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# Stress effect on the mandibular dental arch by mentalis muscle over activity, finite element analysis

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## Abstract

**OBJECTIVES:** The perioral muscles postural and functional abnormality should be clearly evaluated. The influence of the abnormal function of mentalis muscle on the shape and posture of the mandible was evaluated using a finite element approach.

**METHODS:** Finite element analysis was used to create a three-dimensional representation of a human mandible that represents a dry normal mandible with teeth (33-36 gm/cm$^2$). Pressures were applied directly to the labial surface of the mandible's lower anterior dento-alveolar structure reflecting the normal lips muscle function. While on abnormal swallowing pattern, lip muscle force (300 gm\cm$^2$) had been assumed.

**RESULTS:** Shape and postural abnormality of the mandible with malocclusion particularly at the anterior dentoalveolar and basal bone region in sagittal direction as well as inward pressure on the mandibular posterior region.

**CONCLUSION:** Abnormal perioral muscle function throughout growth and development may result in a shape and postural abnormality of the mandible and a companying malocclusion.

**Keywords:**

Abnormal swallow, finite element analysis, mandible, mentalis muscle, stress

## Introduction

Lip seal is the normal configuration guided by upper and lower lips during rest position and swallowing. During the rest oral posture, the upper and lower lips are lightly together, with restful firm contact on swallowing. Both upper and lower lips normally guided by orbicularis oris muscle, as upper and lower compartment consequently, in normal condition and during normal function. The activity of upper and lower compartment of orbicularis oris, as muscle of mastication, guide the lip seal only without involvement of inside and nearby facial muscles like the mentalis.[1,2]

The mentalis muscle is the muscle of facial expression especially pertaining to emotion, like what we call it facial grimace or pout, and do nothing with oral function. The mentalis muscle is a paired muscle originates from the mentum of the mandible at the tip of the chin, runs vertically from below the lower lip to the lower part of the chin, and inserts into the soft tissue of the chin. This muscle provides stability to the lower lip and it is sometimes referred to as the "pouting muscle" as it is raising the lower lip and causing chin wrinkles.[3]

Therefore, during normal lip seal, the facial muscles should not reflect any form of tonicity, just the orbicularis oris which involve in swallowing. The orbicularis oris force is light and continuous, as estimated by means of the force transmitted to lip bumpers.[1]

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Mentalis muscle activity on the mandibular dentoalveolar structure is represented by a mandibular finite element model. This model was used to explore the effect of stress on the stomatognathic system in a nondestructive way. When compared to strain gauge and photo-elastic methods, it is a quantitative evaluation made easier with a more solid and precise biomechanical basis to examine the stress within the mandibular dental arch using finite element analysis.[4]

The impact of the cheek and tongue posture with soft-tissue dysfunction on the dentofacial growth and development with consequent malocclusion have shown more attentions. There have been few studies on the mentalis muscle, with none evaluating the actual effect of the mentalis muscle on the jaw form. Therefore, using finite element model, the aims in this study were to:

1. Assess the potential effect of the mentalis muscle on the mandible.
2. Determine stress distribution of mentalis muscle on the mandibular dental arch.
3. Examine the likely form or shape of a mandibular abnormality that may result from the severity of the incorrect swallow.
4. Can give an idea that if with the elimination of the habit or reduce its severity, this may correct the physiologic form and shape of the mandible, as well as preventing future defects.

## Methods and Materials

The protocol of the study was approved by the research ethics committee of University of Mosul/College of Dentistry, REC reference No. UoM.Dent/DM.76/21. In 12/10/2021

In the present research paper, a three-dimensional figure of mandible with teeth model was developed using AutoCAD (2010).[5-8] Program to study the distribution pattern of stresses and displacements of mandible and mandibular teeth in following conditions:

a. Lips muscle function during normal swallowing pattern (in normal swallow, the main function of the orbicularis oris muscle is the anterior oral seal with light pressure without any tonicity).
b. Lips muscle function during abnormal swallowing pattern (over constriction of orbicularis oris muscles that mainly is evident by facial grimes following contraction of mentalis to compensate orbicularis oris function loss).[1]

