Numerical Simulation of Polymeric Removable Partial Dentures

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Removable partial dentures are widely and successfully used in the rehabilitation of partial edentulous patients. These types of dentures can be made from PMMA (poly methyl methacrylate resin) or polyamides, both types of materials having their advantages and disadvantages. Evaluation of these removable partial dentures is accurate only if are considered all the parameters. Computer-Aided Engineering (ANSYS) software is used with a 3D Computer-Aided Design (3D CAD) solid geometry and simulates the behaviour of solid bodies under thermal or structural loading conditions. ANSYS automated the Finite Element Analysis (FEA) technologies and deliver the results listed. All considered criteria materialized by Numerical Simulation concept serve as guides for a qualitative evaluation of known design requirements.

Keywords: PMMA, ANSYS, 3D CAD, FEA

Dentures made from poly methyl methacrylate (PMMA) resin are widely used in rehabilitation of edentulous patients. PMMA is characterized by simple technological process, low water absorption and solubility, relatively toxicity, excellent aesthetics and in case of fractures these dentures can be repaired. The disadvantage of this material is the allergenic potential of residual monomer [1-4]. It has been showed that heat curing and chemical curing increase the risk of residual monomer which can cause cytotoxicity to sensitive patients [5]. Increased proportion of monomer reduces the water storage phase. PMMA denture bases mechanical properties were improved by reinforcement with fibres (glass or carbon) because of the low impact strength [6-8].

Alternative materials like polyamides were developed and proposed. Polyamides had specific issues like warpage, water sorption, increased surface roughness and difficulty in polishing [9-11]. A major problem is the lack of chemical bonding between the base and the acrylic teeth. This bonding is present in case of PMMA and acrylic teeth. Another issue of polyamide denture basis is the inability to reline and repair the dentures. Modified polyamide denture base materials have a low level of water sorption and higher flexural strength [12]. Increased flexibility of polyamide denture permits undercuts of a certain degree which lead to improved retention. This advantage supposes that the teeth position can be less modified but the comfort for the patients is increased [13]. The low melting point of polyamides is limiting the polishing procedure and wet polishing is necessary to obtain good results but never equal to the one obtained after PMMA polishing. The surface base of dentures and especially the surface roughness is a concern for plaque accumulation and Candida albicans adherence [14, 15]. It is accepted a surface roughness of 0.2 μ in prosthetic and dental restorative materials as it is mentioned in the specific literature [16 - 18]. Considering all the advantages and disadvantages polyamide denture base is a good alternative for patients with sensitivity to PMMA monomer.

Due to the disadvantages and compromises, the present study is proposing a numerical simulation method which includes all the factors of the two types of denture materials. The results of a simulation provide insight into how the bodies may perform and how the design might be improved. Multiple scenarios allow comparison of results given for different loading conditions, materials or geometric configurations

Experimental part

ANSYS as a numerical simulation method was employed for this experiment. The ANSYS CAE (Computer-Aided Engineering) software program was used in conjunction with 3D CAD (Computer-Aided Design) solid geometry to simulate the behaviour of mechanical bodies under thermal/structural loading conditions. ANSYS automated FEA (Finite Element Analysis) technologies from ANSYS, Inc. to generate the results listed in this paper.

Each scenario presented below represents one complete engineering simulation. The definition of a simulation includes known factors about a design such as material properties per body, contact behaviour between bodies (in an assembly), and types and magnitudes of loading conditions. The results of a simulation provide insight into how the bodies may perform and how the design might be improved. Multiple scenarios allow comparison of results given for different loading conditions, materials or geometric configurations.

Convergence and alert criteria may be defined for any of the results and can serve as guides for evaluating the quality of calculated results and the acceptability of values in the context of known design requirements.

The removable dental prosthesis with clasps was considered made entirely from the polymethilmethacrilate for the first experimental part while in the second part of the experiment, the polyamide materials were considered for the entirely dental prosthesis (fig.1).

The removable dental prosthesis has a total volume of 5.53×10^{-6} m^3. After the discretization the model had 11496 nodes and 4611 elements.

The masticatory forces along with the retentive forces provided from the frontal teeth were considered as in the literature (fig.2.). 200 N was the magnitude of the forces

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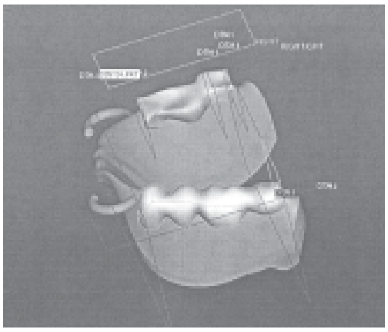

Fig. 1. The 3D aspect of the removable dental prosthesis considered in this study

