

Selective osteotomy-assisted molar uprighting and simultaneous ridge augmentation for implant site development

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Orthodontic treatment to upright an inclined molar adjacent to an edentulous space 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 before orthodontic uprighting. 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. (Am J Orthod Dentofacial Orthop 2019;156:846-57)

Moderate or severe inclination of the molars next to the edentulous space may compromise the periodontal health and the prognosis of a dental prosthesis.^{1,2} Orthodontic treatments to upright these molars are often necessary to correct unfavorable root angulations, insufficient edentulous space, or compromised occlusion. This adjunctive treatment may take several 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*.¹² Corticotomy-assisted orthodontic treatment has

been reported as an adjunctive orthodontic treatment for moving molars, and it was demonstrated that the treatment time to upright inclined molars or intrude elongated molars was significantly reduced.¹³⁻¹⁵

A good percentage of patients with missing posterior teeth need additional bone grafting or ridge augmentation procedures because of resorbed edentulous ridge. The bone grafting procedure for implant site development is commonly performed after orthodontic treatment is completed, which adds extra time before 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.

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 was 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 of this treatment protocol were discussed.

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DIAGNOSIS AND ETIOLOGY

A 46-year-old African American male patient was referred by his general dentist to have the molars uprighted before implant placement. His initial orthodontic records (Figs 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 included minor spacing in the mandibular arch and the edge-to-edge anterior occlusion. His periodontal examination revealed no bleeding on probing, and all probing depths were <4 mm. There was no history of temporomandibular disorders.

TREATMENT OBJECTIVES

During the treatment consultation, 2 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 a preference for the adjunctive treatment and denied the comprehensive treatment plan. Therefore, the following orthodontic treatment objectives were confirmed:

1. Upright the molars for implant site development. The records indicated the edentulous spaces were 5.9 mm on the right side and 8.6 mm on the left side, measured as the shortest intercrown distance between the second molar and second premolar. The distal crown movement and mesial root movement was required to upright the right and left molar, respectively, to achieve a 9–10 mm implant space.
2. Maintain the posterior and anterior occlusal relationship, specifically, without creating an anterior open bite. This goal required careful mechanical designs to avoid any extrusion of the posterior teeth during treatment.
3. Minimize the treatment time before implant placement.

TREATMENT ALTERNATIVES

After a consultation with his periodontist, it was confirmed that the left edentulous span also required a ridge augmentation before 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 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. Orthodontic appliances (0.022-inch preadjusted edgewise brackets and molar tubes; Opal Orthodontics, South Jordan, Utah) were attached to the teeth. On the right side, a miniscrew (tomas, Dentaaurum, Ispringen, Germany) was placed between the premolars to provide indirect anchorage for an uprighting T-loop (bent with 0.017×0.025 -inch 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 tied in before the osteotomy surgery.

Step 2 (periodontal surgery): On the right side, the incision and flap reflection was made distal to the second molar. A 3-mm-wide \times 10-mm-deep buccal-lingual through cut was made 1 mm distal to the tooth with a surgical bur (Fig 4). On the mesial alveolar ridge, multiple perforations were placed into the bone before 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 8-mm-deep buccal-lingual through cut was made 1 mm mesial to the tooth (Fig 5). The cut was 2 mm wide at the top and 4 mm wide at the bottom. The existing mesial 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 1 N of distalizing force and 0.5 N of intrusion force were delivered via the T-loop. On the left side, approximately 5 mm of mesial root movement moment was 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 shown in Figures 6 and 7. In the third month, the T-loop on the right side was replaced by a 17×25 -inch stainless steel (SS) wire with nickel-titanium open coil to refresh the force delivery system. The left side spring was replaced by a 17×25 -inch SS wire with 1.5–2.0 mm 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



Fig 1. Pretreatment extraoral and intraoral photographs.