In this study, the periodontal ligament was not involve.[6] The cancellous bone was considered as a solid part inside the cortical bone[9] X, Y-axis, and Z-axis coordinate system was applied on the model; the X-axis signified the mesio-distal movement, the Y-axis characterized the bucco-lingual one, and the Z-axis showed the vertical movement. Autodesk Inventor (2022) software was used for finite element analysis, the assumption for the materials properties was made, materials behavior was assumed to be homogenous and linear elastic.[10,11] The material properties for cortical and cancellous bone[12] and teeth[13] were listed in Table 1. The boundary condition for this study model was designed by restraining the external surface of the condyle movement in all direction resembling glenoid fossa.[8,13] Finite element method involves dividing a complex model into a many of elements and nodes, creating a grid or mesh. Auto mesh option was used to create fine highly organized mesh. The final mesh for this research model was consisted nearly half million elements. The force of 33-36 gm/cm$^2$[1] had been applied straight to labial surface of lower anterior dentoalveolar structure reflecting normal lips muscle function. While on abnormal swallowing pattern, lip muscle force (300 gm\cm$^2$) had been assumed.[1] This study explains the stress distribution and the change occurs in the mandible at the moment of force application, that is, the times of applying pressure are the same times of salivary swallow.

## Result

Finite element outputs can be interrupted qualitatively and quantitatively. Stresses and displacements distribution pattern of the mandible within normal and abnormal lip function are studied in this paper. Table 2 shows the maximum values for Von Mises stresses and displacements for both circumstances. In this research paper, the most prominent displacements effects for lip muscle were detected in vertical direction, with little effects in bucco-lingual one.

### Von Mises stress

The highest stresses value for normal lip muscle function was 2.469 Mega pascal; however, the highest stresses value during abnormal lip muscle force during

**Table 1: Material mechanical properties**

| Material | Young's modulus (GPa*) | Poissons ratio |
|---|---|---|
| Cortical bone | 20.7 | 0.3 |
| Cancellous bone | 14.8 | 0.3 |
| Teeth | 18.6 | 0.31 |

*GPa Gaga Pascal

**Table 2: Maximum Von Mises stress and displacement values**

| Variables | Normal lips muscle function | Abnormal swallowing pattern |
|---|---|---|
| Von Mises (Mpa*) | 2.469 | 18.39 |
| X-Displacement (mm**) | 0.01637 | 0.1228 |
| Y-Displacement (mm) | 0.003086 | 0.02314 |
| Z-Displacement (mm) | 0.03236 | 0.2427 |

*(MPa) Mega Pascal, **(mm) millimeter.

swallowing was 18.39 Mega pascal. Both lip muscle conditions have the same design for stress distribution; the high stresses were seen adjcent to the location of fixation and force application, as seen in Figure 1.

## Displacement

### *X-displacement*

In both lip muscle functions, the lower jaw moves distally, the highest distal displacement can be found within pogonion and the area of chin. Middle range of distal movement was noted along central teeth, their associated alveolar bone, and the angle of mandible [Figure 2].

### *Y-displacement*

In this research, the lingual movement was seen with central incisors teeth and their associated alveolar bone, nearly zero bucco-lingual movement within canine and premolars area. Buccally twisting was seen in the angle of mandible [Figure 3].

### *Z-displacement*

The area of the mandible that is located under the influence of lip muscle force was displaced in downward direction; the highest range of vertical movement was detected along the chin, anterior teeth with zero movement within area of fixation [Figure 4].

## Discussion

The size, shape, and position of body structures reach its full genetic potential under the control of the environment. The craniofacial structures in specific are under the control and guidance of functions like breathing, swallowing, speaking, and mastication which all further guided by the posture of the oral cavities. The oral cavity is a complex structure composed of hard tissue enveloping the upper and lower compartment with the soft-tissue muscular structures envelope the remaining parts that guide its normal rest posture, normal swallow, and mastication.

The craniofacial structure muscles in general related to various functions either in combinations or alone. Some related to facial expression, other related to the swallowing or mastication, speaking, and abnormality in the functions that expressed by muscular weakness or overactivity or interplay could affect the growth of the structure/s related. One of the craniofacial structures that could be affected by the abnormal functions like mouth breathing, tongue thrust swallow, or thumb sucking is the mandible.

