Estimation by FEA of Mandibular Bone Strength Affected by the Presence of Benign Tumors Associated with Impacted Teeth

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In an Ameloblastoma case we used CT data to create a 3D representation of the affected mandible and Finite Element Analysis allows us to study its behavior under masticatory forces. In this manner is possible to better understand case evolution and to decide the treatment plan, specific for each patient.

Keywords: Impacted molar, ameloblastoma, stress, strain, FEA

In the oral cavity, it can develop different cysts, but also tumors that start in the follicular sack of impacted teeth, which by their slowly progress can affect jaw’s strength. A small part from the total number of such lesions, about 1%, is represented by ameloblastoma.[1] Ameloblastoma was first described by Robinson in 1977[2]. It develops from odontogenic epithelium and occurs with greater frequency in the posterior mandible, associated with a impacted tooth; adults being affected almost equal in both sexes [3-5].

The appearance of these tumors in childhood is very rare and is often presented as a radiolucent lesion, apparently very easy to confuse with a cystic lesion [6].

The latest OMS classification (2005) divides these tumors in several types: solid, multicystic, cystic, desmoplastic and peripheral. In histopathological terms it is describe by six types: follicular, plexiform, acanthomatous, granular, desmoplastic and basilar, which does not have great relevance in clinical terms [6, 7].

The development of this type of tumor is slow, most often asymptomatic, and the symptoms represented by root resorption, tooth mobility or paresthesia occurs in advanced stages. Ameloblastoma has a very aggressive behavior and produce gradual thinning of the bone and if treatment is not correctly applied it has a tendency to local recurrence.[8]

Diagnosis can be made by FNAC (Fine-Needle Aspiration cytology), imaging examinations, histopathology associated immuno-histochemical examination. Correlation of the clinical information and histological imaging can contribute to make the most accurate therapeutic decisions [9, 10].

The modality of treatment, conservative or radical, varies by location, size and histological type of the tumor. As conservative methods are described enucleation or curettage that may be associated with cryotherapy and cauterization, and as radical methods are cited marginal or segmental resections [11, 12]. Small tumors (less than 1cm) was treated by enucleation; large ones (above 1cm) are treated with partial or total resection, followed by reconstruction where needed. [13-15] Regardless of the method of treatment, patient’s monitoring by clinical and radiological periodical controls is mandatory, considering the risk of recurrence, especially in large tumors. [16]

Experimental part

In this study we took a particular case of a 12 years old boy, diagnosed with large ameloblastoma developed in ascending mandibular ramus, around tooth 38 found in inclusion.

Initially, dates from patient’s CT examination were loaded into Mimics © Materialise NV and we achieved 3D reconstruction of the mandibular bone structure with affected resistance by the increase of tumor.

Subsequently, using 3-matic © Materialise NV, the 3D object was remeshed to prepare itself to simulation of stress and strain that appear in the process of mastication. Mandibular bone prepared for numerical analysis was imported into ANSYS© SAS IP, Inc. The structure was made up of 155.279 volumetric elements and 41.717 nodes. FEM analyzes were performed in two variants: with force applied on incisors and molars respectively. For the simulations we applied successively a force of 110 N to the anterior teeth to simulate the incision of aliments and a force of 200 N in the lateral teeth to simulate food trituration.

The characteristics defined for mandibular bone were [17]:

- modulus of elasticity (Young): E = 17 GPa
Results and discussions

Total deformation of mandibular bone ranged between nearly the same limits, whether we applied a force of 110 N to the frontal teeth (minimum 1.915 mm - maximum 2.011 mm) or have used force of 200 N at lateral teeth (minimum 1.900 mm - maximum 2.013 mm). In both cases, the minimum values were recorded at basilar level, in menton region, and maximum values occurred at the coronoid process, in limited areas of the head of condyle and in the upper portion of mandibular ramus of the affected side (fig. 3A and B).

Deformation on OX axis also varied in comparable levels:
- in the case of applying a force of 110 N, it varies between a minimum of -0.030 mm and a maximum of 0.0002 mm;
- in the case of applying a force of 200 N, it varies between a minimum of -0.035 mm and a maximum of 0.0002 mm.

In both cases, the minimum values occurred in the frontal group and maximum values on mandibular right condyle and the entire upper portion of the left ascending ramus (fig. 4 A and B).

Deformation recorded on OY axis varied:
- at a value of force of 110 N - between a minimum of -2.010 mm and a maximum of -1.913 mm
- at 200 N force - between a minimum of -2.012 and a maximum of -1.898 mm.

At application of 110 N of force (fig. 8 A, B, C), normal tension has:
- on the OX axis, a maximum of 29.44 MPa and a minimum of -59.09 MPa;
- on the OY axis, a maximum of 58.51 MPa and a minimum of -80.69 MPa;
- on the OZ axis, a maximum of 78.31 MPa and a minimum of -123.71 MPa.

At the experimental application of the force of 200 N, the normal tension (fig. 9 A, B, C) ranged from:
- 35.79 MPa and -70.99 MPa on OX;
At both types of applied forces, the extreme normal tensions appeared on both the OX and the OZ axis at the level of the right condyle and at the level of the left mandibular angle on the OY axis.

The shear stress when applying the force of 110 N (fig.10 A, B, C) has had:
- in the XY plan: a maximum of 19.18 MPa and a minimum of -21.06 MPa;
- in the YZ plan: a maximum of 33.91 MPa and a minimum of -35.13 MPa;

When we experimentally applied the force of 200 N, the shear stress (fig.11 A, B, C) has varied between:
- 26.53 MPa and -23.06 MPa in the XY plan
- 40.87 MPa and -41.55 MPa in the YZ plan
- 31.08 MPa and -17.42 MPa in the XZ plan

The lower jaw is frequently exposed to fracture, by accidents, violence, accidental falls, sports injuries, pathological fracture, etc. [19].

The presence of the impacted tooth is frequently associated with such benign tumors which can increase two or three times the risk of mandibular fracture in case of a trauma, transforming this area into a very fragile one [20-22].

It has been demonstrated that at the level of the included tooth’s follicular bag, the epithelial rests and the odontogenic epithelium preserve their proliferative capacity, being able to produce benign cystic tumors [23]. This is the reason why we support the surgical removal of impacted teeth, especially of the molars, with the purpose of preventing the apparition of tumors and implicitly of fractures in pathological bone.

Conclusions
We appreciate that a concerted effort within the masticatory normal range are not in danger of fracturing in area affected by ameloblastoma, but in case of more powerful forces in this zone it can be possible to produce fractures in pathological bone.

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