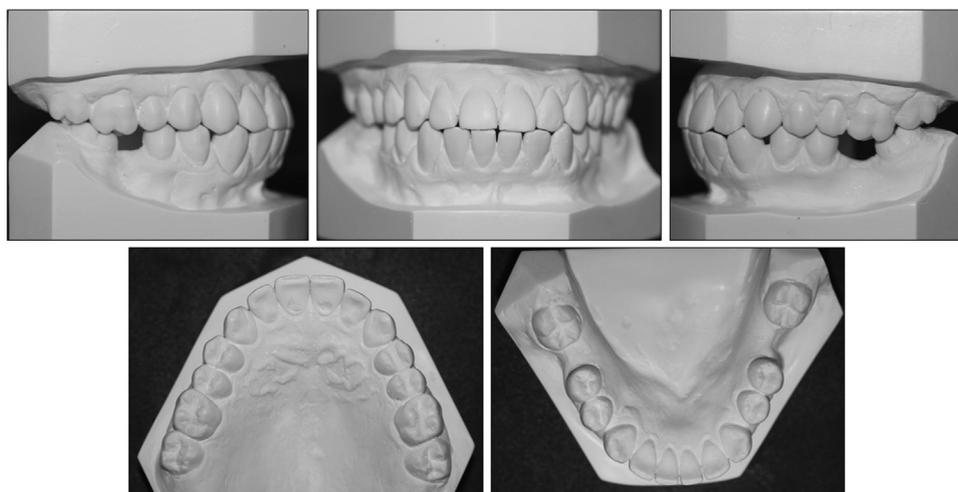


Fig 2. Pretreatment dental casts.

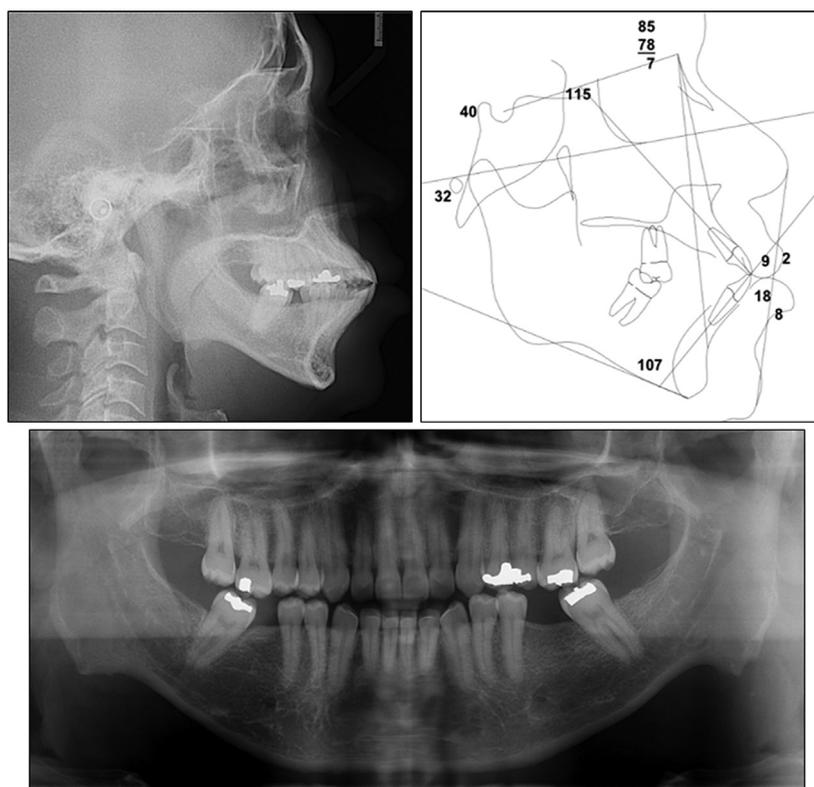


Fig 3. Pretreatment panoramic and cephalometric radiograph, cephalometric tracing, and measurements.

