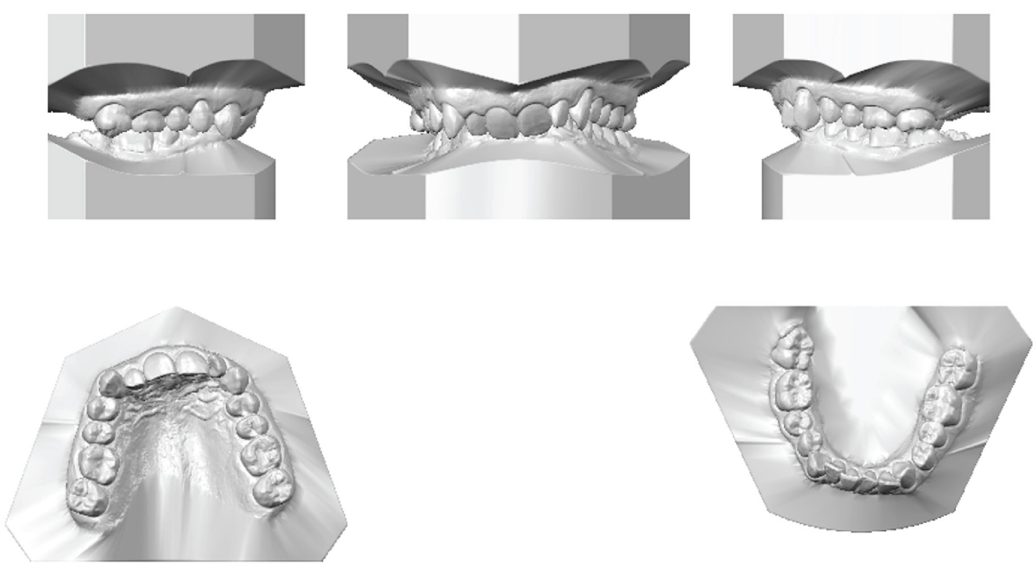

Figure 2: Pre-treatment digital casts. *Pre-treatment digital casts show a Class II molar and canine relationship on both sides with a severe deep bite. The maxillary dental arch shows a reverse Curve of Spee and the mandibular dental arch shows an accentuated Curve of Spee. Both maxillary and mandibular dental arch widths were constricted. Severe crowding was found in both dental arches. A Bolton discrepancy due to a maxillary excess was also observed. A buccal crossbite was present on the maxillary right second molar. Measurements indicated a cant of the incisal plane elevated on the left side.*

The panoramic radiograph (Figure 3) revealed a complete dentition except for the maxillary and mandibular third molars, which had been previously extracted. Roots on all teeth were fully developed and showed no signs of pathology. The CBCT scan (Figure 4) and lateral cephalometric analysis (Table I) showed a skeletal Class II relation (ANB= 10.9°) with a hypodivergent mandible (FMA = 15.4°, SN-MP = 16.3°). The maxillary incisors were severely retroclined, while the mandibular incisors demonstrated a smaller magnitude of retroclination (U1°- SN = 66.2°, IMPA = 86°, respectively). Soft tissue analysis indicated that the distance of the maxillary and mandibular lips to the E-line was deficient.

Figure 3: Pre-treatment panoramic radiograph. *Panoramic radiograph shows a complete dentition except for the third molars. Bone loss is clear around mandibular anterior teeth. Short condylar processes with some degree of flattening of their anterior surface is observed. Mandibular morphology shows prominent gonial angles.*

Figure 4: Pre-treatment lateral view of cone-beam computed tomography (CBCT) scan. *Pre-treatment lateral view of CBCT scan shows a skeletal Class II relation, hypodivergent profile, retroclined maxillary and mandibular anterior teeth and severe deep bite.*

