**Original Article**

J Babol Univ Med Sci
Vol 20, Issu 11; Nov 2018. P:7-12

# Second Molar Uprighting with Temporary Anchorage Devices: A Finite Element Study

**A. Geramy (DDS,MS)[1], S. Sheikhzadeh (DDS,MS)[*2], H. Majd (DDS)[2]**

1.Department of Orthodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, I.R.Iran
2.Dental Materials Research Center, Institute of Health, Babol University of Medical Sciences, Babol, I.R.Iran

**J Babol Univ Med Sci; 20(11); Nov 2018; PP: 7-12**
**Received: Feb 15th 2018, Revised: May 21st 2018, Accepted: Jul 25th 2018.**

## ABSTRACT

**BACKGROUND AND OBJECTIVE:** Premature loss of mandibular first molar is a common problem in adults. Mesial tipping of second molar may occur in this situation. Various orthodontic mechanics have been proposed for molar uprighting. The aim of this study was to compare four methods of molar uprighting using Finite Element Analysis(FEM).

**METHODS:** In first model of this finite element study, a 0.019×0.025 inch beta-titanium segmental arch wire with a T-loop was used. In second model a miniscrew was inserted in retromolar space and force was applied using elastomeric chain. The third model was a piece of 0.016×0.022inch beta-titanium wire with a bend which was placed more occlusal than the screw. The fourth model contained a mesially inserted miniscrew with an angle of 70 degrees to bone surface and a 0.018×0.025inch beta-titanium wire with helix. Extrusion, center of rotation and stress distribution in PDL during movement was compared between methods.

**FINDINGS:** Buccal cusp extruded 1.36E-03, 1.13E-03, -9.74E-04 and 1.49E-03 mm in first, second, third and fourth model, respectively. Similarly, in lingual cusp, the amount of vertical displacement was at least in third model (-6.83E-04 mm). This amount in second and first method was 1.12E-03 and 4.05E-04 mm, respectively. The maximum amount of extrusion of lingual cusp occurred in fourth model (9.01E-03 mm).

Mesial and distal cusps extruded 2.12E-04 and 1.58E-03 mm in first model, -1.14E-03 and 3.80E-03 mm in second method, -2.37E-03 and 7.04E-04 mm in third design and, 1.88E-03 and 8.57E-03 mm in the fourth model.

The center of rotation was located at molar bifurcation in third model.

**CONCLUSION:** The maximum amount of extrusion in both mesiodistal and buccolingual path was seen in fourth model. The best type of movement was found in third model, in which minimum extrusion occurred and center of rotation located at molar bifurcation.

**KEY WORDS:** *Finite Element Analysis, Tooth Movement Technique, Tooth Uprighting.*

**Please cite this article as follows:**

Geramy A, Sheikhzadeh S, Majd H. Second Molar Uprighting with Temporary Anchorage Devices: A Finite Element Study. J Babol Univ Med Sci. 2018;20(11):7-12.

**[*]Corresonding Author: S. Sheikhzadeh (DDS, MSc)**
**Address:** Department of Orthodontics, School of Dentistry, Babol University of Medical Sciences, Babol, I.R.Iran
**Tel:** +98 11 32291408
**E-mail:** elfsh@yahoo.com

## Introduction

Premature loss of mandibular first molar is a common problem in orthodontic treatment of adults. In such situations, mesial tipping of second molar and distal tipping of second premolar may occur (1). Mesio-inclination of the molar can cause tooth extrusion, periodontal complications and difficulties for replacing first molar with restoration. Gross teeth reduction and sometimes root canal therapy of abutment teeth may be necessary, if the treatment plan is to construct a bridge. Uprighting the adjacent teeth can help creating enough space and avoiding the unwanted endodontic treatments.

If implant –supported prosthesis is indicated, leveling of marginal ridges and creating enough space by second molar uprighting may be helpful. Uprighting also decreases the pocket depth in the mesial portion of tipped molar, facilitates plaque control and creates an angular crest of alveolar bone between the uprighting molar and adjacent tooth (2). In previous studies, various orthodontic mechanotherapies with continous archwires, conventional segmental appliances and temporary anchorage devices (TAD) application have been proposed for molar uprighting (3-6). Lau et al, indicated that a continuous wire that uprights the molar has some adverse effects on the other teeth in the arch. They suggested segmented mechanics to prevent such side effects (7).