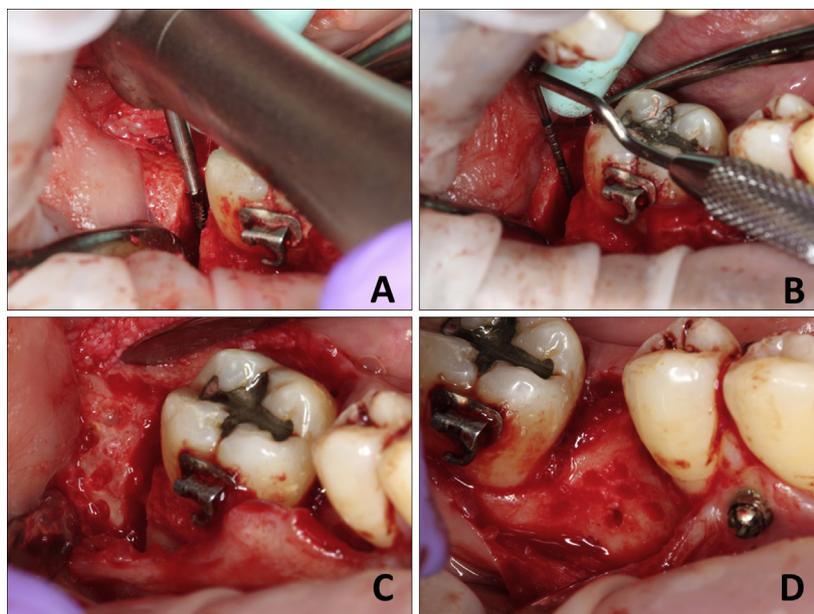


Fig 4. Surgical procedures for the right side. **A**, osteotomy cut 1 mm distal to the tooth with a hand piece; **B**, measuring the depth of the bony cut; **C** and **D**, perforated corticotomy at the distal and mesial buccal bone.

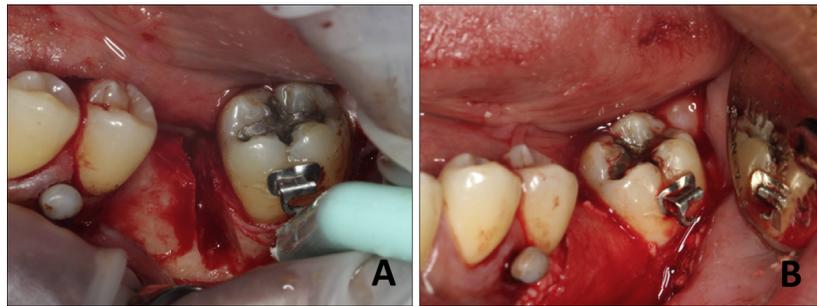


Fig 5. Surgical procedures for the left side. **A**, mesial osteotomy cut 1 mm away from the tooth; **B**, placement of the mesial bone graft.

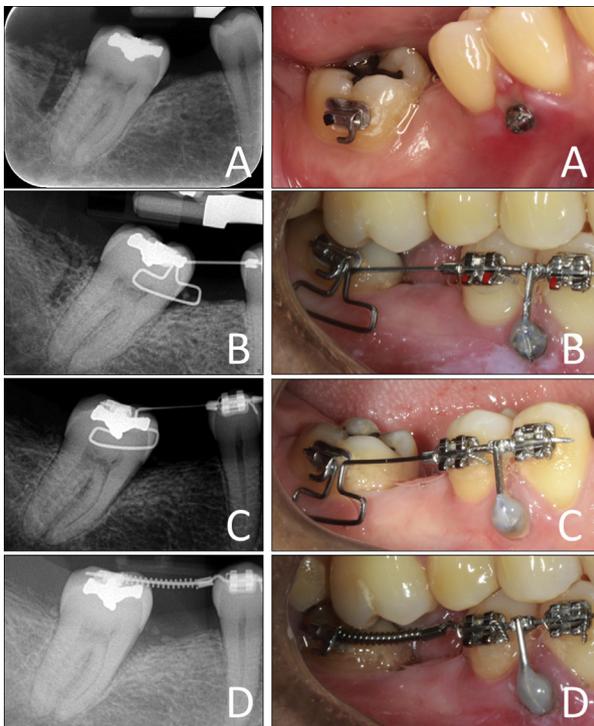


Fig 6. Progress periapical radiographs and photographs for the right side. **A**, before uprighting; **B**, 1 month after appliance delivery; **C**, 3 months after appliance delivery; **D**, 5 months after appliance delivery.

finishing, the mandibular second molars had satisfactory root angulations (Figs 8-11). After implant placement, a fixed retainer using a 21 × 25-inch 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 (Figs 12 and 13, C).

