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

ADINA SIMONA COSARCA[1], RADU GRIGORAS[1], VIOLETA HANCU[2], COSTIN COMAN[2], RALUCA MONICA COMANEANU[2]*, LILIANA MORARU[3], MIHAI TARCOLEA[4], ALINA ORMENISAN[2]

[1] UMF Targu Mures, Faculty of Dental Medicine, 38 Ghe. Marinescu Str, 540139, Targu Mures, Romania

[2] Titu Maiorescu University of Bucharest, Faculty of Dental Medicine, 67A Gh. Petrascu Str., 031593, Bucharest, Romania

[3] Central Military Hospital, 134 Calea Plevnei, 010825, Bucharest, Romania

[4] Politehnica University of Bucharest, Faculty of Material Science and Engineering, 313 Splaiul Independentei, 060042, Bucharest, Romania

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.

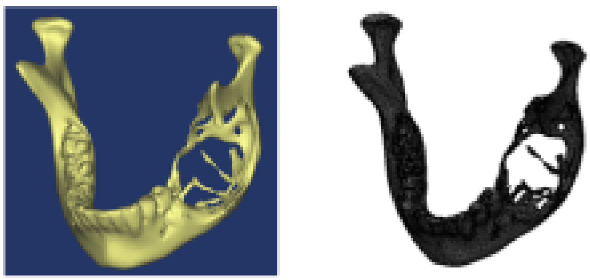


Fig. 1. 3D calculated mandible in Mimics © and its discretization for FEA in 3-matic ©

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

* email: monica_tarcolea@yahoo.co.uk; Tel. 0723860069

Fig. 2. Diagram unit for FEA in ANSYS

- Poisson's ratio: ν = 0.4

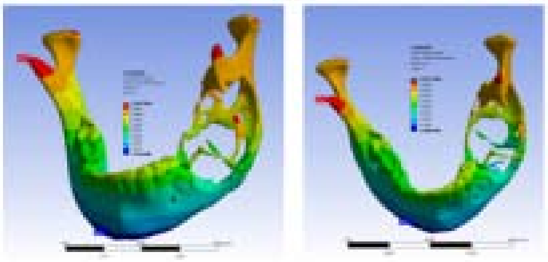
Mechanical resistance limits considered were [18]:

- tensile ultimate strength, σ_r = 133 MPa
- compressive strength, $\sigma_{r\,compr}$ = 195 MPa
- shear strength, τ = 69 MPa.

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).

A



B

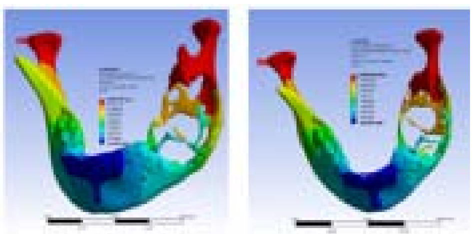
Fig. 3. Total deformation of the mandible at the experimental application of force: A) 110 N on the front group; B) 200 N on the lateral group

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 front group and maximum values on mandibular right condyle and the entire upper portion of the left ascending ramus (fig. 4 A and B).

A



B

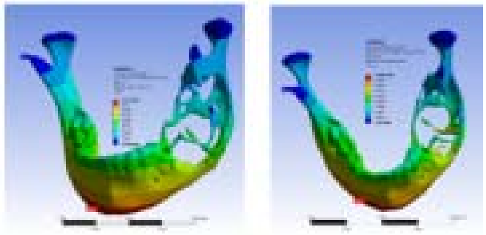
Fig. 4. Deformation on OX axis at experimental application of force: A) 110 N on the front group; B) 200 N on the lateral group

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.

The maximum deformation occurred in the basal mandible in menton region and minimum values occurred at coronoid process, in the upper portion of the condyles and in limited areas of the left mandibular ramus.

A



B

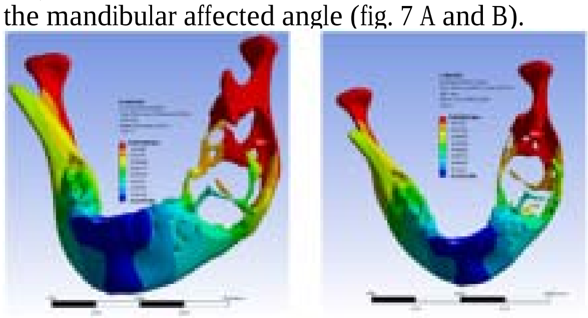
Fig. 5. Deformation on OY axis at experimental application of force: A) 110 N on the front group; B) 200 N on the lateral group

On OZ axis, deformation varied between:

- a minimum of -0.1104 mm and a maximum of 0.0024 mm at a value of force about 110 N
- a minimum of -0.1282 mm and a maximum of 0.0028 mm at a value of force about 200 N

If calculated equivalent stress by von Mises criterion, at force about 110 N, equivalent stress ranged from a maximum of 90.21 MPa and a minimum of 6.87×10^{-9} MPa. At applying a force of 200 N, von Mises equivalent stress ranged between 106.86 MPa and 5.69×10^{-9} MPa. In both cases, the maximum and the minimum values occurred at the mandibular affected angle (fig. 7 A and B).