Measurement	Initial Value	Final Value	Norm
SNA (deg)	88.4°	86.3°	81.8 ± 3.7°
SNB (deg)	77.5°	81.4°	79.2 ± 2.3°
ANB (deg)	10.9°	4.9°	2.6 ± 2.4°
FMA (deg)	15.4°	19°	25.8 ± 3°
SN-MP (deg)	16.3°	20.1°	31.2 ± 3°
Maxillary Incisor to SN (deg)	66.2°	98.4°	102.4 ± 5.5°
IMPA (deg)	86°	99.3°	92.1 ± 9°
Maxillary Incisor to NA (mm)	-11.3 mm	0.1 mm	3.8 ± 2.7 mm
Mandibular Incisor to NB (mm)	-1.8 mm	3.1 mm	3.4 ± 3.6 mm
Maxillary Lip to E-Plane (mm)	-6.5 mm	-4.1 mm	-2 ± 2 mm
Mandibular Lip to E-Plane (mm)	-7.2 mm	-5.6 mm	-2 ± 2 mm
Nasolabial Angle (deg)	136.8°	129.9°	90-95°
Labiomental Angle (deg)	65.1°	103.8°	120 ± 10°
Chin-Throat Angle (deg)	150.7°	138.1°	120 ± 126°
Chin Throat Length (mm)	31.7 mm	36.3 mm	42 ± 6 mm

Table 1: Cephalometric Analysis Pre- and Post-treatment. *Angular and linear measurements were completed between craniofacial skeletal, dental and soft tissue landmarks identified on pre- and post-treatment lateral cephalograms (° - degrees, mm - millimeters).*

Treatment Objectives

The overall objective was to establish a long-term functional harmonic and stable occlusion and improve the facial and dental esthetics. The treatment objectives were as follows:

I. Facial esthetics: improve the facial profile and lip position relative to the E-line, decrease the buccal corridors, increase lower facial height, and correct the incisal plane cant.

II. Skeletal objectives: correct the maxillary transverse deficiency, and sagittal jaw disharmony and improve Class II skeletal relationship, decrease the hypo-divergency by extruding the posterior teeth, decrease pain and discomfort in the TMJ area.

III. Dental objectives: develop the maxillary and the mandibular arch, correct the unilateral buccal crossbite by coordinating the arch widths, relieve dental crowding, improve incisal inclination, eliminate the severe deep bite and establish proper overjet and overbite relation, level the occlusal plane and correct the Curve of Spee, establish a functional and stable Class I canine and molar relationship, correct the incisal cant, improve marginal ridge discrepancies, level gingival margins and gingival height of contour around the anterior teeth, maintain alveolar bone height around maxillary and mandibular anterior teeth, and prevent or minimize root resorption of maxillary and mandibular anterior teeth.

Treatment Options

After comprehensive assessment, different treatment options were discussed with the patient. Orthognathic surgery was suggested due to the severity of the skeletal Class II malocclusion, and was declined by the patient. Therefore, orthodontic treatment without surgery was selected with the understanding of the limitations posed by the severity of the skeletal malocclusion and the patient's age.

Mechanotherapy Plan

In the maxillary arch a free-object mechanical design was used for anterior segmental intrusion and proclination [19]. Based on this design, the intrusion force was initially applied in front of the center of resistance of the anterior segment and gradually moved distally as the proclination of anterior teeth improved [20]. When the inclination of the anterior teeth improved, retraction forces were added to the intrusion forces. This treatment was delivered in combination with Alikhani Bite Block Therapy (MA therapy) to open the bite and allow extrusion of posterior segment in response to reaction forces.

MOPs were applied once every month on the maxillary and mandibular anterior area due to the need to facilitate extensive root movements in these regions. Due to severe recession in the labial area of the mandibular anterior teeth a free gingival graft was completed at the end of treatment in this area.

Duration of Treatment

The total treatment duration was 26 months and 24 days, including a 5 months interruption during confinement during the Covid-19 Pandemic in 2020.

