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Selective Osteotomy-Assisted Molar Uprighting and Simultaneous Ridge Augmentation for Implant Site Development

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Abstract

Orthodontic treatment to upright an inclined molar adjacent to an edentulous span is often necessary before implant placement. The implant site may also require a ridge augmentation if the bony volume is not sufficient. The time required for both treatment steps can be lengthy and can discourage patients from accepting dental implants. This case report presents a novel interdisciplinary approach to implant site development. Selective osteotomy and simultaneous ridge augmentation were performed on the bilateral mesially inclined second molars prior to orthodontic uprighting. It was revealed that the severely inclined second molars were uprighted in 5 months and the enhanced implant sites were ready for implant placement without complications. A finite element analysis revealed that the osteotomy partially affected the biomechanical responses of the dentoalveolar structures during molar uprighting.

INTRODUCTION

Moderate or severe inclination of the molars next to the edentulous span may compromise the periodontal health and the prognosis of dental prosthesis.^{1,2} Orthodontic treatments to upright these molars are often necessary to correct unfavorable root angulations, insufficient

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Contribution

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edentulous span, or compromised occlusion. This adjunctive treatment may take up to months, even with miniscrew-assisted mechanics.²⁻⁵

Clinical evidence has shown that orthodontic treatment time can be reduced by superficial decortication procedures.⁶⁻¹⁰ The mechanism was summarized as the induction of a transient stage of osteopenia via decortication lines and points around the teeth to be moved to enhance bone and periodontal turnover.¹¹ This is referred to as the “Regional Acceleratory Phenomenon (RAP)”.¹² The corticotomy-assisted orthodontics has been reported in adjunctive orthodontic treatments for moving molars.¹³⁻¹⁵ In these cases, it was demonstrated that the treatment time of uprighting inclined molars or intruding elongated molars was significantly reduced.¹³⁻¹⁵

A good percentage of patients with missing posterior teeth need additional bone grafting or ridge augmentation procedures due to resorbed edentulous ridge. The bone grafting procedure for implant site development is commonly performed after orthodontic treatment is completed, which add extra time prior to implant placement. The total time for implant site development, implant placement, and the final dental restoration can be lengthy and can discourage patients from accepting dental implants.

Here we report a case using simultaneous osteotomy and ridge augmentation procedures to facilitate the orthodontic treatment for the inclined molars and to improve the implant site. The intention of this modification is to improve the treatment efficacy and eliminate the need for a second surgical procedure.

A retrospective finite element analysis (FEA) was performed to study the effect of the osteotomy to the orthodontic tooth movement. The initial displacement of the teeth and the strain distribution in the periodontal ligament (PDL) space were analyzed. The effect of the combined procedure on bone integration and periodontal health, and the clinical significance this treatment protocol was discussed.

CASE REPORT

DIAGNOSIS

The patient is a 46-year-old African American male referred by his general dentist to have the molars uprighted before implant placement. His initial orthodontic records (Fig 1-3) revealed normal convex facial profile and symmetry. His dental arches were in normal ovoid shapes (Fig 2). The mandibular first molars were missing and the second molars were inclined mesially (Fig 3). The other occlusal problems include minor spacing in the mandibular arch and the edge to edge anterior occlusion (Fig 2). His periodontal examination revealed no bleeding on probing and all probing depths are less than 4mm. There was no history of temporomandibular disorders.

TREATMENT OBJECTIVES AND ALTERNATIVES

During the treatment consultation, two treatment options were presented: 1. a limited adjunctive orthodontic treatment to upright the mandibular second molars, or 2. a comprehensive orthodontic treatment to address all listed occlusal problems. The patient

expressed the preference of the adjunctive treatment and denied the comprehensive treatment plan. Therefore, the following orthodontic treatment objectives were confirmed:

1. To upright the molars for implant site development. The records indicated the edentulous spaces are 5.9mm on the right side and 8.6mm on the left side, measured as the shortest inter-crown distance between the second molar and second premolar. To achieve a 9-10mm implant space, a distal crown movement was required to upright the right molar, and a mesial root movement was required to upright the left molar.
2. To maintain the posterior and anterior occlusal relationship, specifically, not to create an anterior open bite. This goal required careful mechanical designs to avoid any extrusion of the posterior teeth during the treatment.
3. To minimize the treatment time prior to implant placement.

After a consultation with his periodontist, it was confirmed that the left edentulous span also required a ridge augmentation prior to implant placement. Therefore, a preorthodontic surgical procedure that combined selective osteotomy and augmentation followed by miniscrew-supported uprighting of the molars were presented to the patient.

The risks and potential benefits that involved in the treatment procedures were explained thoroughly to the patient. The patient fully understood and consented to the treatment plan.