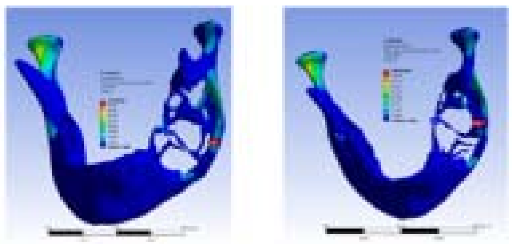
A



B

Fig. 6. Deformation on OZ axis at experimental application of force: A) 110 N on the front group; B) 200 N on the lateral group

A



B

Fig. 7. von Mises equivalent stress at experimental application of force: A) 110 N on the front group; B) 200 N on the lateral group

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;

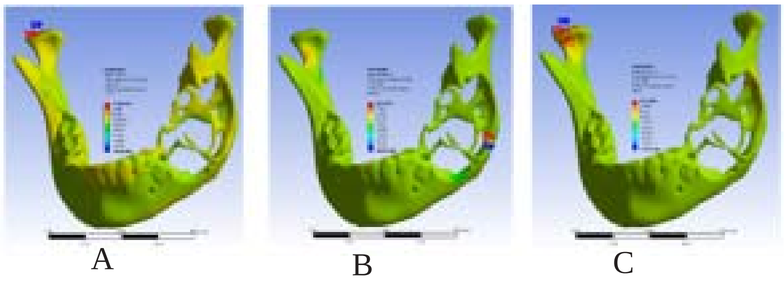


Fig. 8. The normal tension when applying the force of 110 N: A) on the OX axis; B) on the OY axis; C) on the OZ axis.

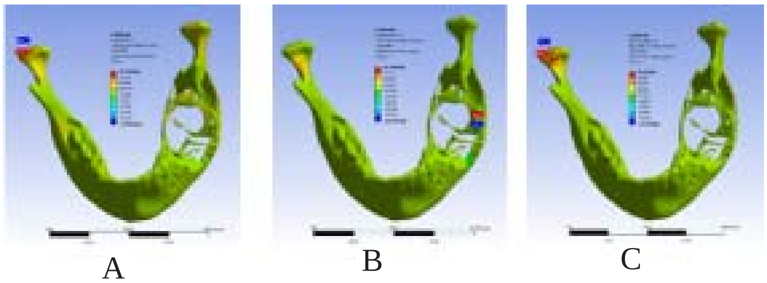


Fig. 9.The normal tension when applying the force of 200 N: A) on the OX axis; B) on the OY axis; C) on the OZ axis.

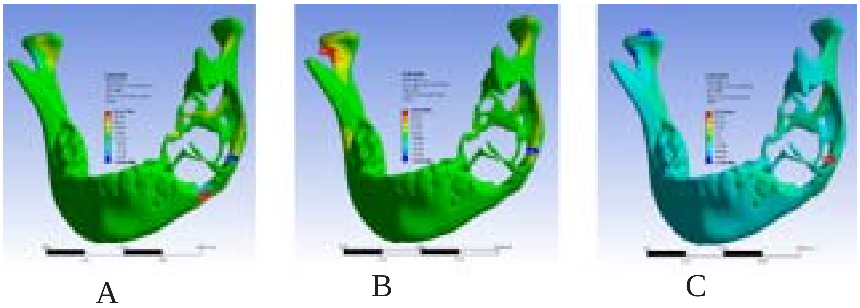


Fig. 10. The shear stress when applying the force of 110 N: A) on the OX axis; B) on the OY axis; C) on the OZ axis

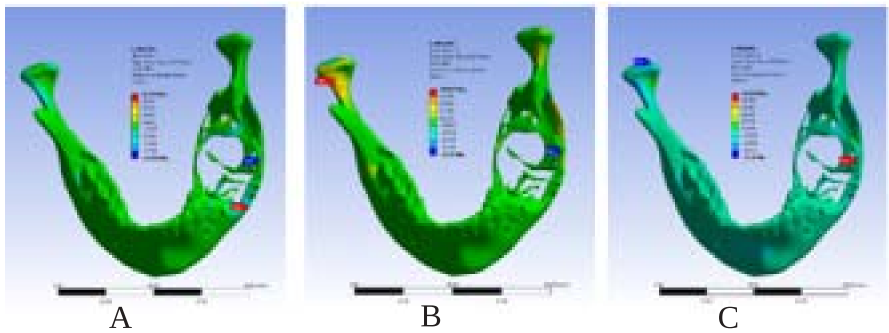


Fig. 11. The shear stress when applying the force of 200N: A) on the OX axis; B) on the OY axis; C) on the OZ axis

- 65.30 MPa and -95.60 MPa on OY;
- 95.22 MPa and -147.99 MPa OZ axis.

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;

-in the XZ plan: a maximum of 27.278 MPa and a minimum of -13.465 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.

Acknowledgement: This paper was partially sustained by the Project No. 912/2015 financed by S.C. OPTOMED SRL in collaboration with UMF TG. MURES.