Treatment Outcome

I. Facial and Soft Tissue analysis

The overall facial balance was improved and the lower facial height was increased. Profile analysis showed 2.4 mm and 1.6 mm improvement in the distance of maxillary lip and mandibular lip, respectively, relative to the E-line (Figure 5). The chin-throat length improved 4.6 mm, while the chin-throat angle improved 12.6^{o}. Along with these changes, the nasolabial angle and the labiomental angleimproved 6.9^{o} and 38.7^{o}.

II. Smile analysis

The patient showed a wider maxilla and a significant decrease in buccal corridor width during smile. The correction of the incisal plane cant also contributed to the significant improvement of the smile esthetics. Gingival display evaluation showed leveling of the gingival margins and the height of contour around the anterior teeth without detrimental effects on the periodontal health of the patient.

III. Digital Cast analysis

Analysis of casts at the end of treatment showed the following outcomes:

1) The maxillary and mandibular dentitions were expanded transversely with an increase in the inter-molar width of 2.2 mm and inter-canine width of 0.9 mm in the maxilla, while in the mandible the inter-molar width increased 1 mm and the inter-canine width increased by 2.3 mm (Figure 6).

2) The crowding in the maxillary and mandibular dental arches was eliminated.

3) The severe deep bite was resolved, and proper overjet (1.2 mm) and overbite (2.5 mm) were established. The Curve of Spee in both maxillary and mandibular arches was leveled.

4) Class I canine and molar relationships were achieved on the left side. The Class II molar and canine relationships significantly improved.

5) The unilateral buccal crossbite was corrected and the maxillary and mandibular arch forms were coordinated.

6) The incisal plane cant was corrected.

Figure 5: Post-treatment and intra-oral photographs. *Post-treatment photographs demonstrate an improvement in the facial profile, with an increase in the lower facial height, improved smile esthetics, correction of the incisal plane cant, and improved maxillary and mandibular lip position. Intra-oral photographs show maxillary and mandibular arch development, aligned dentition in the maxillary and mandibular arches, normalized incisal inclination into an ideal overjet and overbite relation, and Class I molar and canine occlusal relationship on the left side. Both maxillary and mandibular dental midlines are aligned with the facial midline. Gingival margins and heights of contour improved around the anterior teeth. Lingual fixed retainers are shown extending from canine to canine in both arches.*