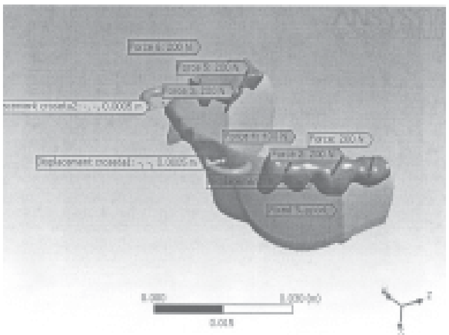

Fig. 2. The considered forces that are involved in the interaction between the removable dental prosthesis and the oral cavity

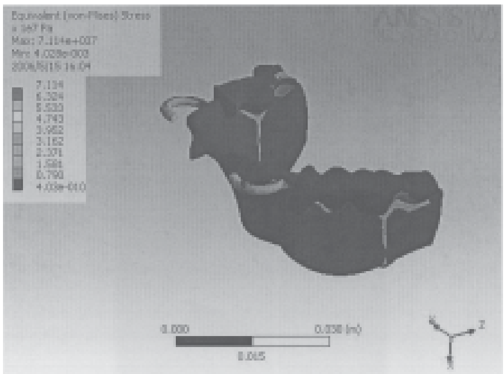

Fig.3. Equivalent Elastic Strain Contours for the all polymethilmethacrilate removable dental prosthesis with clasps

that were applied on the occlusal area of the removable dental prosthesis and also on the clasps. The body of the removable dental prosthesis was considered fixed.

The properties of the materials considered for both experiments were listed below (table 1 and 2).

Table 1
POLYAMIDE CONSTANT PROPERTIES

Name	Value
Density	0.0 kg/m³
Poisson's Ratio	0.3
Young's Modulus	2.0×109 Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	0.3 W/m·°C

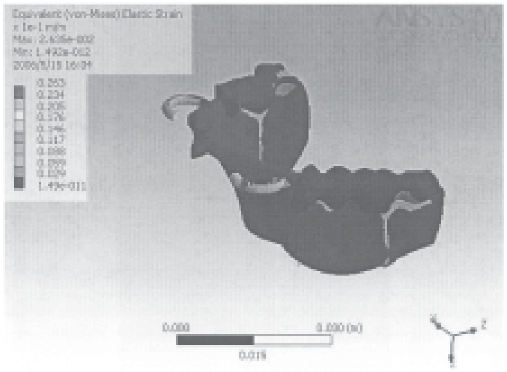

Fig. 4. Total Deformation Contours for the all polymethilmethacrilate removable dental prosthesis with clasps

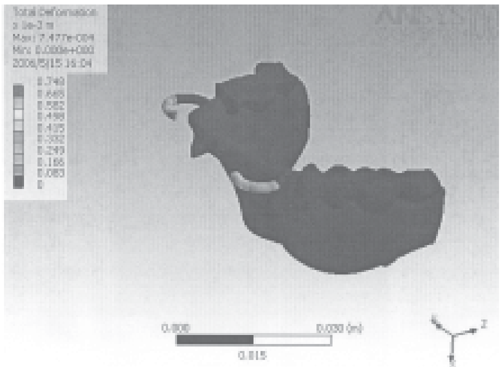

Fig.5. Total deformation on OX axe for the all polymethilmethacrilate removable dental prosthesis with clasps

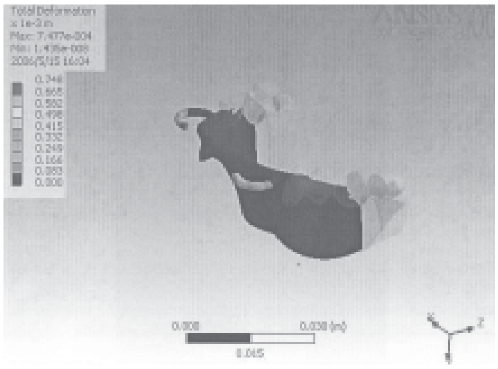

Fig.6. Total deformation of the clasps only on OX axe for the all polymethilmethacrilate removable dental prosthesis with clasps

Table 2
POLYMETHILMETHACRILATE CONSTANT PROPERTIES

Name	Value
Density	0.0 kg/m³
Poisson's Ratio	0.35
Young's Modulus	2.7×109 Pa
Thermal Expansion	0.0 1/°C
Specific Heat	0.0 J/kg·°C
Thermal Conductivity	0.19 W/m·°C

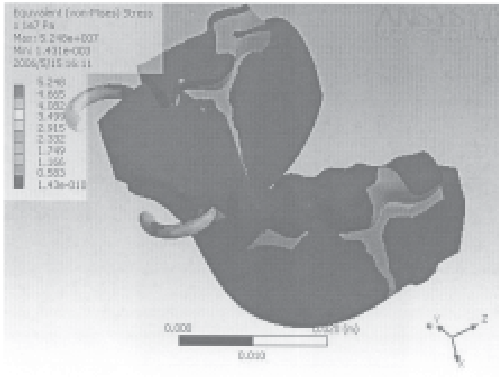

Fig. 7. Equivalent Elastic Strain Contours for the all polyamide removable dental prosthesis with clasps

