Original Article

The Effect of Different Positions of Unerupted Lower Third Molar Teeth on the Fragility of Mandibular Angle: Finite Element Analysis

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Abstract

Background: The mandibular bone is the largest and strongest bone in comparison to the other bones in the face skeleton. However, it is the most commonly fractured in facial injuries. The location of the fracture in mandible depends on various factors. The relationship of the impacted lower third molar teeth to mandibular angle fracture has been the subject of many epidemiological studies. It is argued that the risk of fracture in mandibular angle is two to four times more when there are particularly an impacted or partially impacted third molar teeth. However, the effect of the position of the impacted tooth on mandibular angle fracture is not clear yet. **Aim:** This study seeks to reveal the effect of third molar teeth that are impacted in various positions on the angle fragility. **Materials And Methods:** This study was performed using three-dimensional finite element stress analysis and static linear analysis methodology. Computed tomography (CT) images obtained previously from a patient were used to construct models of the bone tissue. An ILUMA CBCT device (3M Imtec, OK, USA) was used for tomographic scans. Impacted teeth in various positions were digitally modeled separately. Different direction forces were applied to the mandible, the stress values on the bone surrounding the third molar teeth impacted in different positions were determined. **Results:** Third molar teeth are impacted in mandibular bone in the following positions: mesioangular, vertical, horizontal, and distoangular positions. The study showed that the force that created the highest stress in the Mandibular angle among the modelled groups is the force by ipsilateral angle. **Conclusion:** For all kinds of impacted teeth, there was more stress accumulation in the buccal area than in the lingual area when the force is from the symphisis.

Keywords: *Finite element analysis, impacted third molar teeth, mandibular angle, trauma*

Received: 15-Mar-2021; **Revision:** 29-Jul-2021; **Accepted:** 10-Aug-2021; **Published:** 26-Oct-2022

Introduction

The mandible is the largest and strongest bone in the human facial skeleton; yet, mandibular fractures occur very commonly.[1,2] Mandibular angle fractures represent about 40% of mandibular fractures.[3] In general, fractures of the mandibular angle result from a blow to the chin from the opposite side or a blow to the mandibular body area on the same side. Mandibular angle fractures are usually associated with contralateral subcondylar or mandibular corpus fractures.[4]

In one study, Meechan *et al*. hypothesized that since the lower third molar is located near the angle of the mandible, its presence may increase the risk of fracture. They suggested that a mandibular third molar may weaken the jaw by decreasing the cross-sectional area of the bone and therefore, extracting the third molar would presumably allow the tooth socket to fill with bone, resulting in a reduced risk of an angle fracture.[5-7]

Access this article online

Quick Response Code:	
	Website: www.njcponline.com
	DOI: 10.4103/njcp.njcp_1317_21

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How to cite this article: Seyrek NK, Kahraman OE. The effect of different positions of unerupted lower third molar teeth on the fragility of mandibular angle: Finite element analysis. Niger J Clin Pract 2022;25:1629-34.

The association between the presence of a third molar and fracture risk in patients with mandible fractures has been investigated in previous studies.[8] It has been suggested that an impacted or partially erupted third molar in the mandible increases the risk of a mandibular angle fracture by 2 to 4-fold.[5,9] Moreover, some studies demonstrated that mandibular condyle fractures are more likely to occur in the absence of a third molar in the mandible.[10] In retrospective studies, the prevalence and relative risk of mandibular angle fractures were found to be significantly higher in patients with completely erupted third molars compared to individuals without these teeth.[11]

The finite element method was developed as a branch of applied mathematics by numerical modeling of physical systems for use in a variety of engineering disciplines.[12] Given disparate clinical data and limitations of conducting experimental trials in human mandible, numerical simulations, and virtual models obtained with the finite element analysis are used in studies.[12-17] In studies using the finite element analysis, the stress distribution in the mandibular angle from impact forces to the mandible was examined in the presence of a third molar. These studies found a high level of stress in the mandibular angle region when a third molar was present.[12-15] However, angular variations in the position of impacted mandibular tooth were not assessed in these studies.