During normal oral rest posture or during the salivary swallow, the mentalis should be in fully relaxed state and the only activity is at the orbicularis oris muscle which guides the function of the lips, and mentalis muscle is related to doubt and contempt expressing, as it protrudes, elevates, and everts the lower lip and wrinkles the skin of the chin. While in an abnormal swallowing pattern whatever reverse swallow (is a negative oral habit known as orofacial myofunctional disorder), tongue thrust or buccinators swallow (sucking), there will be an overactivity in the lower lip guided by mentalis muscles, muscles of facial expression, to help establish anterior oral seal and in ability of patient to establish proper lip seal during swallowing due to lower activity of oral muscles and overactivity of perioral muscles.[14,15]

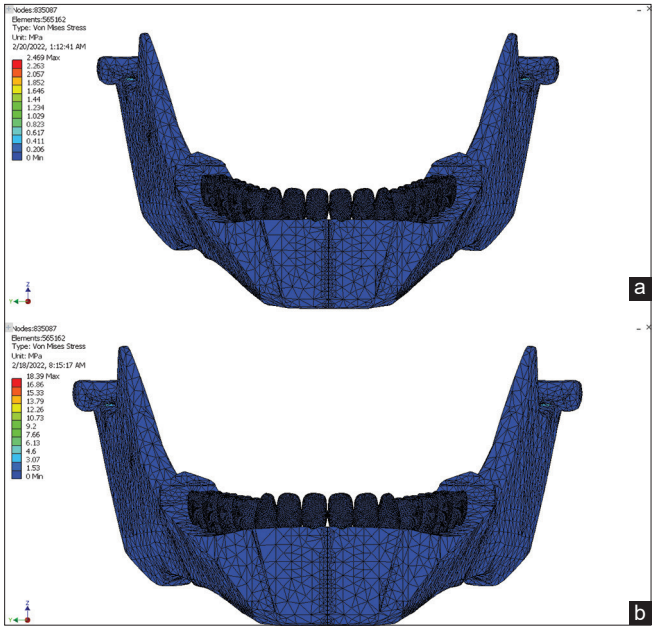


**Figure 1:** Von Mises stress distribution. (a) Normal lips muscle function. (b) Abnormal swallowing pattern

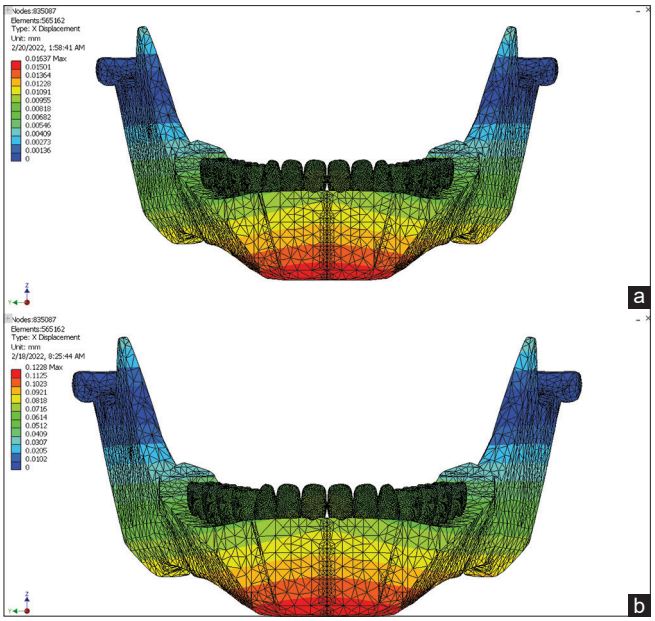


**Figure 2:** X-Displacement within (a) normal lips muscle function. (b) Abnormal swallowing pattern

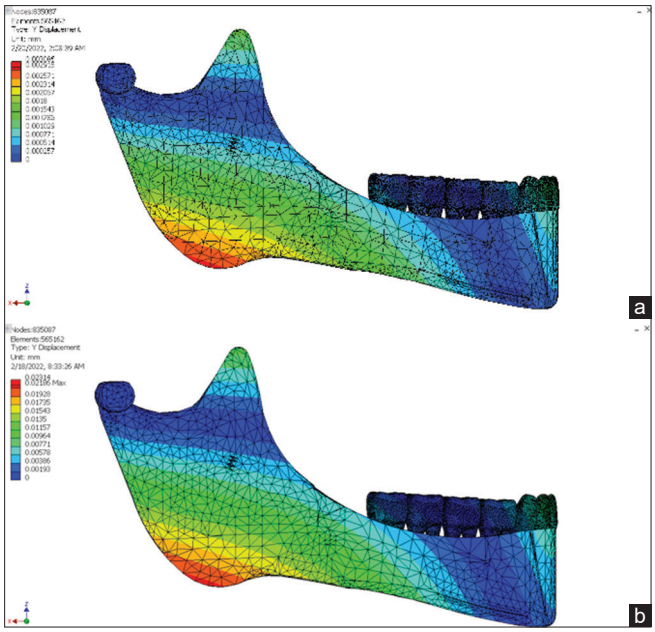


**Figure 3:** Y-Displacement within (a) normal lips muscle function. (b) Abnormal swallowing pattern

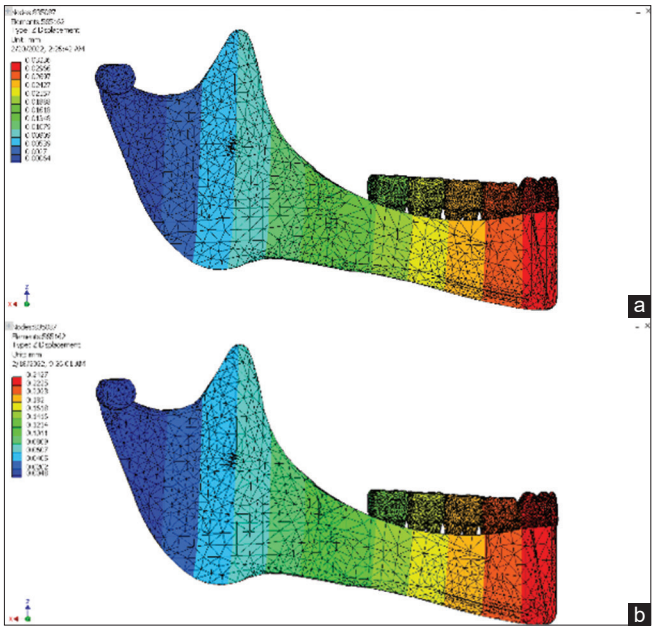


**Figure 4:** Z-Displacement within (a) normal lips muscle function. (b) Abnormal swallowing pattern

This mentalis overactivity will create a lot of false inward pressure on the anterior structure of the mandible that could result in lower anterior crowding or even flattening of the lower dentoalveolar structure with possible concomitant mandibular backward displacement. Appliances with labial shied-like lip bumper, Frankel regulator, and more efficient the trainers or myobraces from Myofunctional Research Company "MRC" all have the ability to help subsidizing the menalis overactivity, thus relieving this false pressure on the anterior part of the mandible and re-establishing the normal function of lower compartment of the orbicularis oris muscle to help anterior oral seal on swallowing.

According to the findings of this preliminary investigation, greater stress was measured at the sites where force was applied, fixation, and the chin in the group of aberrant muscle forces than in normal group.

It could be explained, rationally, that the force application area will show greater stress accumulation in Z-axis due to the direct muscular contact to the bone with X-displacement possibly with backward jaw displacement in an aberrant muscular force with abnormal function. It is important to say that there is a probable concomitant reaction coming from the X-displacement stress and the hinge articulation with rotatory nature of the mandible possibly could result in further downward displacement of the mandible that represented as mandibular posterior rotation with concomitant long face tendency.[3,16-18]

## Conclusion

From this research study, it could be concluded that an abnormal function like an aberrant swallow that happened during growth and development of craniofacial structure there will be abnormal activities from the perioral muscles like mentalis muscle which in turn will exert a backward pressure on the anterior part of the mandible that could result in various forms of dento-alveolar under development and abnormal mandibular posture.

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## Conflicts of interest

There are no conflicts of interest.

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