TREATMENT PROGRESS

Step 1-Placement of orthodontic appliances—The orthodontic appliances (0.022” pre-adjusted edgewise brackets and molar tubes, Opal Orthodontics, South Jordan, UT) were attached to the teeth. On the right side, a miniscrew (tomas[®] Dentaaurum, Ispringen, Germany) was placed between the premolars. It was planned to serve as the indirect anchorage for an uprighting T-loop (bended with 0.017x0.025” titanium molybdenum alloy wire) from the premolars brackets. On the left side, a tomas[®] molar uprighting spring directly from a miniscrew between the premolars was designed to upright the molars by mesial root movement moment. The springs were tried in before the osteotomy surgery.

Step 2- Periodontal Surgery—On the right side, the incision and flap reflection were made distal to the second molar. A 3mm wide x10mm deep buccal-lingual through cut were made 1mm distal to the tooth with a surgical bur (Fig 4). On the mesial alveolar ridge, multiple perforations were placed into the bone prior to augmentation with freeze-dried bone allograft. The bone graft was secured by a resorbable membrane and osseous tacks. The flaps were then secured with Vicryl sutures. At the left side, an 8mm deep buccal-lingual through cut were made 1mm mesial to the tooth (Fig 5). The top of this cut is 2mm wide whereas the bottom is 4mm wide. The mesial existing bone was treated in the same fashion as the right.

Step 3-Orthodontic Force Delivery and Recalls—Immediately following the surgery (on the same day), the uprighting springs were delivered. On the right side, the T-loop from the premolars was secured by ligature ties and a crimpable stop distal to the second premolar bracket. Approximately 1N of distalizing force and 0.5N of intrusion force were delivered

via the T-loop. On the left side, approximately 5 Nmm of mesial root movement moment were delivered on the left second molar. The forces were measured by a force gauge on the models with duplicated activation of the wire.

The patient was recalled monthly to check the appliances. Progress radiographs and photographs are showed in figure 6-7. In the third month, the T-loop on the right side was replaced by a 17x25 stainless steel (ss) wire with nickel titanium open coil to refresh the force delivery system. The left side spring were replaced by a 17x25 ss wire with 1 ½ 2mm diameter helices mesial to the second molar.

Step 4-Orthodontic Appliance Removal, Retention, and Implant Placement—

The orthodontic treatment was completed and both molars were uprighted after 5 months. The edentulous ridge mesial to the left molar was significantly wider for implant placement. Upon finishing, the mandibular second molars had satisfactory root angulations (Fig 8-11). After implant placement, a fixed retainer using a 21x25 ss wire was placed to keep the edentulous spaces. The retention wires were then removed 3 months after that, when the crowns were placed for the implants (Fig 12, 13C).

TREATMENT RESULTS

The changes of the edentulous span and the root angulation of the second molar is listed in table 1. The second molar root angulation was measured on the pre- and posttreatment panoramic X-ray using the lines tangent to the root surfaces. It was revealed that the edentulous space was increased by 3.2mm on the right side and 0.6mm on the left side. The second molar root angulation change was 32.9° on the right side and 13.7° on the left side. These results revealed distal crown movement on the right molar and the mesial root movement on the left molar. The average monthly rate in the 5-month treatment period was 6.6° and 2.7° on the right and left side molars, respectively. The authors understood the panoramic X-ray film is not a very reliable way to measure root angulation, but it provided an insight for the treatment result.

The patient was recalled 6 weeks after the implant placement and every 6 months for orthodontic recall for over 2 years. His oral hygiene was maintained in every 6 months. All probing depths are less than or equal to 4mm in the recall visits.

FINITE ELEMENT ANALYSIS

A retrospective finite element analysis was performed to study the effect of the osteotomy to the orthodontic tooth movement. Four geometric models were built, including distal crown movement of right side second molar with and without distal osteotomy, and mesial root movement of left side second molar with and without mesial osteotomy. The initial displacement of the teeth and the strain distribution on the PDL were analyzed in these models.