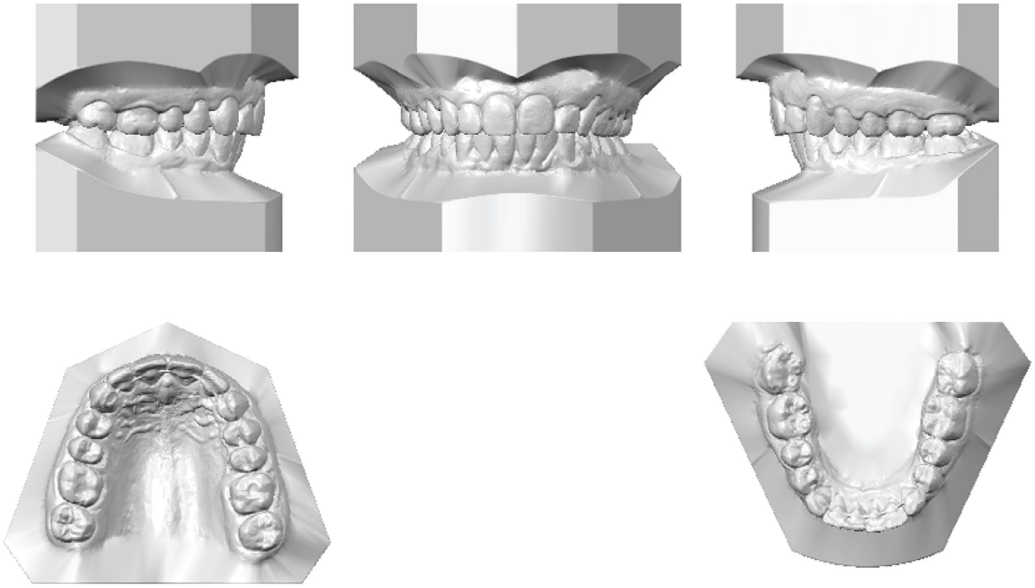

Figure 6: Post-treatment digital casts. *Post-treatment digital cast analysis showed Class I molar and canine relation on the left and significant improvement in Class II relation on the right side. Maxillary and mandibular transverse dimensions were increased, dentition was aligned on both arches, coincident dental midlines, and an ideal overjet and overbite were established.*

IV. Panoramic Analysis

Post-treatment panoramic radiograph (Figure 7) showed root alignment with no additional loss in vertical height of alveolar loss around any teeth.

Figure 7: Post-treatment panoramic radiograph. *Panoramic radiograph at the end of treatment showed good root alignment and no additional bone loss.*

V. CBCT and Cephalometric analysis

Pre-treatment and post-treatment comparison of CBCT (Figure 8) and lateral cephalometric analysis (Table 1) of skeletal and dental values demonstrate significant improvement in sagittal skeletal relationship between the maxilla and mandible. The ANB angle decreased from 10.9º to 4.9º. The skeletal vertical dimension improved as shown by a change in FMA from 16º to 19º. Dental analysis showed extrusion of maxillary and mandibular molars and flattening of the occlusal plane. Maxillary and mandibular anterior teeth underwent significant proclination and intrusion, as demonstrated in the superimposition of cephalometric tracings (Figure 9).

Figure 8: Post-treatment lateral view of cone-beam computed tomography (CBCT) scan. *Post-treatment lateral view of CBCT scan showed an overall improvement in the maxillary and mandibular relationship, improved mandibular plane angle, correction of the deep bite into an ideal overjet and overbite.*

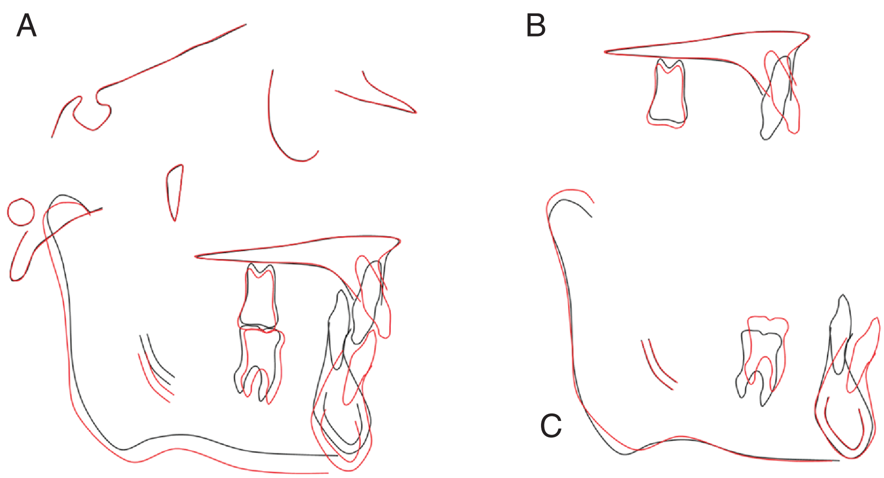

Figure 9: Superimposition of pre- and post-treatment cephalometric tracings. *Cephalometric superimposition of pre-treatment (black tracing) and post-treatment (red tracing) on the anterior cranial base shows extrusion of the maxillary and mandibular molars, Class I jaw relation, improvement of inclination of maxillary and mandibular incisors, intrusion and palatal root movement of the maxillary and mandibular anterior teeth, and flattening of the occlusal plane (A). Superimposition on the body of the maxilla shows maxillary molar extrusion and uprighting, with intrusion and improvement of the incisor inclination (B). Superimposition based on the inferior-alveolar nerve and inner profile of the mandibular symphysis reveals mandibular molar extrusion and uprighting with intrusion and improvement of mandibular incisor inclination (C).*

VI. Root resorption findings

Root length was measured in radiographic views constructed from CBCT scans along the axis of the tooth from the incisal edge to the root apex in mid-sagittal sections of anterior teeth (Figure 10). In the maxillary and mandibular anterior teeth, which underwent the most root movement both vertically and horizontally, the root resorption did not exceed 0.2 mm. (Table 2).