However, Kim et al, showed when a T-loop is used for second molar uprighting, adjacent teeth are served as anchorage unit undergoing different forces and moments (8). Use of TADs in recent studies in terms of direct and indirect anchorage allowed altering the force compliance. TADs make it possible to apply forces exclusively on intended tooth and provide desirable direction of force (9-16). Such techniques do not need to engage the rest of teeth in mouth and show successful results in clinical cases (11-13).

Several mechanotherapies used in different studies can affect teeth in different ways and stress distribution in surrounding structures can be in various ranges. To design and select the best machanotherapies in orthodontics, it is important to determine the reaction of teeth and supporting tissues to different forces. FEM is a useful method to analyze these reactions. With a three-dimensional computer modeling, various conditions of loading in the oral cavity can be simulated.

This method divides a system to individual elements and evaluates the response of these components to different ways of loading. The data is then unified to represent the whole system and stress distribution in the teeth, periodontal ligament (PDL) and alveolar bone can be assessed in this way. FEM is a powerful tool that can resolve the different dilemmas in dentistry and also various adverse effects of different mechanotherapies (17). Different studies evaluated the clinical effects of molar uprighting methods but the exact movements and stress distributions can be better assessed through FEM analysis. To our knowledge, there is no FEM study to evaluate the stress diagrams in different ways of molar uprighting.

Therefore, present study aimed to compare a conventional T-loop and three methods of TAD application for uprighting a mesially inclined mandibular second molar with finite element method.

## Methods

**Models:** In this finite element study, four 3D models of a posterior segment of mandible (right side) were designed in a top-to-bottom manner in SolidWorks 2011 (Solid-works, Massachusetts, USA). The models contained gingivae, cortical bone (1 mm thick), spongy bone, mandibular right second molar (mesially tilted), PDL of uniform thickness (0.25 mm).

The tooth was modeled according to Ash's dental anatomy18 and the modeling of the maniblular segment was performed using data of cone-beam computed tomography of a patient. In model 1, a 0.019×0.025 inch beta-titanium segmental arch wire with a T-loop inserted uprighting force by gable bend1. This was replaced by a mini screw in the second model which was inserted in a vertical direction in retromolar space. A button was attached in mesial side of molar crown and force was applied by an elastic chain connecting to the distad-inserted miniscrew in retromolar space 19.

The technique employed in the third model was a piece of 0.016×0.022 inch beta-titanium wire with a bend which was placed more occlusal than the screw and inserted in the second molar tube9. The fourth model contained a miniscrew inserted mesially with an angle of 70 degrees to bone surface and a 0.018×0.025inch beta-titanium with helix was used for uprighting20. Loading was done by activating the wire segments with elastic deformation. The models were then transferred for calculation to the ANSYS Work-bench Ver. 12.1 (ANSYS Inc., Cononsburg, USA). All the living tissues were presumed elastic, homogeneous and isotropic. The corresponding elastic properties such as Young's modulus and Poisson's ratio were defined (Table 1).

**Table 1. Young's modulus and Poisson's ratio for various materials**

| Material | Young's modulus (MPa) | Poisson's ratio |
|---|---|---|
| Cortical bone | 1.37×104 | 0.30 |
| Cancellous bone | 7.90×103 | 0.30 |
| Tooth | 2.07×104 | 0.30 |
| TMA | 8.00×104 | 0.30 |
| Miniscrew | 1.05×105 | 0.33 |
| PDL | 50.00 | 0.49 |

TMA, Titanium molybdenum alloy; PDL periodontal ligament

The models were meshed, between 29811 and 38099 nodes; between 13864 and 18129 10-node-quadratic tetrahedron body elements. Contact elements were defined to let the wire segments slide in tube (model 1,3,4). In model 2 the mini screw was considered to be solid in the bone. As boundary condition, all nodes at the mesial and distal sides of the models were restrained so that all rigid motions were prevented.