TREATMENT RESULTS

The changes in the edentulous span and the root angulation of the second molar are listed in the Table.

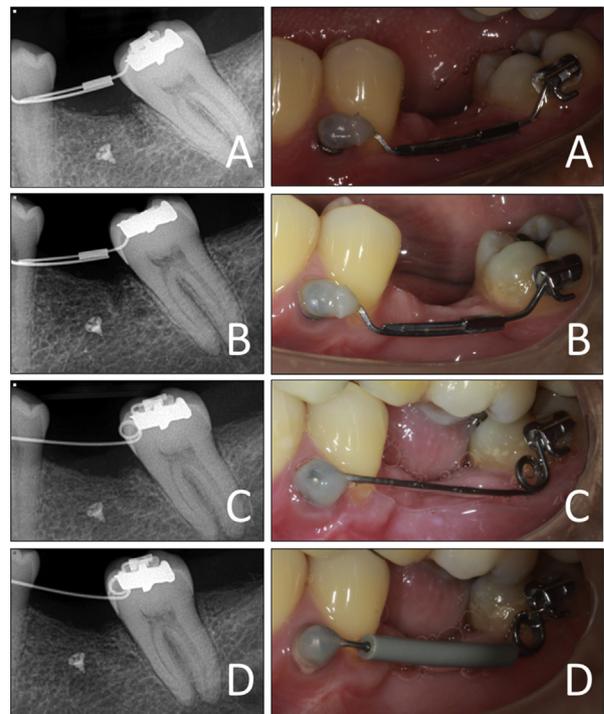


Fig 7. Progress periapical radiographs and photographs for the left side. **A**, 1 month after appliance delivery; **B**, 2 months after appliance delivery; **C**, 3 months after appliance delivery; **D**, 5 months after appliance delivery.

The second molar root angulation was measured on the pretreatment and posttreatment panoramic x-rays using the lines tangent to the root surfaces. The edentulous space increased by 3.2 mm on the right side and 0.6 mm 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,



Fig 8. Posttreatment extraoral and intraoral photographs.

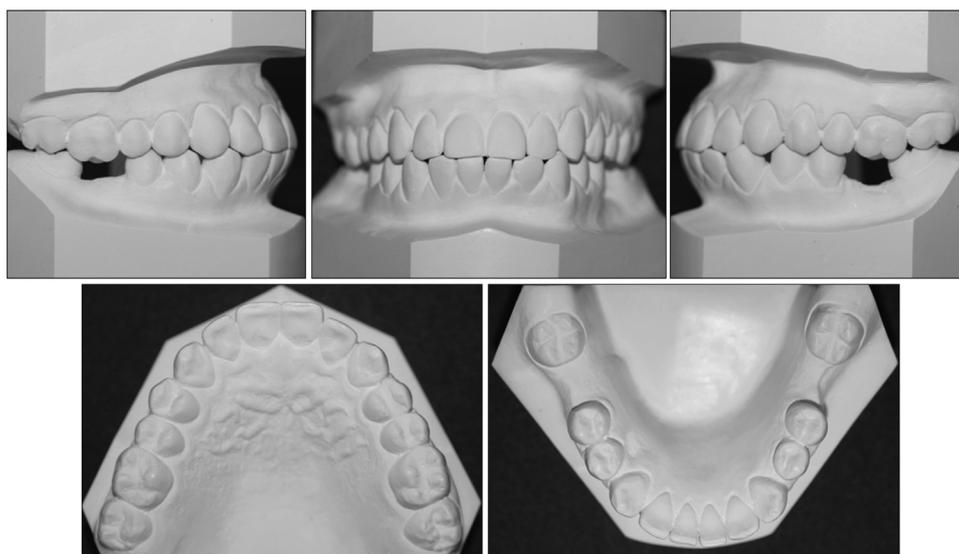


Fig 9. Posttreatment dental casts.