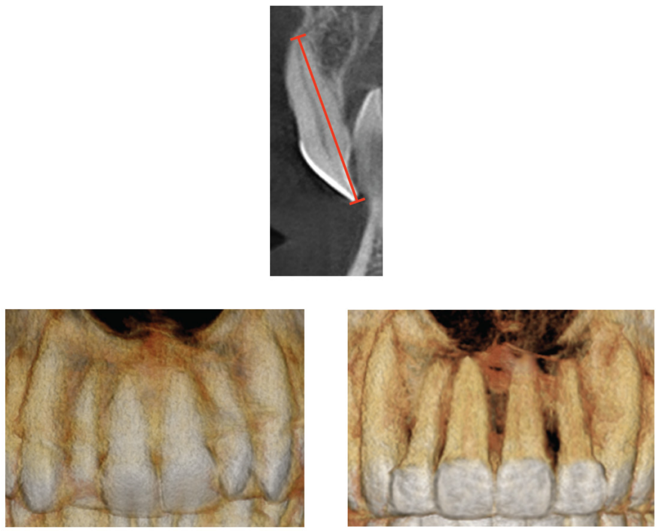

Figure 10. Root length analysis. *(A) The height of each tooth was measured along its long axis. The distance between the incisal edge to the apex of the teeth was measured in the sagittal view radiographs. (B) Hard tissue 3D images of maxillary anterior teeth segment before and after treatment, were constructed from CBCT scans.*

Maxillary anterior teeth

Tooth	Length of Maxillary Teeth - Right		Length of Maxillary Teeth - Left	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Central incisor	23.6 mm	23.5 mm	23.9 mm	23.7 mm
Lateral incisor	22 mm	21.9 mm	22.8 mm	22.7 mm
Canine	27.3 mm	27.3 mm	27.7 mm	27.6 mm

Mandibular anterior teeth

Tooth	Length of Mandibular Teeth - Right		Length of Mandibular Teeth - Right	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Central incisor	22.4 mm	22.3 mm	21.9 mm	21.7 mm
Lateral incisor	22.8 mm	22.7 mm	21.6 mm	21.5 mm
Canine	24.1 mm	24 mm	24 mm	23.9 mm

Table II: Pre- and Post-treatment Tooth Length Analysis. *Length of maxillary and mandibular anterior teeth was measured in radiographic views of pre- and post-treatment CBCT scans for anterior and posterior teeth (mm - millimeters) as described on Figure 10.*

Discussion

In this report we presented a Class II Division 2 patient with severe retroclination of maxillary anterior teeth, severe cant and asymmetry of the maxillary and mandibular dental arches in addition to mandibular retrognathism and severe gingival recession around the mandibular anterior teeth due to traumatic occlusion. To improve the underlying skeletal problem, orthognatic surgery was suggested as a treatment option but refused by the patient. Since the majority of skeletal deformities can still be corrected or improved without surgery, orthodontic/orthopedic treatment was completed with full understanding of the level of complexity of the malocclusion and the limitations of treatment.