## Results

In buccolingual aspect, buccal cusp was extruded 1.36E-03, 1.13E-03, -9.74E-04 and 1.49E-03 mm respectively with T-loop, miniscrew in retromolar pad, distal-inserted miniscrew and mesially inserted miniscrew.(table2). The maximum amount of extrusion in lingual cusp occurred using mesially inserted miniscrew (9.01E-03 mm) in comparison with miniscrew in retromolar pad (1.12E-03 mm), T-loop (4.05E-04 mm), and distal-inserted miniscrew(-6.83E-04 mm). Buccal and Lingual cusps extrusion was at least using distal-inserted miniscrew. In mesiodistal path, mesial and distal cusps extruded 2.12E-04 and 1.58E-03 mm in first model, -1.14E-03 and 3.80E-03 mm in second method, -2.37E-03 and 7.04E-04 mm in third design and, 1.88E-03 and 8.57E-03 mm in the fourth model. Mesial cusp was extruded more than distal cusps in all methods (table 3). The maximum amount of extrusion occurred with mesially inserted miniscrew (8.57E-03 mm in mesial cusp). Whereas, extrusion in both mesial and distal cusps were at least while using distal-inserted miniscrew (-2.37E-03 and 7.04E-04 mm) in comparision with other methods.

**Table 2. Vertical Displacement (the amount of extrusion/intrusion) in buccolingual plane in buccal and lingual cusps in different designated methods.**

| | T-Loop | Ratio† | Retromolar | Ratio | Distal Insert | Ratio | Mesial Insert | Ratio |
|---|---|---|---|---|---|---|---|---|
| Buccal | 1.36E-03 | 3.36 | 1.13E-03 | 2.79 | -9.74E-04 | -2.4 | 1.49E-03 | 3.67 |
| Lingual | 4.05E-04 | 1 | 1.12E-03 | 2.76 | -6.83E-04 | -1.68 | 9.01E-03 | 22.2 |

†= the lowest finding is considered as the unit. -Displacements are measured in millimeter.

**Table 3. Vertical displacement (the amount of extrusion/intrusion) along a disto-mesial path in mesial and distal cusps in different designated methods.**

| | T-Loop | Ratio‡ | Retromolar | Ratio | Distal Insert | Ratio | Mesial Insert | Ratio |
|---|---|---|---|---|---|---|---|---|
| Distal | 2.12E-04 | 1 | -1.14E-03 | -5.38 | -2.37E-03 | -11.17 | 1.88E-03 | 8.86 |
| Mesial | 1.58E-03 | 7.45 | 3.80E-03 | 17.92 | 7.04E-04 | 3.32 | 8.57E-03 | 40.42 |

‡= the lowest finding is considered as the unit. - Displacements are measured in millimeter.

When TMA loop was used, center of rotation translated to distolingual portion of distal root and maximum displacement was 2.46E-03 mm which occurred at mesiobuccal surface of crown (Fig 1). The least displacement was 1.78E-04 mm in the center of rotation. By placing a miniscrew in retromolar pad and inserting force with an elastomeric chain, the center of rotation was transferred to mesial portion of distal root in bifurcation of second molar (Fig 2). Therefore, maximum extrusion in this model was 7.35E-03, found in mesial portion of occlusal table. Minimum displacement occured in the center of rotation (8.17E-04 mm). When the screw was inserted in distal portion in third method, tooth movement was observed around a center of rotation at distal root (Fig 3).