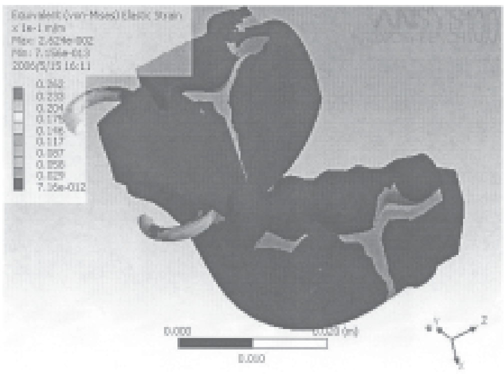

Fig. 8. Total Deformation Contours for the all polyamide removable dental prosthesis with clasps

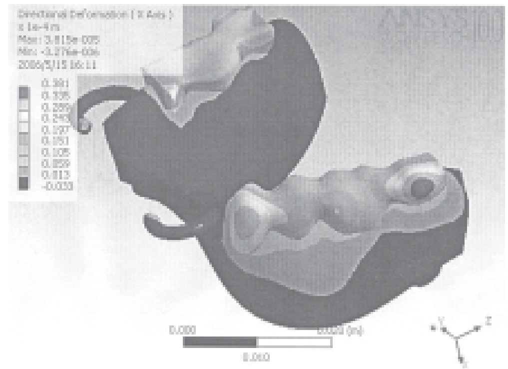

Fig. 9. Total Deformation Contours for the all polyamide removable dental prosthesis with clasps.

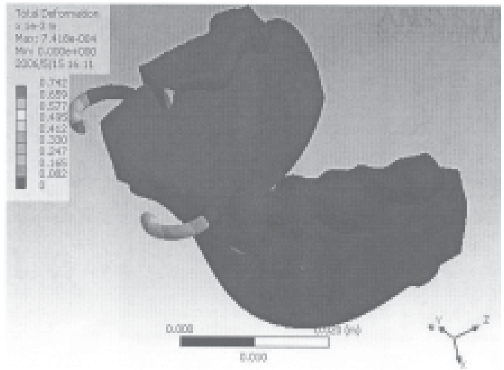

Fig. 10. Total deformation of the clasps only on OX axe for the all polyamide removable dental prosthesis with clasps.

Results and discussions

The numerical simulation revealed the following biomechanical comportment of the removable dental prosthesis.

The polymethilmethacrilate removable dental prosthesis had a considerable higher stress (26.22%) in the whole body compared with the polyamide one (fig. 2, 70.

The total deformation of the polymethilmethacrilate removable prosthesis had a similar value with the polyamide one (fig. 3, 8).

The total deformation of both removable prosthesis only on the OX axe was higher for the polymethilmethacrilate one (49,06%) compared with the one made from polyamide. Considering the materials characteristics, based on this observation, the fracture of the polymethilmethacrilate removable prosthesis could happen more often than the one of polyamide (fig. 4, 9).

Related to the clasps total deformation on OX axe the deformation was similar (fig. 5, 6 and 10).

Conclusions

Thermoplastic resins have been used in dentistry for many years. During that time the applications have continued to grow and the interest in these materials by both the profession and the public have increased. The materials have superior properties and characteristics and provide excellent esthetic and biocompatible treatment options. With the development of new properties, there is certain to be additional new applications for thermoplastic resin in the future, to help patients with damaged or missing teeth.

Flexible resins were introduced in the market as an alternative to the use of conventional acrylic resins for the construction of complete and partial removable dentures.

For polyamide samples, load deflection curves show a sudden increase in the strain at a particular value of stress and the elongation increases rapidly. This cold drawing behaviour is associated with the internal irregularity of polyamide. Polyamide is a crystalline polymer, whereas polymethilmethacrilate is amorphous. Thus in polyamide, there is more or less ordered parallel packing of the long-chain molecules which is due to strong attractive forces between the chains. The consequence is a more perfect parallel orientation of the molecules in the direction of elongation, which results in considerable increase in mechanical properties like high flexural modulus, high resistance to shock, impact and resistance to abrasion.

Polyamide is promoted as a denture base material on the basis of its good flexural strength, which allows it to engage certain degree of undercuts for retention. It is usually indicated in certain clinical situations where flexibility is desired like torus, tuberosity, protuberance, extremely bulging alveolar processes, especially in the maxillary anterior (labial) area posing problems of esthetics as well as retention and as an alternative to patients who have sensitivity or allergy to methyl methacrylate monomer.

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