To be precise in each movement, major targets for treatment were defined and personalized mechanics was designed to address each target's needs. One of the major targets of treatment included a combination of proclination and intrusion of anterior teeth. Application of full braces or aligners in these patients would not only limit the magnitude of corrections, but could also prolong the treatment and negatively affect the adjacent teeth. All these side effects could expose the roots of anterior teeth to unnecessary movement and possible resorption. To prevent unwanted movement, a free-object design and a one-couple system was selected to precisely control the movement of the anterior teeth based on the relation between the point of force application and the center of resistance of the teeth [20]. However, even when using precise mechanics, the risk of root resorption was high due to dense alveolar bone in the maxillary anterior region. We reasoned that any treatment that could decrease bone density temporarily, in combination with light forces, would be beneficial.

One way to increase the number of osteoclasts in a highly localized alveolar bone region and increase the rate of bone remodeling is by applying Micro-Osteoperforations (MOPs), which were used in this case. During orthodontic tooth movement osteoclasts are recruited in response to cytokine release in the area where orthodontic force is experienced by the alveolar bone, periodontal ligament and tooth root [16]. Osteoclasts undergo maturation and activation and start resorbing alveolar bone causing localized and temporary osteopenia. MOPs can magnify this effect by increasing the cytokine levels in the area and therefore the number of active osteoclasts [15].

Odontoclasts, like osteoclasts, undergo cytokine-induced differentiation and activation [21]. This means that MOPs could simultaneously increase odontoclast activity., however, it is the duration of the presence of osteoclasts and odontoclasts, rather than their numbers, that significantly impacts root resorption [17].

High alveolar bone density increases the chance of necrotic areas in the PDL when orthodontic force is applied to teeth. Osteoclasts only have access to these areas from its borders or from the endosteal side. The larger the necrotic area, the longer it takes for the limited number of osteoclasts to clear the path of movement. These will prolong osteoclast and odontoclast presence in one area, which increases the possibility of resorption of the adjacent root. In these situations, increasing the magnitude of orthodontic forces does not increase the rate of tooth movement or the number of osteoclasts and odontoclasts, as saturation of biological response is attained [18]. On the other hand, treatment with MOPs in adults can recruit a large number of osteoclasts, which will clear out the necrotic zone, giving the odontoclasts less time to resorb the root surface, and thereby decrease the possibility of permanent root resorption. It should be emphasized that histologically the number of resorptive craters on the surface of the root may temporarily increase; however, these lacunae are shallow and the root is restored to its original shape shortly after treatment [22-25]. Similarly, the activation of osteoclasts can provide the molecular signaling for activation of bone-forming osteoblasts, which restore the structure of the bone after treatment [26]. In the patient presented here, no further loss of vertical height of alveolar bone was observed.

MOPs should be repeatedly applied during active tooth movement to keep the osteoclasts active and the rate of bone remodeling high in the area. Therefore, monthly MOPs application is recommended. It should be emphasized that MOPs should only be applied when the bone density is high. Taking that into consideration, MOPs treatment in children is not recommended. In addition, applying MOPs around teeth that may function as anchor units should be avoided to prevent further movement of those teeth.

It is common for severe Class II Division 2 adult patients to present with gingival trauma and recession around the mandibular anterior teeth, due to an impinging deep bite. As with the patient presented here, a consult with a periodontist and the possibility of gingival graft should be considered, as was implemented in this case.

This case report shows how treatment of a Class II Division 2 adult patient may be accomplished without surgery using a thoughtful and personalized mechanotherapy design in combination with MOPs. This method induces localized bone remodeling and decreased bone density, which can facilitate significant anterior tooth intrusion without increased risk of root resorption. Clinical research on the role of MOPs in facilitating extreme orthodontic root movement without measurable root resorption is necessary.

Applied Innovation

Micro-osteoperforations have been introduced in Orthodontics as a tool for accelerated orthodontic treatment. Here for the first time, we propose the use of MOPs in conjunction with orthodontic treatment as a preventive approach for root resorption. In skeletal Class II Division 2 patients when significant anterior tooth intrusion and root movement are necessary, applying MOPs is a safe, minimally invasive method to decrease bone density locally and facilitate root movement.

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