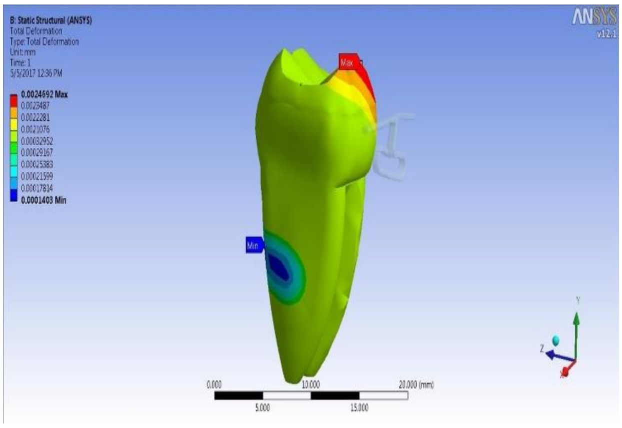

**Figure 1. Pattern of second molar movement with TMA loop from distal view**

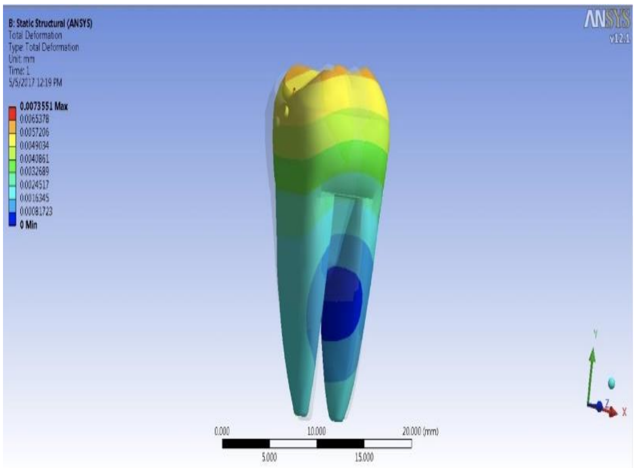

**Figure 2. Second molar uprighting with force exerted with elastomeric chain.**

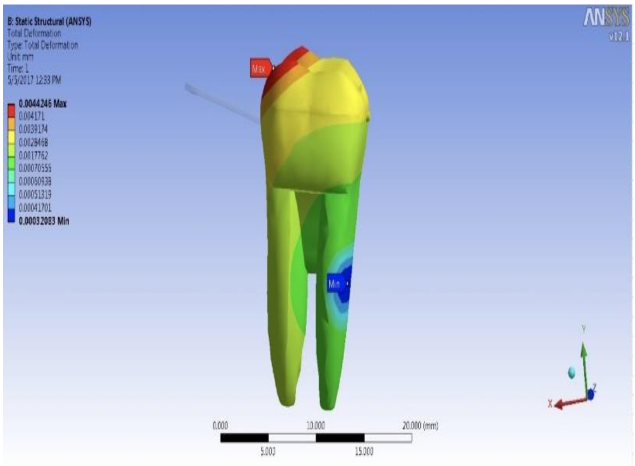

**Figure 3. Pattern of tooth movement induced by distal inserted screw**

Displacement at mesial marginal ridge was in maximum amount (4.42E-03 mm). In application of mesial- inserted screw, the center of rotation was located at distolingual surface of distal root (Fig 4). The highest amount of extrusion (1.50E-02 mm) occured in buccal cusp. The minimum amount of extrusion was 4.17E-04 mm that was seen in center of rotation.

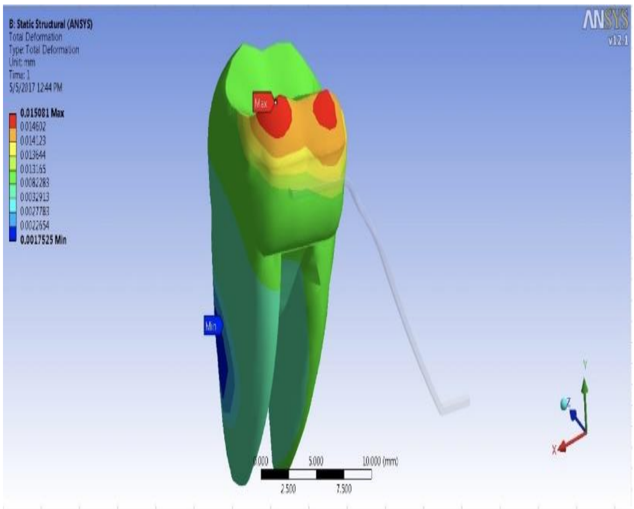

**Figure 4. Second molar uprighting with mesial-inserted screw**

## Discussion

In modeling of distal miniscrew with elastic chain, the center of rotation was found at the mesial portion of distal root in bifurcation of second molar. In a finite element analysis, Kojima et al reported buccal tipping of the second molar by using molar uprighting spring. They proposed that a spring-arm bending can be used to decrease tipping of anchor teeth which may induce increased buccal tipping of molar in comparison to a spring arm without bending 21.