The aim of the present study was to examine the effects of different positions of an impacted third molar on mandibular angular fracture by using simulations of three standard conditions of trauma to the mandibular symphysis, ipsilateral corpus, and contralateral corpus.

Materials and Methods

This study was performed using three-dimensional finite element stress analysis and static linear analysis methodology. Computed tomography (CT) images obtained previously from a patient were used to construct models of the bone tissue. An ILUMA CBCT device (3M Imtec, OK, USA) was used for tomographic scans. Images were acquired at 120KvP, 3.8mA with a scan time of 40 seconds. (ethics committee: 17.05.2018, 09/11).

A computer equipped with Intel Xeon® CPU 3.30 GHz processor, 500 GB Hard drive, 14 GB RAM and Windows 7 Ultimate Version Service Pack 1 operating system was used to construct 3D solid model and to conduct finite element stress analysis. 3D scans were performed using an Activity 880 optic scanner (Smart Optics Sensortechnik GmbH, Sinterstrasse 8, D-44795 Bochum, Germany). The Rhinoceros 4.0 (3670 Woodland Park Ave N, Seattle, WA 98103 USA) software was used for 3D modeling. VRMesh Studio (VirtualGrid Inc, Bellevue City, WA, USA) and Algor Fempro (ALGOR, Inc. 150 Beta Drive Pittsburgh, PA 15238-2932 USA) software programs were used for analysis.

Following geometric construction of the models using the VRMesh software, they were transferred to the Algor Fempro software (Algor Inc., USA) in STL format for further analyses. Each structure forming the model were assigned material values (modulus of elasticity and Poisson's ratio) describing their physical properties [Table 1].[15,18] In the software, the material properties of the solid object were characterized as linear elastic, homogeneous, and isotropic. In the model, upper condylar regions of the jaw bone were fixed at 0 degree of freedom (DOF).

Masticatory muscles were simulated in the model as described previously taking into account their effect on deformation.[19] Anterior and posterior temporal muscles, masseter muscle, and medial and lateral pterygoid muscles were chosen for the model. These muscles were modeled as springs with no resistance during compression. The stiffness values of spring tension were taken from the relevant literature: masseter muscle: 16.35 N/mm, lateral pterygoid muscle: 12 N/mm, medial pterygoid muscle: 15 N/mm, anterior temporal muscle: 14 N/mm, and posterior temporal muscle: 13 N/mm [Figure 1].[14,20]

From the constructed mandible, study models with an impacted third molar were generated. In the study models, impacted third molar was placed in only one side of the mandible with no symmetrical modeling. To ensure standardization among the models, the third molar was simulated as completely impacted and Class III according to the Pell and Gregory's classification in all groups.

On the simulated mandible, a control model without an impacted third molar and four separate models including mesioangular [Figure 2], distoangular [Figure 3], vertical [Figure 4], and horizontal [Figure 5] models were constructed based on differential angular positions of the long axis of the impacted third molar relative to the long axis of the second molar.

Each model was subjected to a blunt trauma force of 2000 N. Loading was applied laterally on a 1 cm² circular surface area, perpendicular to the mandibular angle with the impacted third molar and the symmetrical area with no impacted tooth and perpendicular to the center of the symphysis area in the frontal plane. [Figure 6] A 2000 N impact force was employed in our study since it has been commonly used in former studies of finite element analysis.[13-15]

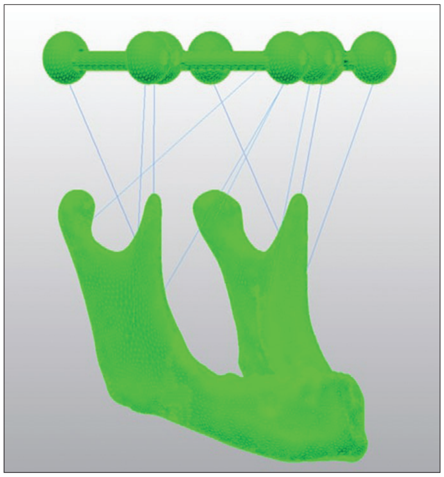

Figure 1: Muscles supports were illustrated

Figure 2: Model of the human mandible with impacted third molar in the mesioangular position

