Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
DAAAM Symposium

FRACTURE STRENGTH EVALUATION OF COMPLETE DENTURE BASED ON FEM ANALYSIS AND FRACTURE MECHANICS CONCEPTS

CERNESCU, A[nghel]; FAUR, N[icolae]; BORTUN, C[ristina] & BOLOS, O[tilia]

Abstract: *In this paper is analyzed the fracture strength of complete denture in presence of cracks, based on FEM analysis. For this study was used a geometrical model obtained by 3D scanning process and reverse engineering technique. For two cracks located in an loaded area were calculated the stress intensity factors and were compared with fracture toughness value of the material for fracture strength evaluation.*
Key words: *Total denture, crack, stress intensity factor, fracture toughness, fracture strength*

1. INTRODUCTION

Total dentures are generally for old persons, for rebalancing dental-jaw bone device, in cases patients no longer have any dento-parodonthal units. Total dentures are made of acrylic resins and artificial teeth. Resins composite consist of three primary ingredients: an organic resin matrix, inorganic filler particles and a coupling agent (Craig R.G. et al., 2002). Processing technology of these materials sometimes lead to obtain total dentures with small defects which can initiate cracks and resulting in failure of total denture before the expected lifetime (Beyli M.S. et al., 1981).

Following an inspection of a denture made of acrylic resin Eclipse, were observed some pore and cracks, Fig. 1. For fracture strength evaluation of total denture was used finite element analysis and was calculated the stress intensity factors for two located cracks and were compared with fracture toughness of the material.

The fracture toughness, K_{IC}, is a material property that characterizes the resistance of a material to fracture in the presence of a crack and is used to estimate the relation between failure stress and defect size for a material in service.

Fig. 1. Complete denture from acrylic resin Eclipse

2. MATERIAL AND METHOD

For this analysis was used a geometric model of the total denture obtained by 3D scanning with Roland 3D scanner, model LPX-1200, Fig. 2.

The point cloud resulted from scanning process was imported in PixformPro software and has been transformed by „ reverse engineering'' technique into a network surfaces. These surfaces were exported as igs file and open in SolidWorks CAD software as solid model (Y.Y. Cheng et al., 2010), (Yuchun S. et al., 2009)

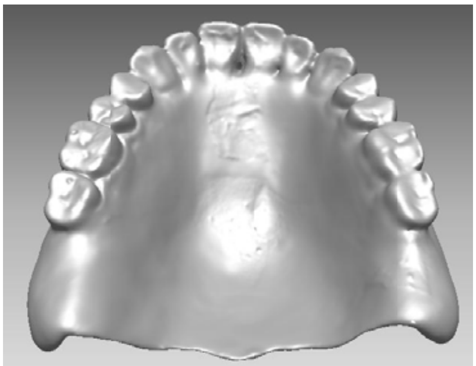

Fig. 2. The geometrical model of total denture obtained by 3D scanning

This model was imported into finite element software – ABAQUS/CAE V6.6 and was evaluated the state of stress and the stress intensity factors, K_I, for two cracks (Darbar U.R. et al., 1995), (Rees J.S. et al., 1990).

The Eclipse resins have a linear elastic behaviour with following mechanical properties (Narva K.K. et al., 2005), (Ward I.M., 1990):

- Young's modulus: E = 2908.45 MPa
- The Ultimate Tensile Strength: σ_u = 59.49 MPa
- Fracture toughness: K_{IC} = 24.93 MPa√mm

For numerical analysis the model was meshed with a total of 117632 quadratic elements and the boundary conditions consist of three supports with displacements imposed by 0.1 and 0.2 mm as in Figure 3 and the surface normal pressure of 0.2 MPa applied uniformly distributed on the contact surfaces of teeth with conjugated denture, Fig. 4.

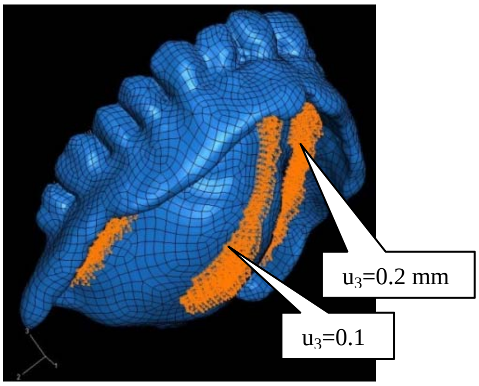

Fig. 3. The boundary conditions

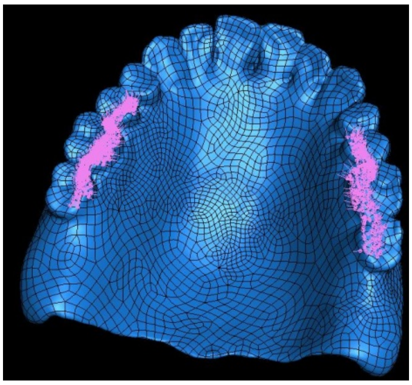

Fig. 4. The applied pressure

In Figure 5 is given the distribution of maximum principal stress showing areas of maximum loading. Based on this distribution, in the second part of this analysis we considered two cracks for which we calculated the stress intensity factors, Fig. 6 and 7.