Another study with similar findings is a systematic review by Magkavali-Trikka et al in 2017, that presents the use of miniscrew implants (MIs) for mandibular molar uprighting. MIs were inserted in several insertion sites including retromolar area, vertically in edentulous alveolar ridge or between the roots of adjacent teeth, mesial to molar. Uprighting forces were applied using elastomeric chains attached to buttons, coilsprings or cantilevers. Most of these different methods produced buccal and intrusive forces on lingually tipped molar13. Differences in results may be related to the point of force application and different mechanotherapies used in various studies. The mesial inserted miniscrew was associated with the most vertical changes. The least vertical changes were about distally-inserted miniscrew. Application of forces distal to the center of resistance in distal inserted miniscrews which can help vertical control when second molar tends to extrude during uprighting movement. Musilli et al also believed that this method is a good choice for distoinclination of molar and space opening when vertical control is important 9. However, they mentioned that precise screw positioning is necessary for good vertical control 9. Extrusion of the molar during uprighting movement may reduce the pocket depth on the mesial portion of second molar. However, it can also cause premature contacts and bite opening which are often unfavorable, especially if comprehensive orthodontic treatment is not considered 22. In mesio-distal plane, the present study showed that mesial cusps were extruded more than distal cusps in all methods. However, when distal-screw was used, vertical changes were the least and most vertical changes occurred with mesial-inserted miniscrew.

Center of rotations during molar uprighting varied in four different methods. In first and last methods (T-loop and mesial miniscrew), center of rotation was at distolingual portion of distal root. Maximum displacement with T-loop occurred at mesiobuccal surface of crown. Derton et al, achieved uprighting, intrusion and also bodily mesialization of the molar using mini-implants and 0.018 × 0.025-inch TMA sectional archwire with helix in a case-report study 20. By placing a miniscrew in retromolar pad and using an elastomeric chain (second approach), the center of rotation was transferred to mesial portion of distal root in bifurcation of second molar. The best type of movement expected is noticed in distal miniscrew with chain elastic. Musilli et al confirmed this method produces a distalizing force which has a point of application and line of action far from the Center of Resistance and leads to rotation of molar. Distal tipping of crown was more than mesial root movement in their measurements. Musilli supposed that this technique is more common because force system of appliance is easily understood 9. In present study when distal miniscrew with a cantilever was used, mesial marginal ridge had maximum movement around a center of rotation at distal root.

According to Musilli et al, the cantilever attached to a distal miniscrew can produce a moment and an intrusive force on uprighting molar. The friction between the wire and the molar tube reduces distal tipping of crown. They suggested this method for mild uprighting and space opening when vertical control is still critical 9. Musilli and Carnei also believe that in mild mesial tipping of molar, distal position of miniscrew is appropriate for producing enough moment to upright the molar but in moderate to severe tipping, prependicular distance between the force and center of resistence is reduced, so placing a miniscrew in mesial is more capable of providing sufficient uprighting moments 9,14. Another limitation of distal miniscrews is presence of any tooth distal to the molar that may interfere with the insertion of miniscrew and also distal movement of uprighting crown15 .

Because clinical measurement of stress distribution in tooth structures is impossible, fininte element modeling is a simulation of the situation, but is not exactly the real condition. Therefore, some biomechanical factors included in our study may be different from in-vivo studie. It should be also noticed that some individual differences in biologic responses and tooth reaction to orthodontic loads may exist 22. Extrusion of all cusps were at least using distal-inserted miniscrew and the most extrusion occurred with mesially inserted miniscrew. The best type of movement was found in distal miniscrew with chain elastic, because extrusion was minimum and the center of rotation located at the bifurcation of second molar.

## References

1.Proffit WR, Fields HW, Sarver DM. Contemporary orthodontics. 5th ed. Elsevier;2013.