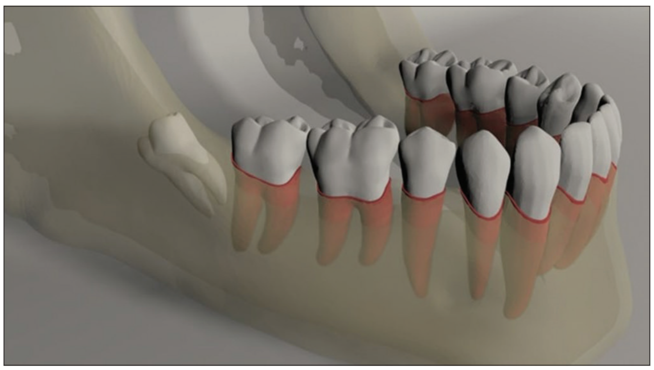

Figure 3: Model of the human mandible with impacted third molar in the distoangular position

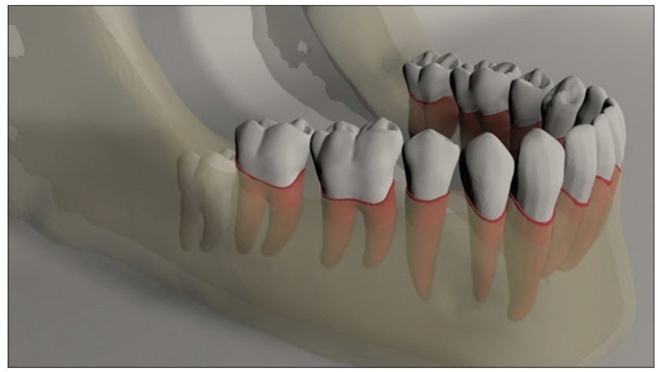

Figure 4: Model of the human mandible with impacted third molar in the vertical position

Figure 5: Model of the human mandible with impacted third molar in the horizontal position

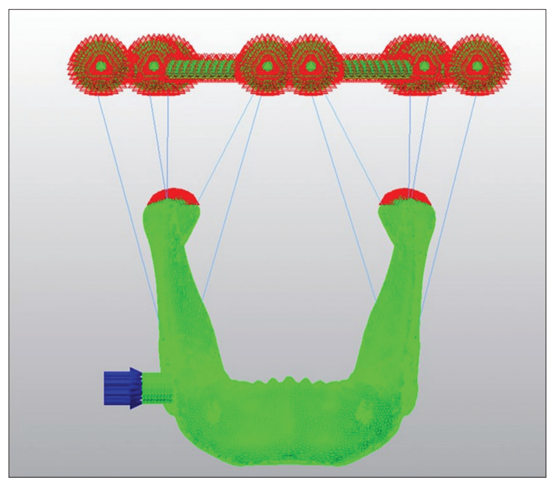

Figure 6: Simulated impact loads to the region of the ipsilateral body

The effect of loading applied at aforementioned sites on the risk of angular fracture was examined by looking at the distribution of stress values.

Results

The results are based on the chromatic analysis of the distributed impact (von Mises stress), compression and tensile stresses and estimation of maximum stress at the areas of interest.

Table 2 shows maximum von Mises stress values (N/mm^2) of the five models (control, mesioangular, distoangular, vertical, and horizontal) following application of force at ipsilateral mandibular angle. Upon loading on ipsilateral mandibular angle, the highest stress value was observed around the lingual surface of the tooth (123,409053 N/mm^2) in the angle of the model with distoangular bony impaction. The lowest stress was located around the buccal surface of the tooth (69,552401 N/mm^2) in the angle of the model with vertical bony impaction.