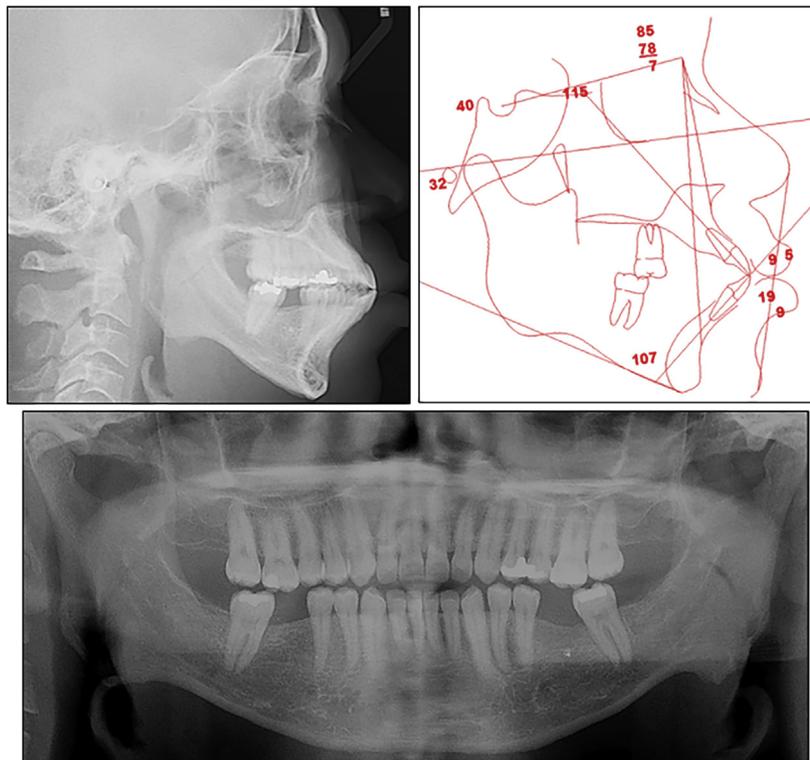


Fig 10. Posttreatment panoramic and cephalometric radiograph, cephalometric tracing, and measurements.

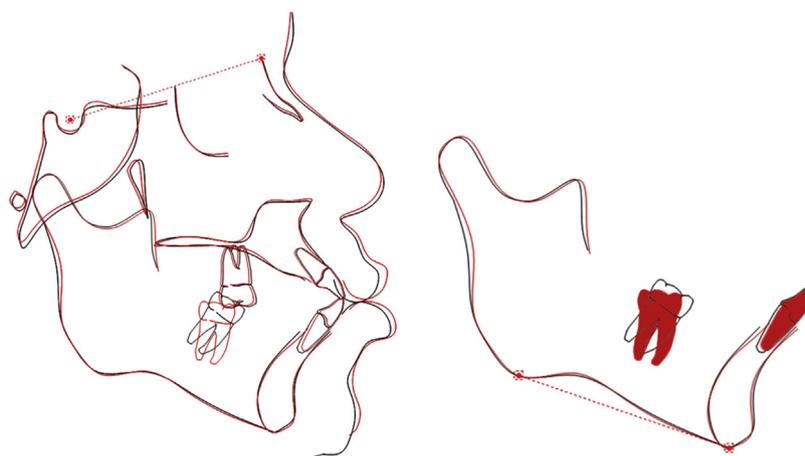


Fig 11. Cephalometric superimposition. Black, pretreatment; red, posttreatment.

respectively. Although panoramic x-ray film is not a very reliable way to measure root angulation, it nevertheless provided insight into the treatment result.

The patient was recalled 6 weeks after the implant placement and every 6 months for orthodontic recall for more than 2 years. His oral hygiene was maintained



Fig 12. Extraoral and intraoral photographs after implant delivery.

in every 6 months. All probing depths were ≤ 4 mm in the recall visits.