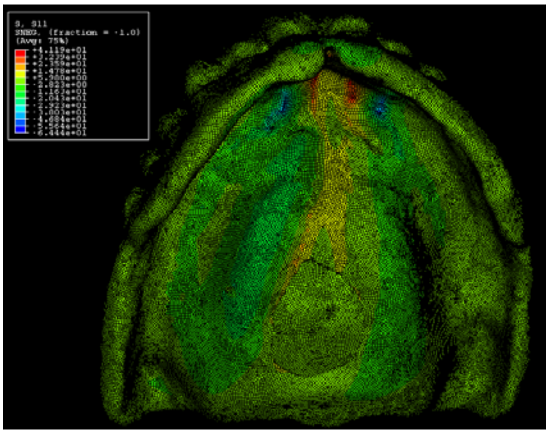

Fig. 5. The distribution of maximum principal stress

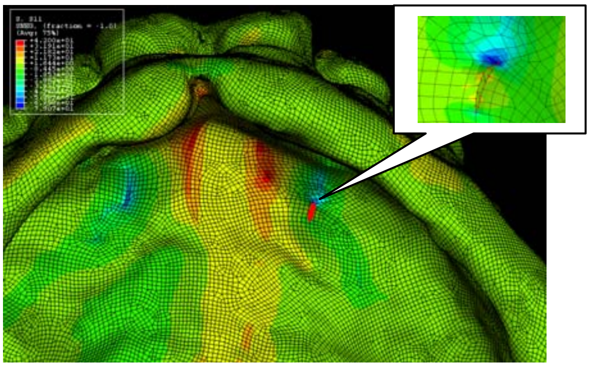

Fig. 6. The location of crack1

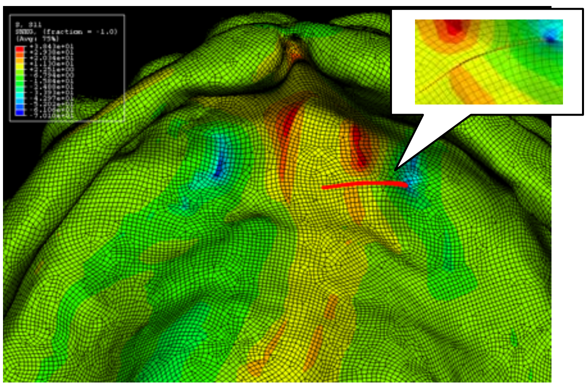

Fig. 7. The location of crack2

The two cracks considered for analysis were located in the most loaded areas of the denture. FEM analysis on a 3D model enables an evaluation of the triaxial state of stress and also allows calculation of the stress intensity factors for the two cracks corresponding to fracture mode I and II (K_1 and K_2).

3. RESULTS AND CONCLUSIONS

The results of this analysis are listed in table 1.

Cracks	Initial length [mm]	Final length [mm]	SIF [MPa√mm]	Fracture toughness, K_{IC} [MPa√mm]
Crack1	1.12	1.12	K_1 = -22.6 K_2 = 8.9	24.93
Crack2	1.96	5.32	K_1 = -2.33 K_2 = -3.12	

Tab. 1. The values of crack lengts and stress intensity factors for considered cracks

This study allows evaluating the fracture strength of dentures in presence of cracks or defects. The FEM analysis was performed by calculating the linear-elastic Fracture Mechanics parameters, represented by stress intensity factors and comparing them with fracture toughness of the material.

While they are in a loaded area, at a crack1 tip is a predominant compression stress state which cause a non-extension of crack1. Through its position, the crack2 have an extension from the initial value of 1.92 mm to 5.32 mm final value, after entering into a compression zone where is stopped.

4. ACKNOWLEDGEMENTS

This study was supported by the project **PERFORM ERA ID-57649, CONTRACT POSDRU/89/1.5/S/57649.**

5. REFERENCES

Craig RG, Powers JM - „ *Restorative dental materials*'', St. Louis: Mosby; 2002. pp. 636-58

Beyli MS, von Fraunhofer JA - „ An analysis of causes of fracture of acrylic resin dentures'', *J. Prosthet Dent*, 1981, 46:238-41

Darbar UR, Huggett R, Harrison A - „ Finite element analysis of stress distribution at the tooth-denture base interface of acrylic resin teeth debonding from the denture base'', *J Prosthet Dent*, 1995, 74:591-4

Narva KK, Lassila LV, Vallittu PK - „ The static strength and modulus of fiber reinforced denture base polymer'', *Dent. Mater.*, 2005, 21:421-8

Ward IM - „ *Mechanical properties of solid polymers*'', Chichester: Wiley; 1990, p. 271

Rees JS, Huggett R - „ Finite element analysis of the stress-concentrating effect of fraenal notches in complete dentures'', *Int. J Prosthodont*, 1990; 3:238-40

YY Cheng, JY Li, SL Fok - „ 3D FEA of high-performance polyethylene fiber reinforced maxillary dentures'', *Dent. Materials*, Article in press, 2010

Chawla K.K. - „ *Composite Materials: science and engineering*''. New York: Springer; 1998; p. 309

Yuchun Sun, Peijun Lu, Yong Wang - „ Study on CAD&RP for removable complete denture''. *Computer Methods and Programs in Biomedicine*; vol. 93; p. 266-272; 2009

Y. Maeda, M. Minoura, S. Tsutsumi, M. Okada, T. Nokubi - „ A CAD/CAM system for removable denture. Part I. Fabrication of complete dentures''; *Int. J. Prosthodont.*; 7(1); p. 17-21; 1994