2.Roberts WW, Chacker FM, Burstone CJ. A segmental approach to mandibular molar uprighting. Am J Orthod Dentofacial Orthop. 1982;81(3):177-84.

3.Gracco A, Lombardo L, Cozzani M, Siciliani G. Uprighting mesially inclined mandibular second molars with a modified uprighter jet. J Clin Orthod. 2007; 41(5):281-4.

4.Gianocotti A, Arcuri C, Barlattani A. Treatment of ectopic mandibular second molar with titanium miniscrews. Am J Orthod Dentofacial Orthop. 2004; 126(1): 113-7.

5.Tuncay OC, Biggerstaff RH, Cutcliffe JC, Berkowitz J. Molar uprighting with T-loop springs. J Am Dent Assoc. 1980;100(6):863–6.

6.Lee KJ, Park YC, Hwang WS, Seong EH. Uprighting mandibular second molars with direct miniscrew anchorage. J Clin Orthod. 2007;41(10):627–35.

7.Lau CK, Whang CZ, Bister D. Orthodontic uprighting of severely impacted mandibular second molars. Am J Orthod Dentofacial Orthop. 2013;143(1):116-24.

8.Kim M, Kim M, Chun YS. Molar uprighting by a nickel-titanium spring based on a setup model. Am J Orthod Dentofacial Orthop. 2014;146(1):119-23.

9.Musilli M, Marsico M, Romanucci A, Grampone F. Molar uprighting with mini screws: comparison among different systems and relative biomechanical analysis. Prog Orthod. 2010; 11(2):166-73.

10.Sohn BW, Choi JH, Jung SN, Lim KS. Uprighting Mesially Impacted Second Molars with Miniscrew Anchorage. J Clin Orthod. 2007;41(2):94-7.

11.Yun SE, Lim WH, Chun YS. Molar control using indirect miniscrew anchorage. J Clin Orthod. 2005; 39(11):661

12.Zachrisson BU, Bantelon HP. Optimal mechanics for mandibular molar uprighting. World J Orthod. 2005;6(1):80-7.

13.Magkavali-Trikka P, Emmanouilidis G, Papadopoulos MA. Mandibular molar uprighting using orthodontic miniscrew implants: a systematic review. Prog Orthod. 2018;19(1):1.

14.Cernei ER, Mavru RB, Zetui IN. Second molar uprighting after premature loss of mandibular first permenant molar-Case report. Rev Med Chir Soc Med Nat Iasi. 2015;119(2):572-8.

15.Ruellas AC, Pithon MM, Santos RL. Miniscrew-supported coil spring for molar uprighting: description. Dental press J Orhtod. 2013 Feb;18(1):45-9.

16.Lin TS, Tsai FD, Chen CY, Lin LW. Factorial analysis of variables affecting bone stress adjacent to the orthodontic anchorage mini-implant with finite element analysis. Am J Orthod Dentofacial. 2013;143(2):182-9.

17.Geramy A, Sheikhzadeh S. Torque Control of Upper Incisor in Intrusive Loads and Comparison of the Lingual and Labial Bracket Systems: A Finite Element Analysis. Prensa Med Argent 2015101:2. doi:10.4172/lpma.1000145

18.Ash MM. Dental anatomy, physiology, and occlusion. 6th ed. Philadelphia: W.B. Saunders Co. 1984:245–86.

19.Park HS, Kyung HM, Sung JH. A simple method of molar uprighting with Micro-Implant Anchorage. J Clin Orthod. 2002;36(10):592–6.

20.Derton N, Perini A, Mutinelli S, Gracco A. Mandibular molar uprighting using mini-implants: Different approaches for different clinical cases- Two case reports. Orthodontics (Chic). 2012;13(1):138-45.

21.Kojima Y, Mizuno T, Fukui H. A numerical simulation of tooth movement produced by molar uprighting spring. Am J Orthod Dentofacial Orthop. 2007;132(5):630-8.

22.Shellhart WC, Oesterle LJ. Uprighting molars without extrusion. J Am Dent Assoc. 1999;130(3):381-5.