References

1. OLIVEIRA L.R., MATOS B.H.F., DOMINGUETE P. R., ZORGETTO V. A., SILVA A.R. Ameloblastoma: report of two cases and a brief literature review. International Journal of Odontostomatology 2011; 5(3):293-299

2. ROBINSON L., MARTINEZ MG., Unicystic ameloblastoma: a prognostically distinct entity. Cancer 1977; 40:2278-2285
3. CHANDAVARKAR VD, UMA K., MITHILESH M., SANGEETHA R., GUPTA R., SHARMA R., Ameloblastoma: Cytopathologic profile of 12 cases and literature review, J Cytol 2014;31(3):161-164
4. AROTIBA GT, LADDEINDE AL, AROTIBA JT., AJIKE SO., UGBOKO VI, AJAYI O, Ameloblastoma in Nigerian children and adolescents: a review of 79 cases. J Oral Maxillofac Surg. 2005; 63:747-751
5. PHILIPSEN H, REICHART P, NIKAI H, TAKATA T, KUDO Y. Peripheral ameloblastoma: biological profile based on 160 cases from the literature. Oral Oncol.2001; 37:17-27
6. SHELLY A, PRIYA K, AADITHYA BU, JEYASEELAN A, Unicystic ameloblastoma in 3 year old paediatric patient-A rare entity, J Clin Exp Dent 2013, 5(1):54-57
7. PHILIPSEN HP, BARNES L, EVERSON JW, REICHART P, SIDRANSKY D. WHO classification of tumors. Pathology and Genetics of Head and Neck Tumors. Lyon: IARC Press; 2005. p.306-307
8. GARDER DG, HEIKINHEIMO K, SHEAR M, PHILIPSEN HP, COLEMEN H, In: World Health Organization Classification of Tumors. Pathology and Genetics of Head and Neck Tumors. IARC Press Lyon, France; 2005: Ameloblastoma; p.296
9. AZZA AA, MAHA MA, EGFR, CD10 and proliferation marker Ki67 expression in ameloblastoma: possible role in local recurrence, Diagnostic Pathology 2012; 7:14
10. SALEH HA, CLAYMAN L, MASRI H. Fine needle aspiration biopsy of intraoral and oropharyngeal mass lesions. Cytojournal 2008; 5:4
11. CURI MM, DIB LL, PINTO DS, Management of solid ameloblastoma of the jaws with liquid nitrogen spray cryosurgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;84:339-344
12. HOLLAND PS, MELLOR WC, The conservative treatment of ameloblastoma, using diathermy or cryosurgery. A 29-year review. Int J Oral Surg 1981; 10:32-36
13. SIMON EN, MERKX MA, KALYANYAMA BM, SHUBI FM, STOELINGA PJ, Immediate reconstruction of the mandible after resection for aggressive odontogenic tumors: a cohort study. Int J Maxillofac Surg 2013; 42:106-112
14. DANDRIAL R, GRUPTA A, PANT S, BAWEJA HH Surgical management of ameloblastoma: Conservative or radical approach. Natl J Maxillofac Surg 2011; 2:22-27
15. FEINBERG S.E., STEINBERG B. Surgical management of ameloblastoma. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 1966; 81:383-388
16. ADEKEYE EO, LAVERY KM Recurrent ameloblastoma of the maxillo-facial region. Clinical features and treatment. J Maxillofac Surg 1986; 14:153-157
17. CATTANEO P.M., DALSTRA M., MELSEN B., The Finite Element Method: a Tool to Study Orthodontic Tooth Movement, J Dent Res 84(5):428-433, 2005.
18. ANDRADE JPD, Biomechanical Simulation of the Load Distribution in Dental Implants, Dissertation, Faculdade de Engenharia da Universidade do Porto, July 2013.
19. ORMENISAN, A, TARCOLEA, M, SUCIU, M, GRIGORAS, RI, BERESESCU, FG, VLASCEANU, D, HANCU, V, COMANEANU, RM, FEA analyses on mastication efforts during osteosynthesis of a fractured mandible, Mat. Plast., in press.
20. FUSELIER JC, ELLIS EE, DODSON TB, Do mandibular third molars alter the risk of angle fracture? J Oral Maxillofac Surg. 2002; 60(5):514-518
21. IIDA S, HASSFELD S, REUTHER T, NOMURA K, MÜHLING J. Relationship between the risk of mandibular angle fractures and the status of incompletely erupted mandibular third molars. J Craniomaxillofac Surg. 2005; 33(3):158-163
22. MEISAMI T, SOJAT A, SÀNDOR G KB, LAWRENCE H P, CLOKIE CML. Impacted third molars and risk of angle fracture. Int J Oral Maxillofac Surg.2002; 31(2):140-144
23. RAHMAN F, BHARGAVA A, TIPPU SR, KAIRA M, BHARGAVA N, KAUR I, SRIVASTAVA S, Analysis of the immunoexpression of Ki-67 and Bcl-2 in the pericoronal tissues of impacted teeth, dentigerous cysts and gingiva using software image analysis, Dent Res J (Isfahan). 2013 Jan-Feb; 10(1):31-37

Manuscript received: 16.07.2015