Archives of Materials Science and Engineering

Volume 31
Issue 2
June 2008
Pages 79-82

International Scientific Journal
published monthly by the
World Academy of Materials
and Manufacturing Engineering

Effort changes of lower complete denture material caused by relining

J. Żmudzki [a,*], W. Chladek [a], J. Krukowska [b]

[a] Department of Technological Processes Modelling and Medical Engineering, Silesian University of Technology, ul. Krasińskiego 8, 40-019 Katowice, Poland

[b] Stomatological Centre "JOMADENT", ul. 3 Maja 11, 41-300 Dąbrowa Górnicza, Poland

* Corresponding author: E-mail address: jaroslaw.zmudzki@polsl.pl

Received 15.04.2008; published in revised form 01.06.2008

ABSTRACT

Purpose: Influence of dentures relining on saddles material effort in case of bone foundation not affected by any atrophic changes has been examined.

Design/methodology/approach: Stresses levels in material of denture saddles bearing structure have been determined for any cases where alveolar ridges of mandible are well preserved. This research has been carried out in simulated conditions of biting loads, by means of a FEM. Compared were not-relined vs. relined saddles for two variants of bottom denture saddles margins, i.e. ended smoothly and with an extension that increases the amount of material of the bearing structure. Analyzed was also the influence on deformability of relining layers.

Findings: Equivalent Huber-Misses stresses on a good saddles surface in case of a not-relined denture have slightly exceeded the level of 2 MPa, whereas in case of a relined denture with a soft margin they have reached 4 MPa; and for variant of relined denture with extended margin they reached a level of 14 MPa. Modulus of elasticity of the relining has not influenced significantly the effort of saddles material.

Research limitations/implications: Assumed were vertical loading forces of 100 N simplified denture geometry without separating any complex shapes of artificial teeth.

Practical implications: Increase of the bearing surface of relined saddles by means of extended margins results in stress concentration. Hence, attempts should be made to form the margins and teeth profiles changes at their base smoothly. All micro damages in endangered areas of saddles' margins should be removed.

Originality/value: Relining of low dentures' saddles in a well preserved bone foundation does not directly result in excedance of allowable stress levels for prosthetic acrylic resins. Hence, the causes of failures should be sought in the impact of geometrical notches, or potentially existing damages that initiate degradation processes.

Keywords: Biomaterials; Acrylic denture resin; Strength; Biting loads

MATERIALS

1. Introduction

Materials used for dentures undergo thorough tests, as far as their biocompatibility and strength is concerned [1-5], tests evaluating material loadings level that reflects the real functions of food comminuting are also known [6]. Nevertheless, the cases of dentures fracture, in clinical practice, still cannot be eliminated [6, 7].

Dentures relining considerably reduces the section of denture bearing structure. However, only in one of the research the authors have deliberated upon to what extent a reduction of denture saddles thickness caused by relining influences increase of stresses in the bearing structure [8]. Determined has been an increased risk of a fatigue damage. Although, this analysis is related only to atrophied foundation, dentures relining is also used in case of well preserved, embossed alveolar ridges. In such cases the primary thickness of denture saddle is usually lower then in case of atrophied alveolar ridges.

In case of multilayer structures, their strength is generally affected by mechanical properties of particular layers [9]. Hence,

crucial is to determine whether the elastic properties of relining might influence the stresses level on saddles.

The aim of this research is to assess the influence of denture relining on denture saddles material effort in case of a not atrophied bone foundation. This assessment was carried out on the basis of a modeling experiment by means of a Finite Elements Method (FEM).

2. Methodology

Examinations were carried out by means of numerical methods based on a FEM. A three-dimensional simplified model was built, in which modeled was the arch shape of alveolar ridge, while assuming a constant thickness of material layers constituting foundation model [10]. Height of the slopes reflected a case of well preserved alveolar ridges – Fig. 1. Thickness of mucous membrane, having significant influence on patients decision regarding denture's acceptance, was assumed at the level of 1.5 mm. While constructing the denture solid, shapes of artificial dentition have not been singled out.

The primary model of a not relined denture, hereinafter referred to as "hard", has been modified by means of introducing, at the cost of the thickness of acrylic resin, a 2 mm thick layer having characteristics of a relining silicones. Their relining has been introduced in two various ways. In the first case, margins were smoothly graded with silicone from points K1 and K2. In the second case acrylic resin margins with sharp edges have been left above the relining layer.

Silicone relining modulus of elasticity was assumed at the level of E=5 MPa; whereas Poisson's coefficient at ν=0.49 [11]. For denture acrylic resin assumed were E=2000 MPa and ν=0.3. For mucous membrane assumed was E=5 MPa; by ν=0.49. For cortical bone assumed Young's modulus equaled E=17 GPa; for spongy bone E=600 MPa; by Poisson`s coefficient equaling, in both cases ν=0.3.

Then, for a relined denture, but only the one with smooth-edged margins, analyzed was the tendency of changes in stresses distribution caused by the varying elasticity of relining. The range of elastic properties of commercial relining materials characterized by a longitudinal Young's elasticity modulus can be assumed between 0.5 and 20 MPa. Leaving the fixed system parameters unchanged, introduced were the two extreme values of that range.

A complete adherence has been assumed for the denture with a soft tissue mucosal foundation. Comparison was made for the case of loading of 100 N biting force acting vertically in scissors area.

3. Results

Occurrence of maximal stress values in the point of applied biting forces is a natural phenomenon [12]. It results from the pattern of contact reactions and internal forces. The object of the analysis was, however not the phenomena of pressure patterns on occlusal surfaces but the assumed cross-section of the denture bearing structure where the higher effort takes place, presuming a hypothesis in the range of equivalent Huber-Misses` stresses.

On Fig. 2a shown is the exemplary equivalent stresses pattern in plane of a loading force acting perpendicularly to saddles. Results are related to a relined denture with sharp-edged margins.

On stresses pattern marked is the „K" path, along which the equivalent stresses has been read. The graph has been prepared on the basis of those stresses values.

In Fig. 2b a comparison of the achieved results for both of the analyzed cases. Length of the „K" path for each of the cases is naturally different is presented.

In Fig. 3 the influence of relining elasticity modulus on values of equivalent stresses in the model with smooth-edged margin along the „K" path is shown

As the phenomenon of stresses patterns on occlusal surfaces was not the object of this research, the maximal stresses values in the point of applied biting forces have not been analyzed.

In the model, linear elastic mechanical characteristics for all the system components were assumed. This assumption simplifies significantly all calculation procedures and it is often used in modelling of biomechanical models that are complex, as far as their geometry and materials are concerned [13-16]. Simplification of non-linear soft-tissue flow phenomena does not have any remarkable influence on the analyzed values in the denture bearing structure. Assumed value of biting loads of 100 N reflects the upper forces values that are registered in case of soft tissue supported complete dentures. Perfect denture adherence to

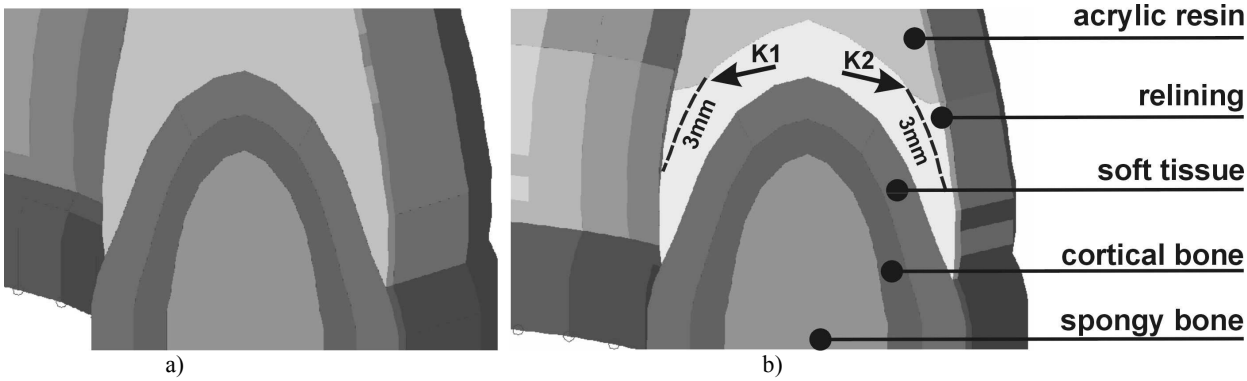

Fig. 1. Cross-section of spatial denture models: (a) without relining; (b) with relining having a resilient margin (smooth-edged) – showed is the outline of the sharp-edged margin (additional 3mm)

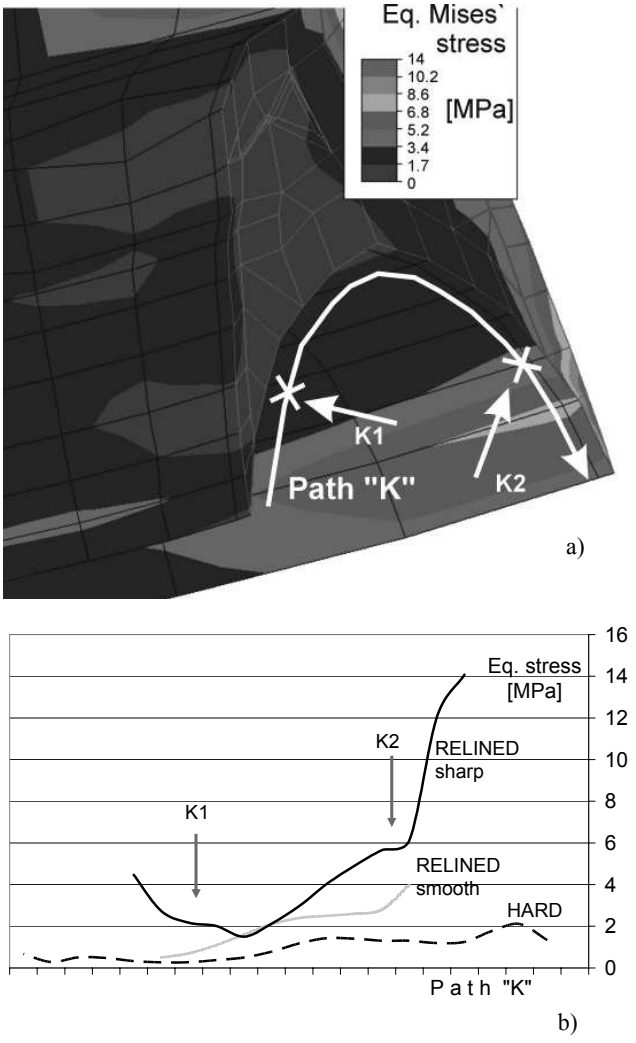

Fig. 2. (a) Equivalent stresses pattern for relined saddles; variant with sharp-edged margin. Marked „K" path and points K1 and K2; (b) Comparison of stresses values along „K" paths for the analyzed denture cases: hard, relined with a sharp- and smooth-edged margin

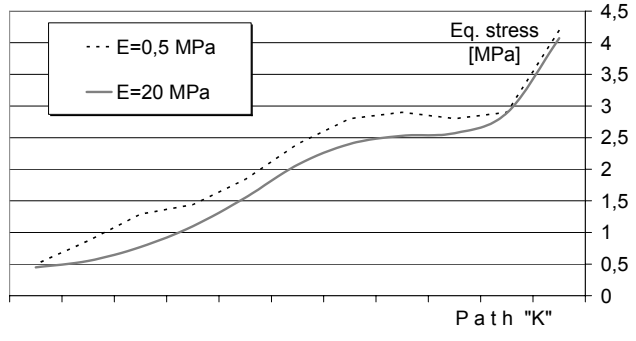

Fig. 3. Influence of relining elasticity modulus: E=0,5 and E=20 [MPa] on equivalent stresses along „K" path in case of relining with a smooth-edged margin

foundation simplifies computing because of eliminating of the non-linear model behaviour on the contacting interface with mucous membrane. In case of a strength analysis of denture saddles such assumption is even more justified as it reflects a situation of a stable denture supporting, in which achievement of high value of biting forces is possible. Justified is also a simplified shape of denture teeth. The real shape of teeth is characterized by numerous geometrical notches constituting stress concentrators, strongly influencing local stresses patterns, which was not the object of the research, whereas the evaluation of their influence on the effort of reduced bearing structure cross-section might not be unequivocal. On the other hand, preparation of two relined models with sharp- and smooth-edged margins was aimed at determining, to which extent leaving the stiffer margins' edges, in spite of the potentially increased loads bearing ability, increases the risk of cracking resulting from stresses concentration.

For not relined dentures stresses values remain at the lowest level (Fig. 2b). Relined saddles are more likely affected by bigger longitudinal deflection, as well as by cross-wise unbending. Equivalent stresses reach highest values in the front part because of the intense tension resulting from deflection (Fig. 2a). Sharp-edged margin functions as a strong stresses concentrator. For that margin variation, even stresses in points K1 and K2 (marked on the profile) located far from the edges still exceed the maximum values registered for the variation with smooth-edged margin.

Hence, the bearing surface should not be extended by means of margin elongation, but quite opposite, the edges of margins should be made as smooth as possible.

It is defined [17] that tensile strength of typical denture acrylic resins used for dentures saddles lays between 48-62.5 MPa. In model conditions it has not therefore been determined whether a reduction of bearing area could have caused an increase of stresses that might have been a direct cause of saddle failure, even in the most disadvantageous variation of sharp-edged margins. Hence, the exclusion of that root-cause, points at the effects of stresses concentration in teeth geometrical notches and the possible increase of their influence on strength in case of reduced thickness of the load bearing structure. The second root-cause of damages could be imperfections and micro-damages that initiate degradation processes. Saddles margins, because of their embossed shape, are exposed to possible slight damages and scratches during activities carried out outside the oral cavity. Also these areas are mostly exposed to any impacts during relining or rebasing procedures. Repeated polymerization or gluing processes might lead to local decrease of material durability at margins. Unfortunately, exactly these areas of the margins are the ones where the highest effort takes place.