Amira image processing software (Amira 5.4, Hillsboro, OR) was utilized to generate the three-dimensional (3D) models by extracting the bone contour from the existing pretreatment Cone Beam computed tomography (CBCT) images of the mandible (Voxel dimensions: 0.35×0.35×0.35 mm³) (Planmeca3DMax, Roselle, IL). The cortical, trabecular

portions of the mandible, tooth, PDL, and shear bands mimicking the osteotomy cuts were assembled to form a geometric model in Solidworks (Solidworks 2016, Velizy-Villacoublay, France). The PDL was generated using Geomagic Studio designing software (Geomagic Studio 12, Cary, NC) with an average thickness of 0.2 mm based on the study of Wang et al.¹⁶. The mandible and the molars were modeled to be isotropic linearly elastic material. The Young's Modulus and Poisson's ratio were based on a previous study¹⁷: cortical bone ($E= 10.7$ GPa, $\gamma= 0.3$)¹⁸, trabecular bone ($E= 0.97$ GPa, $\gamma= 0.3$)¹⁸, the molars ($E= 20.7$ GPa, $\gamma= 0.3$)¹⁹, and PDL ($E= 50$ MPa, $\gamma= 0.45$)²⁰. The ss brackets were not involved in the FEA. The forces were directly loaded on where the bracket was bonded on the molars. All components of the geometric model were then exported into FEA software Abaqus (Abaqus 6.14, Velizy-Villacoublay, France) for further analysis.

Upon application of the forces (1N distal and 0.5N intrusion forces), the displacement of right molar in the control model displayed more of a bodily movement pattern, with slightly more movements on the crown (Fig 14). The molar in the osteotomy model demonstrated more movements in the crown than in the root, showing a tipping or controlled tipping movement pattern with a center of rotation closer to the root. The distal view of the PDL space showed a more defused distribution of maximum strain in the osteotomy model. Whereas the strain was concentrated at the area close to the cementoenamel junction (CEJ) in the control model.

Upon the application of 5 Nmm moment, the initial displacement pattern of the left molar in the osteotomy model showed a slight difference from the control model (Fig 15). It was shown that the molar rotated around a pivot near the attachment region of the bracket. The mesial view of the PDL space showed a more concentrated maximum strain around CEJ in the control model, but a relatively diffused strain distribution in the osteotomy model.

DISCUSSION

In this case the mandibular tilted second molars were uprighted using variations on the surgical principles presented in the periodontally accelerated osteogenic orthodontics (PAOO), which we refer to as a selective osteotomy. The mandibular edentulous sites and the tilted molars accepted the combined partial osteotomy and the osseous ridge augmentation surgery simultaneously, instead of in two separate surgeries. The tilted molars were then uprighted in 5 months with careful orthodontic mechanics to create proper root parallelism and enhanced mesial edentulous span for implant placement. The direct clinical significance of this protocol is less surgical procedures and shortened treatment time. The patient gets two benefits from only one surgery, with less pain, time, and cost.

Wang et al.²¹ recently reported two split-mouth comprehensive cases with simultaneous orthodontic molar uprighting and ridge augmentation procedures for implant site development. It was reported that after the initial alignment and leveling, the surgically accelerated uprighting of molars occurred 1.6 times faster than the control site, and that ridge augmentation was successfully achieved with 2.5 to 5 mm of horizontal bone gain. In comparison, we performed a thorough osteotomy mesial or distal to the molars, instead of the surface piezosurgical decortication reported in Wang's cases. Our patient also only went

through a miniscrew-supported adjunctive orthodontic treatment without initial alignment and leveling as in the comprehensive cases. In our case, the mechanical settings to upright the molars also involved careful integration of intrusion forces in order to prevent any bite opening effect. Regardless of these differences, both reports revealed successfully enhanced implant receiving sites within the treatment time frame of molar uprighting. The bone grafts were successfully integrated around the implants without complications. The osteotomy-assisted orthodontic molar uprighting and simultaneous implant side development procedure might be a safe and effective treatment choice for tilted molars.

Uprighting mandibular molars can be mechanically challenging and time-consuming. Variations in corticotomy techniques have been used to facilitate molar intrusion and uprighting.¹³⁻¹⁵ Studies have reported that extruded molars were intruded with corticotomy-assisted orthodontic in 2 to 4 months.¹⁴⁻¹⁵⁻²² Kim et al.¹³ reported three cases that corticotomy was applied for those severely extruded and inclined molars. The treatment time was 7 to 9 months. In our case, the tilted molars were uprighted in 5 months, with satisfactory final root angulations. It was observed that the distal crown movement is 2 to 3 times faster than the mesial root movement. This might be explained by the fact that the mesial root movement requires more moving distance of the root apex.

On the other hand, doubts have been expressed concerning the clinical efficacy of corticotomy accelerated orthodontics. Uribe²³ reported that the corticotomy did not result in less treatment time in a mandibular protraction case. In the authors' opinions, PAOO is more beneficiary for patients who need adjunctive orthodontic treatments. As it is known, the effective period for RAP is only 3 to 4 months,¹² leaving a limited application to comprehensive orthodontic treatment. The adjunctive orthodontic treatments, such as the molar uprighting procedures prior to dental prosthesis, can be hastened with PAOO. The mechanical design, overall case management, the jawbone density, and the local bone configuration should be considered in individual cases when considering PAOO.