FEA

A retrospective FEA was performed to study the effect of the osteotomy to the orthodontic tooth movement. Four geometric models were built, including the 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, version 5.4, Hillsboro, Oreg) was used to generate the three-dimensional models by extracting the bone contour from the existing pretreatment cone-beam computed tomography images of the mandible (voxel dimensions: $0.35 \times 0.35 \times 0.35$ mm³; Planmeca 3D Max, Roselle, Ill). 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; Vélizy-Villacoublay, France). The PDL was generated using Geomagic Studio designing software (Geomagic Studio 12, Cary, N.C.) 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 where the bracket was bonded on the molars. All components of the geometric model were then exported into FEA software Abaqus (version 6.14, Vélizy-Villacoublay, France) for further analysis.

Upon application of the forces (1 N distal force and 0.5 N intrusion force), displacement of the 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

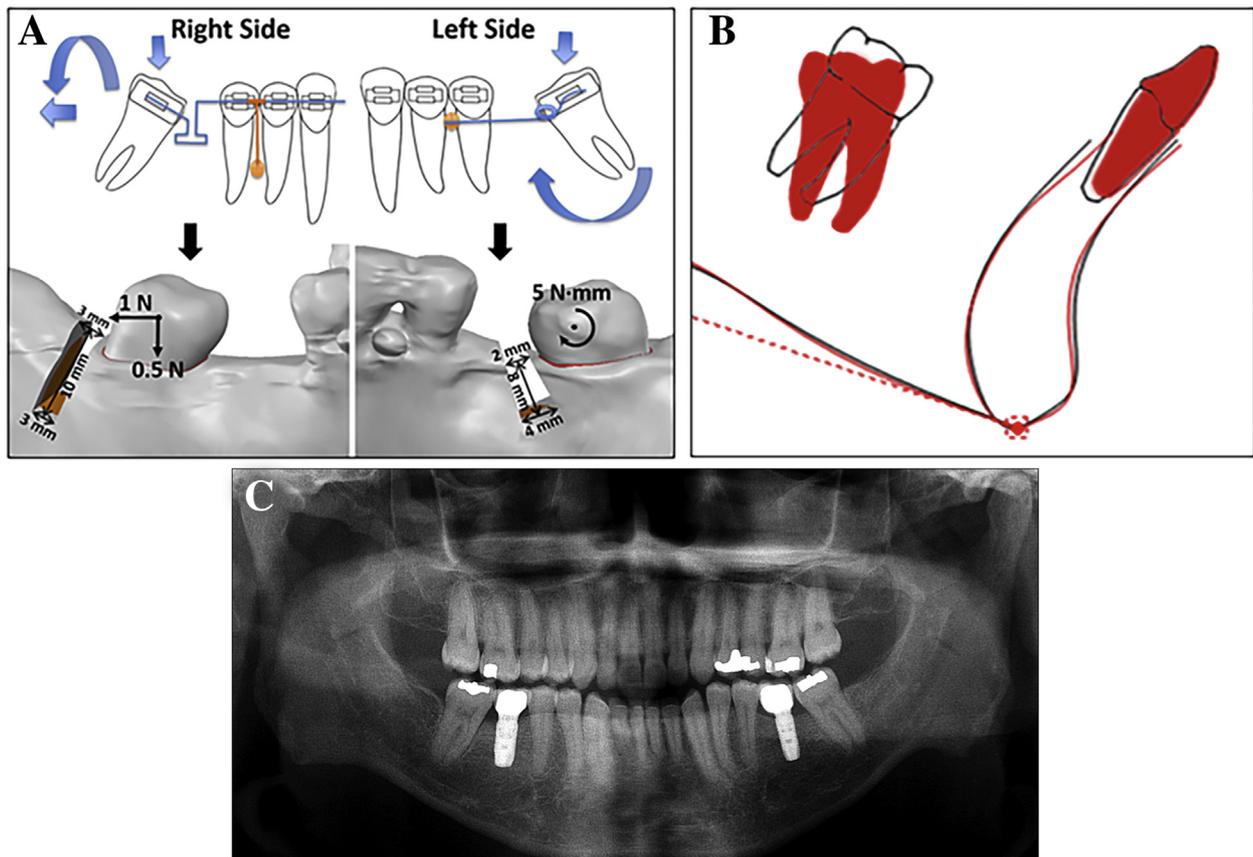


Fig 13. **A**, Geometric setup of orthodontic tooth movement study with osteotomy cut. On the right side, a rectangular cut with 1 mm distance to the PDL of mandibular right second molar was formed to facilitate its distal crown movement under 1 N and 0.5 N forces. On the left side of the mandible, a trapezoidal cut with 1 mm distance to the PDL of mandibular left second molar was created to assist in its mesial root movement under 5 N mm moment; **B**, uprighted right second molar in cephalometric superimposition; **C**, panoramic radiograph after implant delivery.

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

Side		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

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 cemento enamel junction in the control model.

Upon the application of 5 N intrusion force, 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 cemento enamel junction 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

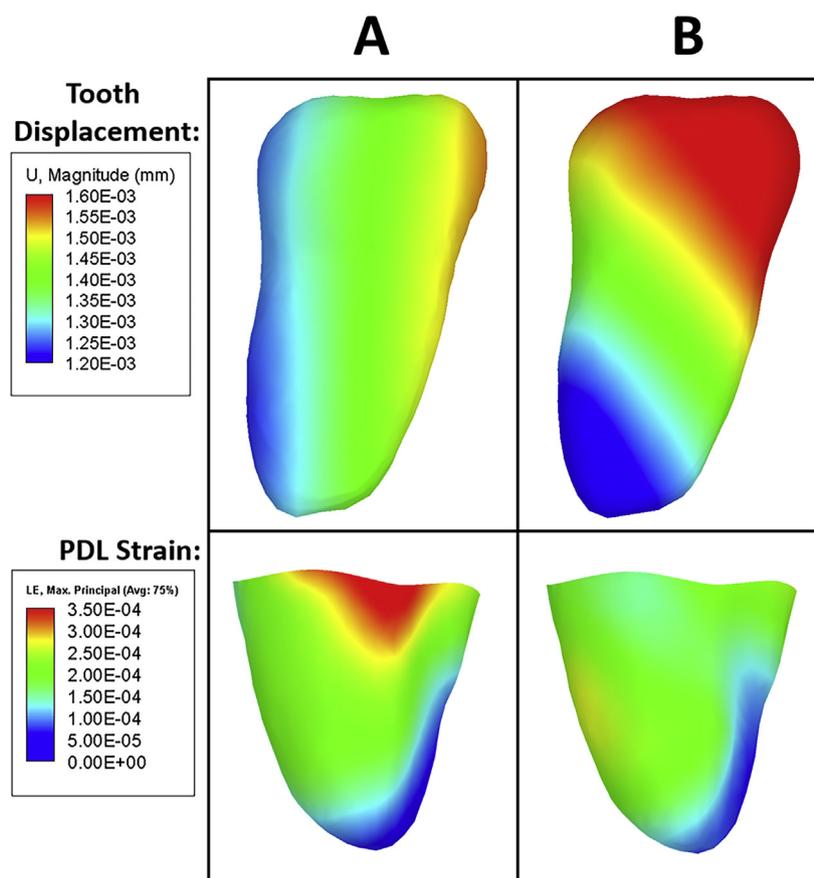


Fig 14. The initial tooth displacement (buccal view) and PDL strain distribution (distal view) on the mandibular right second molar. **A**, without osteotomy; **B**, with osteotomy.

and the osseous ridge augmentation surgery simultaneously, instead of in 2 separate surgeries. The tilted molars were then uprighted in 5 months with careful orthodontic mechanics to create proper root parallelism and enhanced edentulous mesial span for implant placement. The direct clinical significance of this protocol is less surgical procedures and shortened treatment time. The patient gets 2 benefits from only 1 surgery, with less pain, time, and cost.