Analysis of the version with a smooth-edged margin did not show any significant influence on equivalent stresses values of relining elasticity modulus. Decreasing this modulus by 40 times only insignificantly increases stresses in the central cross-section part by app. 0.5 MPa. Maximum stresses values in the critical area adjacent to margin are balanced for the opposite analyzed relining elasticity modulus values: 0.5 and 20 MPa. Hence, while selecting relining, there is no risk that an excessive relining material distortion will impact saddles strength.

An additional factor that might significantly influence on the real conditions of saddles functioning is the change of biting loadings after relining. Attention should be paid to the fact that

relining might cause improvement of the feeling of comfort during chewing function, both because of the increased denture retention, and relieving of soft tissue denture foundation. In statistical clinical analysis it leads to a significant increase of biting loads cycles, even without considerably increased values of biting forces. Therefore, for the two systems: before and after relining the path of the real fatigue loads might vary.

4. Conclusions

In the assumed model conditions it has been determined that the reduction of dentures load bearing structure cross-section resulting from relining does not lead to increase of stresses in lower areas of dentures saddles, above the limit allowable for denture acrylic materials. Hence, root-causes of damages should be searched in the negative influence of geometrical notches or potential failures that accelerate degradation processes in the environment of oral cavity.

References

[1] Y. Takahashi, M . Kawaguchi, J. Chai, Flexural strength at the proportional limit of a denture base material relined with four different denture reline materials, International Journal of Prosthodontics 10 (1997) 508-512.

[2] S. Canay, N. Hersek, I. Tulunoglu, G. Uzun, Evaluation of colour and hardness changes of soft lining materials in food colorant solutions, Journal of Oral Rehabilitation 26 (1999) 821-829.

[3] R.B. Villaverde, J.A.F. Vilán, X.L. Baltar, FEM analysis of a threaded dental implant, Proceedings of the 9th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2000, Gliwice–Sopot–Gdańsk, 2000, 573-577.

[4] T. Laoui, N.K. Tolochko, A.S. Artushkevich, L. Froyen, Bone osseointegration tests performed on titanium dental root implants made by laser processing, International Journal of Product Development 1 (2004) 165-171.

[5] N. Silikas, K. Masouras, J. Satterthwaite, D.C. Watts, Effect of nanofillers in adhesive and aesthetic properties of dental resin-composites, International Journal of Nano and Biomaterials 1 (2007) 116-127.

[6] U.R. Darbar, R. Huggett, A. Harrison, Stress analysis techniques in complete dentures, Journal of Dentistry 22 (1994) 259-264.

[7] M.S. Beyli, J.A. von Fraunhofer, An analysis of causes of fracture of acrylic resin dentures, Journal of Prosthetic Dentistry 46 (1981) 238-41.

[8] J.S. Shim, D.C. Watts, An examination of the stress distribution in a soft-lined acrylic resin mandibular complete denture by finite element analysis, International Journal of Prosthodontics 13 (2000) 19-24.

[9] V.Z. Vlasov, N.N. Leontev, Beams, plates and shells on elastic foundations, GIFML, Moscow, 1960.

[10] V.E. Beresin, F.J. Sciesser, The neutral zone in complete and partial dentures, Second Edition, CV Mosby, St Louis, 1978.

[11] K. Inoue, H. Arikawa, K. Fujii, N. Shinohara, N. Kawahata, Viscoelastic properties of oral soft tissue, A method of determining elastic modulus of oral soft tissue, Dental Material Journal 4 (1985) 47-53.

[12] J. Panduric, M. Husnjak, K. Guljas, S. Kraljevic, J. Zivko-Babic, The simulation and calculation of the fatigue of the lower complete denture in function by means of the finite element analysis, Journal of Oral Rehabilitation 25 (1998) 560-565.

[13] L. Jeziorski, J. Jasinski, M. Lubas, M. Szota, P. Lacki, B. Stodolnika, Numerical modelling of structure and mechanical properties for medical tools, Journal of Achievements in Materials and Manufacturing Engineering 24/1 (2007) 237-244.

[14] T. Smolnicki, E. Rusiński, J. Karoliński, FEM modelling of fatigue loaded bolted flange joints, Journal of Achievements in Materials and Manufacturing Engineering 22/1 (2007) 1-4.

[15] M. Kaczmarek, Biomechanical and material characteristics of plate stabilizers, International Journal of Computational Materials Science and Surface Engineering 1 (2007) 408-423.

[16] T. Ozben, A. Yardimeden, O. Çakir, Stress analysis of shrink-fitted pin-pin hole connections via Finite Element Method, Journal of Achievements in Materials and Manufacturing Engineering 25/1 (2007) 45-48.

[17] R. Craig, J. Powers, Restorative dental materials, Eleventh Edition, CV Mosby, St Louis, 2002.