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finite element analysis of thermal stresses in circumferential cast clasps of removable partial dentures

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Introduction

The oral cavity is subjected to thermal aggressions induced by hot/cold liquids and food every day. In case of the patients wearing removable partial dentures, these thermal changes produce alterations in this prostheses, as a result of heat transfer. It is known that restorative materials expand when warmed by hot liquids or food and contract when exposed to cold substances. Exposing removable partial dentures to a range of temperatures induces stress in all their components [1]. Several studies evaluated the removable partial dentures by the finite element analysis, but none of these evaluated the thermal stress [2, 3].

Objectives

The purpose of the study was to explore the influence of thermal oral changes on the circumferential cast clasps, popular retainers of the removable partial dentures. Only these critical components were selected because high stresses in the dentures are the main causes of deformation and fracture of the clasps [4, 5].

Material and Methods

The object of study was represented by real cast circumferential clasps: Akers clasp and back action clasp. They were selected for a comparative analysis. The Akers clasp is a rigid circumferential clasp, with a rigid minor connector and the back action clasp is a clasp with high elasticity and with a long and elastic minor connector. A 3-dimensional finite element method (Cosmos/M, version 2.5; Structural Research and Analysis, Santa Monica, Calif) was used to explore the temperature distribution, thermal stress and the influence of thermal changes on stress and displacements of the clasps during functions. The geometric models of the clasps were generated by manual measurement of the 3-dimensional coordinates of the clasp surfaces. The finite element models were developed by dividing the model of Akers clasp into 1017 elements, connected at 607 nodes and of the back action clasp into 1772 elements, connected at 1263 nodes. Shell 3 elements (triangular thin shell) were used. In making the finite element models, the mechanical, elastic and thermal characteristics of the Co-Cr alloy (WironiumLA; Bego, Bremen, Germany) used for the framework were entered into the computer program [6, 7]: tensile strength Rm = 1000 MPa; ductile Yield Rp 0.2 = 700 MPa; modulus of elasticity E = 2.2×10^5 MPa; Poisson's ratio = 0.3; Vickers hardness (HV 10) = 340; thermal conductivity 15 J/smK; thermal expansion coefficient 14.3×10^{-6} K^{-1}. The finite element analysis [8] was used in order to assess stress distribution and displacements resulting the simulation of static and thermal charges. At the end, both of them were cumulated to evaluate the importance of considering thermal variations for stress analysis of the cast clasps.

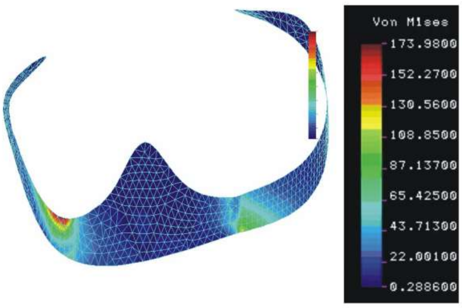


Fig. 1. Von Misses equivalent stress resulting the simulation of a static charge (average force of 20N) in the Akers clasp.

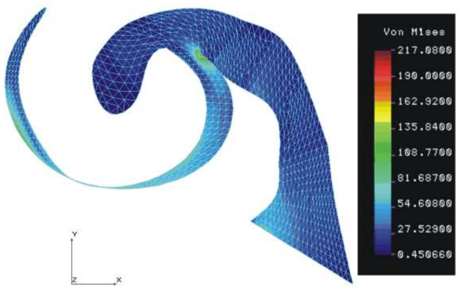
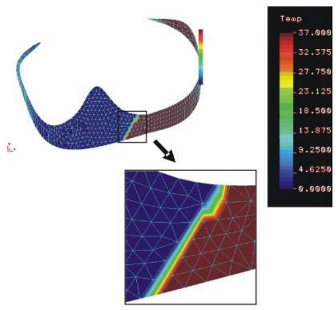


Fig. 2. Von Misses equivalent stress resulting the simulation of a static charge (average force of 20N) in the back action clasp.



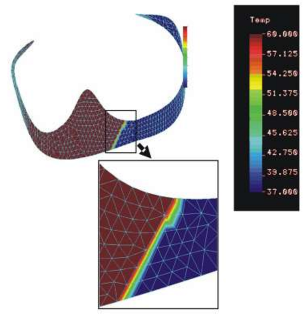
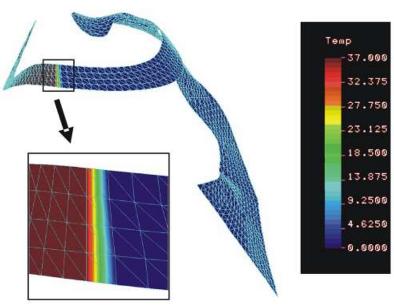


Fig. 3. Temperature distribution for the Akers clasp in case of thermal variations from 37°C to 0°C.

Fig. 4. Temperature distribution for the back action clasp in case of thermal variations from 37°C to 60°C.