Table 3 shows maximum von Mises stress (N/mm^2) values for five models following loading at mandibular symphysis. After loading on mandibular symphysis, the highest stress occurred around the buccal surface of the tooth (42,045690 N/mm^2) in the angle of the model with vertical bony impaction. The lowest stress was observed around the lingual surface of the tooth (21,627052 N/mm^2) in the angle of the mandibular model with mesioangular impaction.

Maximum von Mises stress (N/mm^2) values for five models following loading on contralateral mandibular angle are shown in Table 4. The highest stress was located in the buccal area of the tooth (24,877434 N/mm^2) in the angle of the mandibular model with vertical bony impaction. The lowest stress value was found in the lingual aspect of the tooth (6,055877 N/mm^2) in the angle of the mandibular model with horizontal bony impaction.

Table 1: Elastic modulus values and Poisson's ratios of study materials

Materials	Young's Modulus (MPa)	Poisson's Ratio
Cortical bone	13700	0,3
Trabecular bone	1370	0,3
Tooth	41000	0,3

Figure 7 summarizes the distribution of stresses in the mandible for the models exhibiting highest stress in the angle under loading conditions tested.

The force applied on the ipsilateral mandibular angle was found to be associated with the highest stress on the angle region (123,409053 N/mm^2).

Greater stress concentration was observed around the buccal surface of the tooth compared to lingual area for all types of impaction following loading on mandibular symphysis. Stress concentration in the buccal aspect of the vertically impacted tooth was much higher in comparison to other groups (42,045690 N/mm^2). The control model showed no difference in the stress values obtained from lingual surface of the mandibular angle versus models with impacted teeth.

Discussion

Among mandibular fractures, fractures of the mandibular angle are highly prevalent. Mandibular angle fractures

Table 2: Maximum von Mises stress (N/mm^2) values measured in mandibular regions of five models following application of force on ipsilateral mandibular angle

	Control	Mesioangular	Distoangular	Vertical	Horizontal
Lingual Aspect of the Mandibular Angle	120,218509	118,467917	123,409053	118,274232	113,730990
Buccal Surface of the Tooth		81,480349	71,774002	69,552401	83,975772

Table 3: Maximum von Mises stress (N/mm^2) values measured in mandibular regions of five models following application of force on mandibular symphysis

	Control	Mesioangular	Distoangular	Vertical	Horizontal
Lingual Aspect of the Mandibular Angle	22,827521	21,627052	23,075948	22,062753	21,999405
Buccal Surface of the Tooth		29,882414	27,303323	42,045690	24,382299

Table 4: Maximum von Mises stress (N/mm^2) values measured in mandibular regions of five models following application of force on contralateral mandibular angle

	Control	Mesioangular	Distoangular	Vertical	Horizontal
Lingual Aspect of the Mandibular Angle	6,935773	8,070450	7,677981	7,134095	6,055877
Buccal Surface of the Tooth		15,329620	22,968948	24,877434	14,363209

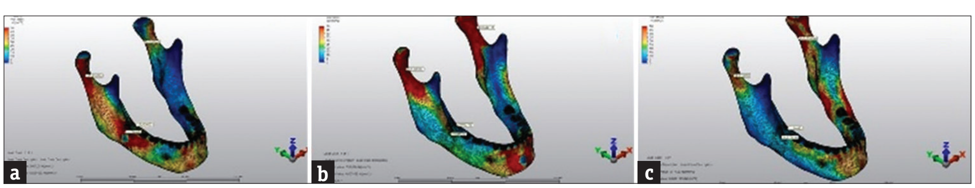

Figure 7: (a) Distribution of maximum von Mises stress (N/mm^2) values following loading on ipsilateral mandibular angle in the model with distoangular bony impaction, (b) distribution of maximum von Mises stress (N/mm^2) values following loading on mandibular symphysis in the model with vertical bony impaction, (c) distribution of maximum von Mises stress (N/mm^2) values following loading on contralateral mandibular angle in the model with vertical bony impaction

account for about 12-32% of all mandibular fractures depending on the population studied. The quality of bone tissue and characteristics of tooth eruption have been suggested to facilitate the occurrence of a fracture.[14] Teeth can be used to determine where a fracture has occurred. Up to 50% of mandibular fractures involve dentate areas. The presence of a mandibular third molar has been cited as a cause of increased occurrence of fractures in the angle compared to other mandibular regions.[21] The position of impacted third molars may be associated with the risk of angle fractures.[22] In light of these data, we set out to examine the effects of various positions of impacted third molars on the bone under traumatic forces coming from different directions.

Retrospective studies also reported that patients with impacted mandibular third molars are at an increased risk of mandibular angle fractures than those without impacted lower third molars.[21-24] In a retrospective study by Rajkumar *et al*.,[21] the effects of the presence and position of a third molar on mandibular angle fracture. Patients with mandibular third molars were 2.16 times more likely to experience an angle fracture than patients without mandibular third molars. When the position of third molars was examined in relation to angle fractures, mesioangular position was most commonly observed in patients presenting with angle fractures. In the present study, highest stress in the angle was observed in the model with distoangular bony impaction following ipsilateral loading, whereas the model with vertical third molar impaction showed highest stress upon forces acting at smyphysis and contralaterally.

In another retrospective study, 88.9% of patients with a mandibular angle fracture had an impacted third molar and mesioangular and vertical positions were most prevalent.[25] Consistently, highest stress was observed in the model with vertical third molar impaction after application of forces on the symphysis and contralaterally in our study.

Bezerra *et al*.[12] investigated the effect of the presence of erupted third molars on the mandible after exposure to trauma. They constructed three mandibular models for finite element analysis including two models with erupted third molars (unilateral or bilateral) and one without a third molar. Greater stress was found around the cervical part of the alveolus in the models with third molars. The authors noted stress concentration on the mandibular external ridge after trauma and stress concentration extended along the alveolar bone when a third molar was present.[12] In the current study, we observed greater stress on buccal aspect of the tooth than on lingual surface upon loading at the mandibular symphysis, which is in line with Bezerra *et al*.'s findings.

Using finite element analysis, Antic *et al*.[12] examined the effects of the presence and position of a lower third molar on the fragility of mandibular angle and condyle by constructing three models including a mandibular model with erupted third molar, a model with partially erupted third molar in the mesioangular position and a model without a third molar. They applied frontal and lateral blows to the models. In the frontal loading, the stress mostly concentrated at the point of impact, posterior segment of the condyle and in the angle region around the third molar. The highest stress in the angle region was observed in the model with partially impacted third molar. In the present study, comparable stress values were obtained at the lingual area of the angle in the models with impacted tooth versus control model.

In the study by Antic *et al*.[14], maximum stress was observed at the point of impact, in the ipsilateral and contralateral angle condylar regions in the case of lateral blow. The highest stresses were recorded in the model with an impacted third molar in the angle. In our study, higher stress distribution was found in the lingual surface of the tooth than in the buccal aspect in the case of loading to ipsilateral angle. This finding is consistent with the fact that fracture occurs on the side where stress is concentrated.[26-29]

Given the increased risk of mandibular angle fractures in the presence of third molars, some studies have suggested that third molars should be extracted as a prophylactic measure in individuals participating in high contact sports.[5,30-32] In our study, highest stress concentration was observed in the angle in the presence of fully impacted third molars in vertical and distoangular positions. Since our study data are based on a finite element analysis, it would not be realistic for us to suggest prophylactic extraction of totally impacted third molars.

Conclusion

Loading on ipsilateral angulus was associated with the highest stress in the mandibular angle region. Lingual area showed higher stress distribution in comparison to the buccal area around the third molar in the case of ipsilateral loading. While peak stress values were measured at the distoangular bony impaction following loading from ipsilateral angle, vertical bony impaction showed highest stress when force was applied on mandibular symphysis and contralateral mandibular angle. A study examining the presence of a third of molar in patients with or without a mandibular fracture following exposure to trauma to the mandible could provide further data on this particular issue.

Acknowledgments

This study was supported by Firat University Scientific Research Project Foundation Department with the project number DHF.18.02.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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