The finite elements analysis²⁴⁻²⁷ provided an insight for the mechanical effect of osteotomy. A previous study has shown that the corticotomy pattern and extend can influence the initial orthodontic tooth displacement, as well as strain distribution on PDL in a reconstructed canine retraction model.¹⁷ The FEA in our patient's reconstructed 3D mandible demonstrated that osteotomy affected the initial tooth displacement and PDL strain distribution. On the right molar, it was observed that the center of rotation changed with the simulated osteotomy. The tooth movement pattern changed from a bodily movement in the control model to a tipping movement with osteotomy, which is more desired in our treatment plan. The range maximum strains PDL in our study is in accordance with previous studies of orthodontic tooth movements.¹⁷⁻²⁸ The strain in PDL space was distributed more evenly in the osteotomy model. These findings may provide partial evidence of the claimed benefits of less root resorption in PAOO³¹, since it was reported that high levels of initial stresses in PDL may relate to orthodontic external root resorption³⁰. On the left side, the initial tooth displacement patterns were similar with or without the osteotomy, with slightly improved root movement and PDL strain distribution in the osteotomy model. This result may be explained by the fact that the osteotomy was performed not as deep on the left side. Further

FEA studies are in need to explore the optimal osteotomy patterns and force application for molar uprighting movements.

CONCLUSION

The authors believe by combining a partial osteotomy with osseous ridge augmentation the patient gets two benefits from only one surgery. Our initial data from the FEA demonstrated that selective osteotomy might facilitate distal crown or mesial root movement of tilted mandibular molars in the mandible. This novel interdisciplinary protocol may encourage more patients to accept molar uprighting before implant placement.

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Highlights

- Severely inclined second molars were uprighted in 5 months by adjunctive orthodontic treatment.
- Osteotomy and ridge augmentation were performed simultaneously prior to molar uprighting.
- The edentulous implant sites were improved without complications.
- The biomechanical effects of the osteotomy were revealed in a finite element analysis.

Fig 1.
Pretreatment extraoral and intraoral photographs.

Fig 2.
Pretreatment dental casts.

Fig 3.
Pretreatment panoramic and cephalometric radiograph, cephalometric tracing, and measurements.

Fig 4.

Surgical procedures for the right side: **A**, osteotomy cut 1mm distal to the tooth with a hand piece; **B**, measuring the depth of the bony cut; **C** and **D**, perforated corticotomy at the distal and mesial buccal bone.

Fig 5.
Surgical procedures for the left side: **A**, mesial osteotomy cut 1mm away from the tooth; **B**, placement of the mesial bone graft.

Fig 6. Progress periapical radiographs and photographs for the right side: **A**, before uprighting; **B**, 1 months after appliance delivery; **C**, 3 months after appliance delivery; **D**, 5 months after appliance delivery.

Fig 7.

Progress periapical radiographs and photographs for the left side: **A**, 1 months after appliance delivery; **B**, 2 months after appliance delivery; **C**, 3 months after appliance delivery; **D**, 5 months after appliance delivery.

Fig 8.
Posttreatment extraoral and intraoral photographs.

Fig 9.
Posttreatment dental casts.

Fig 10.
Posttreatment panoramic and cephalometric radiograph, cephalometric tracing, and measurements.

Fig 11.
Cephalometric superimposition. Black, pretreatment; red, posttreatment.

Fig 12.
Extraoral and intraoral photographs after implant delivery.

Fig 13.

A, Geometric setup of orthodontic tooth movement study with osteotomy cut. On the right side, a rectangular cut with 1 mm distance to the PDL of right lower second molar was formed to facilitate its distal crown movement under 1 N and 0.5 N forces. On the left side of the mandible, a trapezoidal cut with 1 mm distance to the PDL of left lower second molar was created to assist in its mesial root movement under 5 Nmm moment; **B**, Uprighted right second molar in cephalometric superimposition; **C**, Panoramic radiograph after implant delivery.

Fig. 14.

The initial tooth displacement (buccal view) and PDL strain distribution (distal view) on the lower right second molar: **A**, without osteotomy; **B**, with osteotomy.

Fig. 15.

The initial tooth displacement (buccal view) and PDL strain distribution (mesial view) on the lower left second molar: **A**, without osteotomy; **B**, with osteotomy.

Table 1.

Mandibular edentulous space and second molar root angulation before and after orthodontic treatment

		Pretreatment	Posttreatment	Change
Edentulous distance (mm)	Right	5.9	9.1	+3.2
	Left	8.6	9.2	+0.6
Second molar root angulation (°)	Right	59.4	26.5	-32.9
	Left	48.7	35.0	-13.7