Wang et al²¹ recently reported 2 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 in the control site, and that ridge augmentation was successfully achieved with 2.5–5.0 mm of horizontal bone gain. In comparison, we performed a thorough osteotomy mesial or distal to the molars, instead of the surface piezosurgical decortication previously reported.²¹ 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 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 2–4 months.^{14,15,22} Kim et al¹³ reported 3 cases in which corticotomy was applied for those severely extruded and inclined molars. The treatment time was 7–9 months. In our case, the

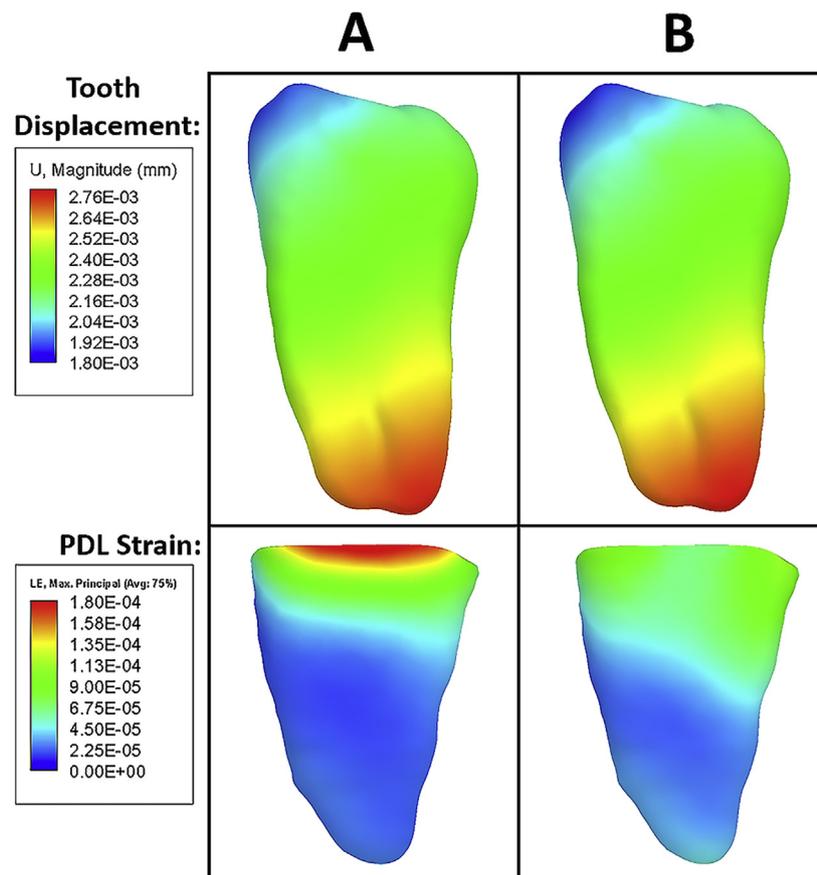


Fig 15. The initial tooth displacement (buccal view) and PDL strain distribution (mesial view) on the mandibular left second molar. **A**, without osteotomy; **B**, with osteotomy.

tilted molars were uprighted in 5 months, with satisfactory final root angulations. It was observed that the distal crown movement was 2–3 times faster than the mesial root movement, which might be because the mesial root movement requires a 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 active period for the *regional acceleratory phenomenon* is only 3–4 months,¹² leaving a limited application to comprehensive orthodontic treatment. The adjunctive orthodontic treatments, such as the molar uprighting procedures before a 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 FEA^{24–27} provided an insight into the mechanical effect of the osteotomy. A previous study has shown that the corticotomy pattern and extent 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 three-dimensional 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 PAOO²⁹ because it was reported that high levels of initial stresses in PDL might relate to orthodontic

external root resorption.³⁰ 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 needed to explore the optimal osteotomy patterns and force application for molar uprighting movements.

Conclusions

Combining a partial osteotomy with osseous ridge augmentation provides the patient with 2 benefits from only 1 surgery. 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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