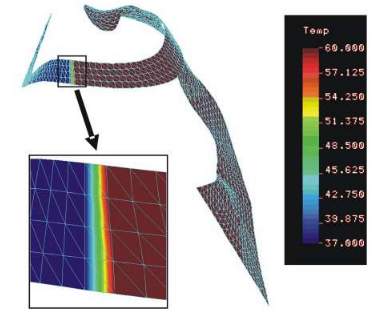


Fig. 5. Temperature distribution for the back action clasp in case of thermal variations from 37°C to 0°C.

Fig. 6. Temperature distribution for the back action clasp in case of thermal variations from 37°C to 60°C.

Results

Generated stresses and displacements were calculated numerically and plotted graphically. Fig. 1 and 2 illustrate the Von Misses equivalent stress resulting the simulation of a static charge (average force of 20 N), which was evaluated for the two models. The thermal analysis was conducted with external stimuli of 0°C and 60°C. Fig. 3 and 4 show the temperature distribution in case of thermal variations from 37°C to 0°C and 60°C, for both of the clasps. The analysis of stress induced by ingestion of cold liquids revealed high stresses in the retentive clasp arms. For the Akers clasp the highest value was 154.58 MPa and for the back action clasp more lower, only 62.46 MPa. Similar was calculated the stress resulting from the ingestion of hot liquids. High stresses were present in the occlusal rests of the clasps and for the back action clasp also in the minor connector, at the end where it connects with the major connector. At the end, both of the static and thermal charges were cumulated to assess stress distribution and displacements, simulating the ingestion of cold and hot food. This complex situation was evaluated to estimate the importance of considering thermal variations for stress analysis of the cast clasps. For the ingestion of could food simulation the maximal stress values were not very different from the cases where the charges were evaluated separate and were closer to them resulting from the thermal stress analysis (Fig. 7). The result is not the sum of the individual maximal values because of the stress distribution alteration. In case of warm food ingestion simulation, the distribution of the equivalent stress was similar to that resulted at the thermal analysis for hot liquids. The maximal values were close to them and were even little smaller (Fig. 8). In this case the magnitude of the displacements is different for the analyzed clasps. The displacements are greater for the more elastic clasp, the back action clasp. For both the maximal values are located at the tip of the retentive arms. Reproducing the displacements is suggestive for the direction of the clasp movements during functions.

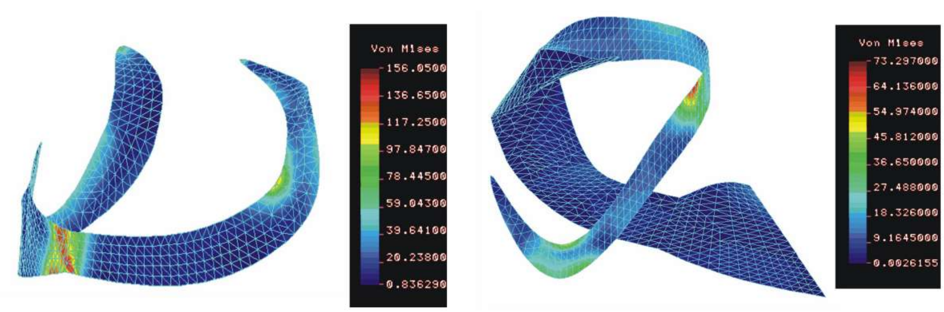


Fig. 7. Equivalent stress distribution when static (20N) and thermal charges (0°C) were cumulated:
a) Akers clasp. b) back action clasp.

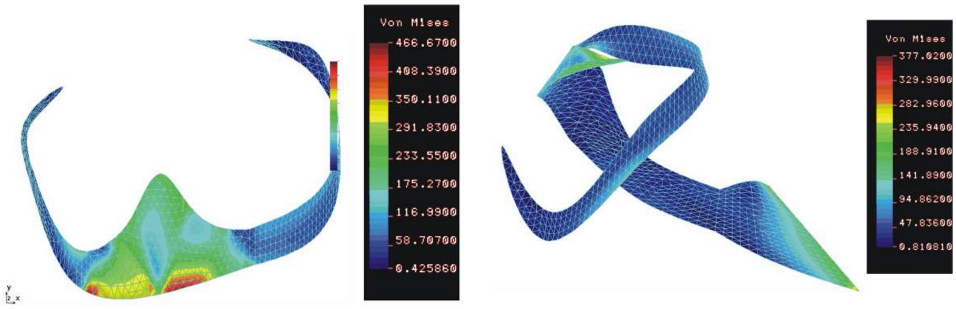


Fig. 8. Equivalent stress and displacement distribution when static (20N) and thermal (60°C) charges were cumulated: a) Akers clasp. b) back action clasp.

Conclusions

1. Thermal variations induce stress in dental clasps, high temperatures having more aggressive effect than lower one.
2. The displacement analysis is suggestive for the direction of the clasp movements during functions.
3. Considering thermal variations is very important for stress analysis of the cast clasps.

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Poster Faksimile: