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ENVIRONMENTAL FAILURE OF DENTAL BIOMATERIALS

ABSTRACT

This work includes the problems connected with the issue of durability of dental biomaterials. Choice criteria have been characterized and the example of dental crowns has served to demonstrate the results of proper assessment of the right selection on the basis of finite elements method. The results of experimental verification have been presented and the possibilities of using this method in designing wear-resistant metal-ceramic crowns have been indicated.

Key words: *dental biomaterials, choice criteria, durability tests, dental crowns*

INTRODUCTION

Materials applied in dental treatment are tissue substitutes and therefore the materials have to meet the requirements related to their biological, esthetical and mechanical aspects. The development of contemporary materials science results in the appearance of new materials or in the modification of the existing ones. Never before have there been such variety of the materials [1].

In the recent years, there has been a tremendous progress as regards dental materials. Glass-ionomer cements, unique in their adhesion, have appeared and fixed their position, complex materials have been modified (especially hybrid forms and compomers), and also very effective joining systems have appeared [2]. Modern composite materials have been constantly modified and improved [3]. They have been increasingly applied squeezing out other materials used as fillings [4].

On the one hand this progress has been the result of great competition among the producers and on the other hand it has been stimulated by international organisations and dentistry associations (mainly American and German) [2].

Almost each dental activity requires some material to be used. The appropriate application is based on the proper selection of the biomaterial and the application that allows for optimal use of its properties [5]. Detailed understanding of the aspects of materials science plays essential role in the appropriate assessment of new products. Also the knowledge of technological processes and how to approach certain materials is of major importance in achieving the final effect [6, 7].

CHOICE CRITERIA

The requirements to be met by dental materials depend on the location and the type of dental cavity and the conditions existing in the oral cavity [8, 9]. Posterior teeth require filling material of high durability properties whereas esthetical criterion is of secondary significance here. Dealing with anterior teeth, the dentist should primarily take esthetical criterion into consideration, approaching the material's durability as of secondary character.

The choice of the material should also depend on the size of the cavity and on the type of tissue it is expected to replace since there are composites perfectly substituting enamel that are not sufficiently durable with reference to dentine or cement. Dentist should also make a choice among many plastic fillings and inlay or onlay materials. There should also be an appropriate application of temporary materials, securing of grooves and the use of appropriate glues [3].

The material used in the substitution of missing tooth substances should meet various requirements. The pressure affecting the tooth while chewing, permanent humidity of the oral cavity, sudden and momentary changes in temperature, direct adjacency of surrounding tissues create the necessity of the application of materials of appropriate properties and they also require special and exact preparation of the cavity for the application of the filling. These are by no means all measures to take to make the filling fulfil its task as long as possible. The right selection of the material, the preparation strictly to the recommendations of the manufacturer and the correct processing of the cavity are basic conditions guaranteeing optimal result of the treatment. In the selection of the materials it is important to remember how they affect the tissues of oral cavity and whether there exists the possibility of toxic effect to appear, should the material be swallowed. The colour of the material and its optical properties are equally important for its selection to be applied in the reconstruction of the tooth [8].

Some materials, e.g. silica cements and amalgams used in fillings, have strictly determined and limited application. Zinc oxide-eugenol, phosphate and carboxylic cements also have a narrow range of applications (bases, fixing the crowns, bridges and points). Other materials, particularly the newer ones (glass-ionomer cements, calcium-hydroxide components), have a very wide application since they are used as liners and typical bases, materials for root canal fillings and also as medicines (non-hardening formulations) [2].

It should also be remembered the way in which a material behaves in pulverisation, in application, in bonding and after bonding. There are general requirements that specify what properties should characterise dental materials so as not to be harmful to both the oral cavity and the whole body. With reference to filling the cavities the material should be characterised by adhesion. When considering its chemical properties it should not dissolve in saliva or in liquids that appear in the oral cavity, it should not oxidise and corrode. Considering its mechanical properties it should be properly durable, stiff, hard and tear resistant.

Also the look of the material both directly after its application as well as after some time should be taken into account. Such physical properties as proper density and thermal properties are also in demand. The material should also be optimally easy in use [5].

The general requirements concerning the filling materials specify that the materials should be harmless for the pulp and the whole human organism, should ideally recreate the colour of the tooth without the necessity of excessive shaping the cavity connected with the loss of healthy tooth tissues. Functionally, the materials should constitute an integral part of chewing organ [3].

Dental fillings are divided into temporary and durable. The materials applied in those two kinds of fillings are subject to different requirements.

Temporary materials, sometimes called provisional, should not be harmful to surrounding tissues, and in particular should not be harmful to pulp and periodontum, should not interact with medicines applied in tooth cavities for therapeutical purposes, should be easily prepared and easily applied to a tooth, they should be possibly dense and cohesive, should tightly fill in the cavity and closely adhere to its walls. They should also harden possibly fast, do not conduct thermal stimuli and they should be completely removable from the cavity [2].

Materials for durable fillings face stricter and wider scope of requirements than in the case of temporary application materials. The basic properties of the material for the durable filling are the following [2, 9]:

- proper hardness – possibly reflecting the tooth substance, the material should resist mechanical injuries connected with the act of chewing,
- proper cohesion – they must not be porous,
- durability of shape – the material should not change its initial form following the influence of external factors,
- high resistance to chemical factors connected with the environment of oral cavity; the material should not be subject to dissolving or washing out from the tooth cavity,
- consistency of chemical properties,
- constant capacity while hardening and at the later time – linear expansion coefficient of the material should be close to that of hard tooth tissues,
- proper adjacency to the cavity walls – close edge adherence,
- high cavity walls adhesion,
- easy introduction into the cavity,
- proper colour, shine and transparency, close to that of enamel,
- proper flexibility,
- bactericidal property – possibly long-lasting and permanent,
- easily removed from the cavity, should there be a need to do so,
- bad thermal conduction,
- harmless to hard tooth tissues, pulp, oral cavity mucosa and the whole organism.

As results from the presented requirements, the material for permanent filling should play its role for a possibly long period. Since we expect 3—4 months at most with reference to the provisional materials, the period should be at least 4 to 5 years in the case of durable fillings.

With reference to the materials applied in prosthodontia (for provisional or durable dentures) the following requirements by the materials should be met [10]:

- they should not be harmful to human organism (locally or generally),
- they should exhibit resistance to chemical and physical factors that exist in oral cavity,
- they should be neutral to the sense of taste and smell,
- the physical and mechanical properties of the applied materials should guarantee their resistance to the forces existing during the act of chewing and the proper transition of these forces onto the bone basis,

- materials applied for implants should be biocompatible.

No ideal dental material meeting all the above requirements have been created. Some materials meet the requirements better and others worse. However, one basic requirement that is presented before all dental materials is their harmlessness towards the surrounding tissues and towards the whole organism. Only those materials that meet that criterion are accepted for the application in dental practice.

The issue of manufacturing dental crowns is one of dynamically developing areas of modern dentistry [6, 8, 10, 11]. The most modern scientific achievements including numerical methods, including FEM finite elements method, have been applied in achieving present solutions [1, 11, 12, 13]. The result includes great achievements in fully ceramic technology introduced in the dental practice in recent years [14, 15, 16, 17]. By great world companies such solutions have been adopted, offering full ceramic crowns made of such extra hard materials as zirconium oxides or aluminium oxides. Their drawback is their high price and the necessity to prepare the tooth stump in such a way that the fully ceramic crown should have sufficiently large cross-section of the crown material in the around-neck part that guarantees safely low level of tensions in the whole crown and protects from its damage.

DENTAL CROWNS TESTS

The subject of tests concerned metal-porcelain crowns made in the dental lab conditions. Crowns prepared manually in dental labs frequently fail and typical damages in the around-neck part of the crowns are irreparable pop-offs. This poses a great problem and is connected with the necessity to apply uncomfortable and expensive repair measures. With the help of computer methods, including FEM finite elements method in particular, this problem may be solved through the analysis of tensions and strains.

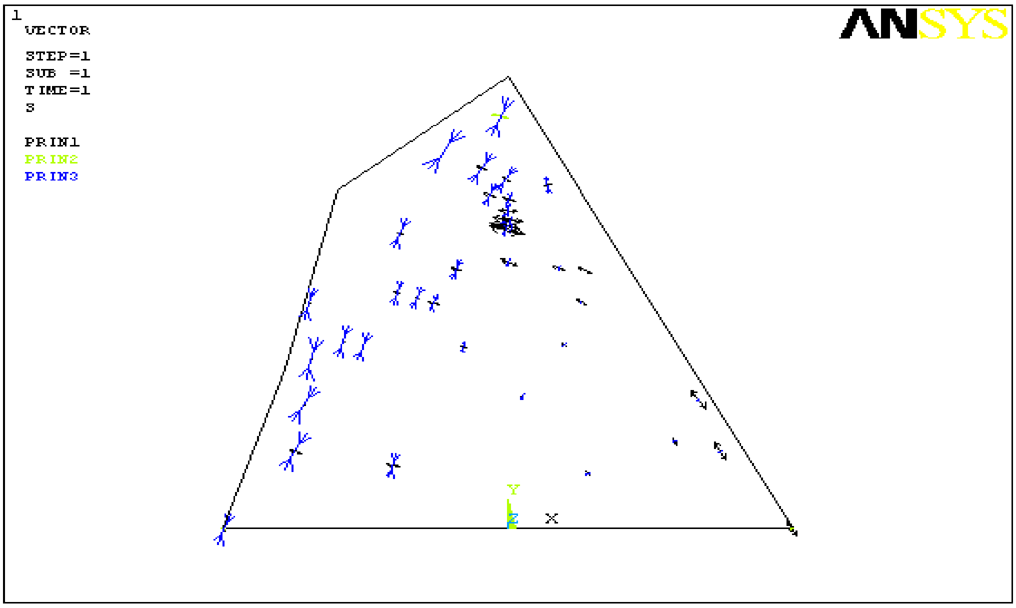

Fig. 1. Tensile stress (right side around-neck part) and shearing stress (left side around-neck part and incising part of the dental crown)

Computer simulations of dental lab made metal-porcelain crown subjected to strain have been conducted. The simulations have enabled to determine the reasons for damages to the ceramic in the around-neck zone (Fig. 1, 2, 3) and to indicate possible measures to eliminate the danger of the ceramic damages to appear.

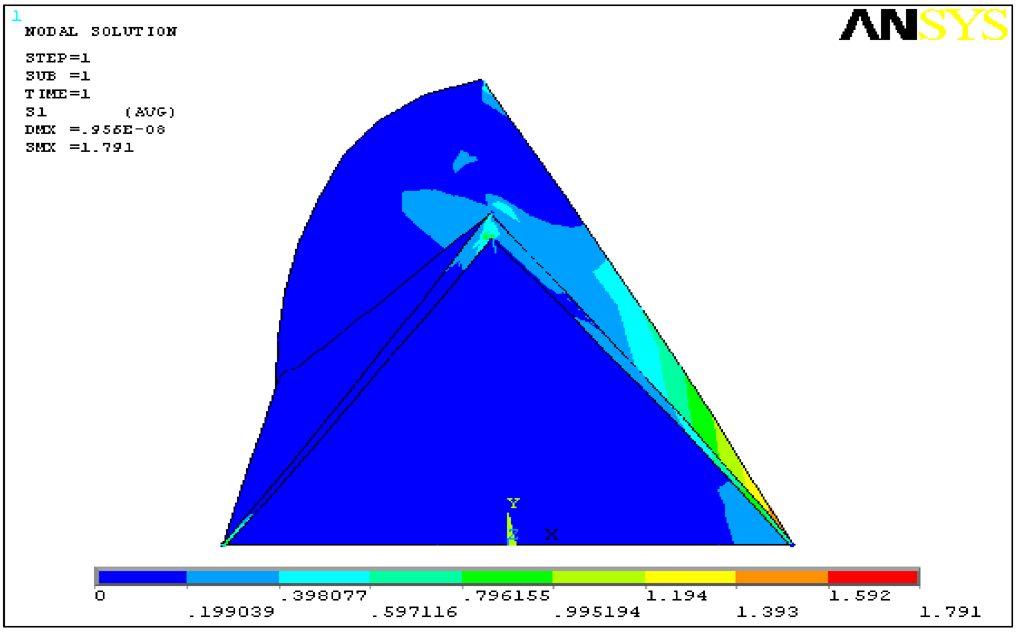

Fig. 2. Tensile stress in dental crown, the highest in the ceramic of around-neck zone

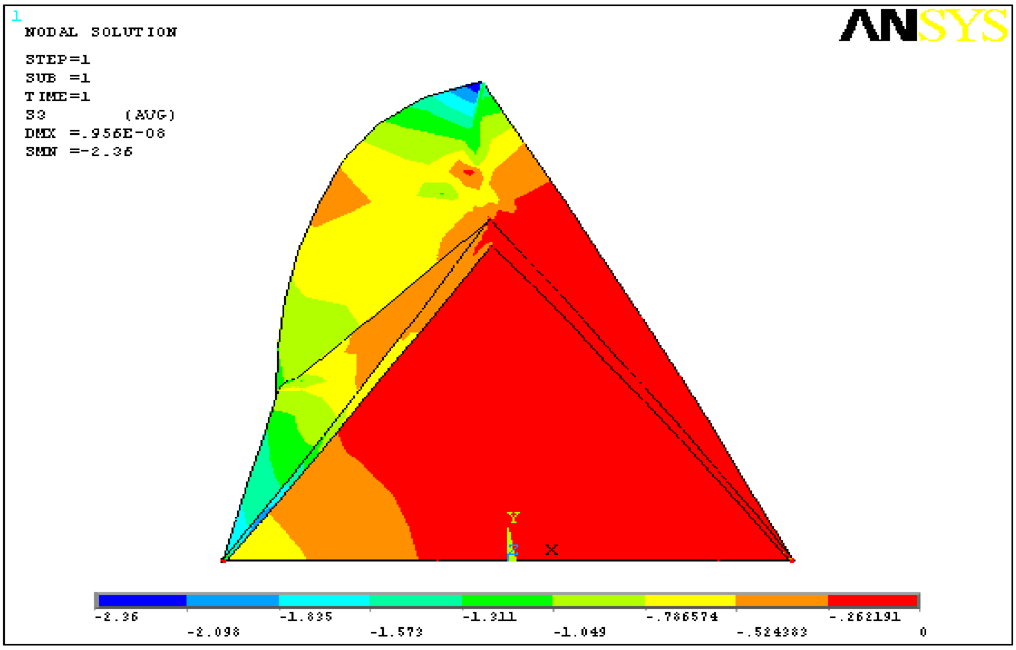

Fig. 3. Shearing stress in dental crown, the highest in the incising and around-neck zone

The resistance tests results of dental lab made crowns have been obtained through applying stress to the crowns placed on a point simulating a processed tooth stump together with root part (Fig. 4). The results have confirmed the forecasts obtained through numerical method and the tests have demonstrated the danger of around-neck damages resulting from minor tensions (Fig. 5) [18, 19].

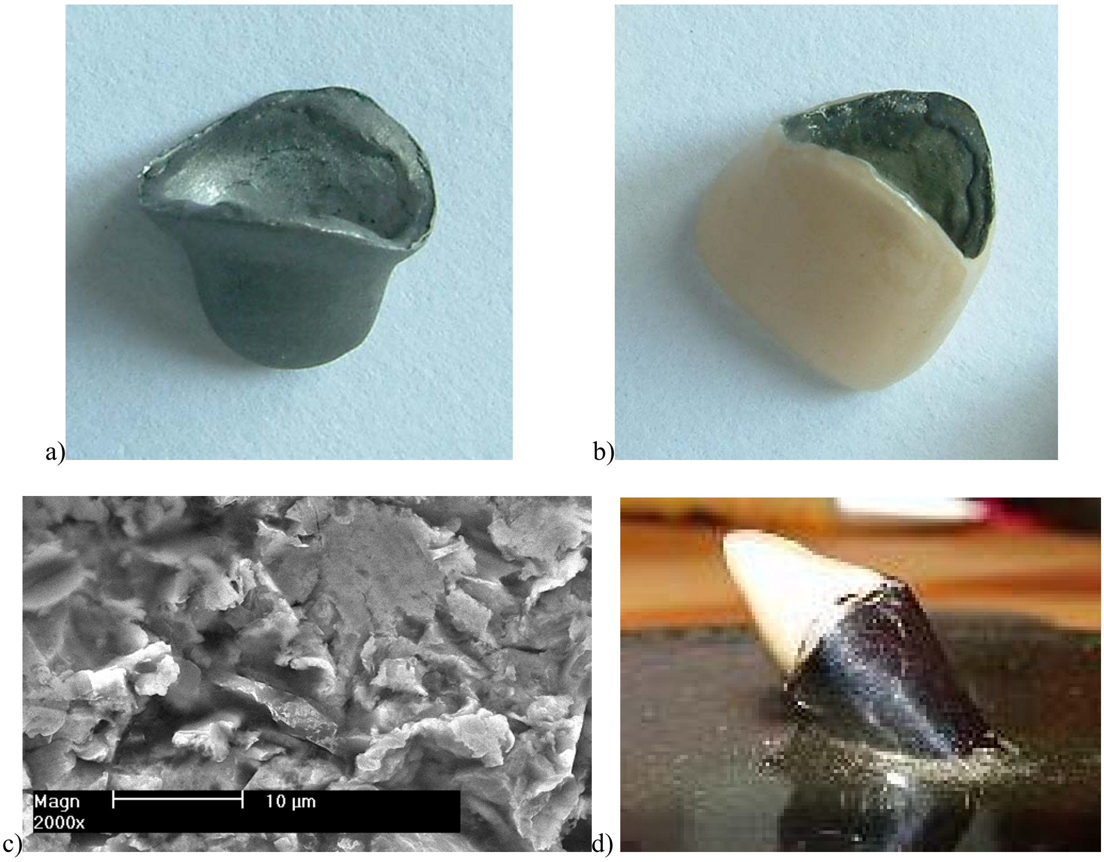

Fig. 4. Crown test: a) metal cap, b) the crown prior to the test c) the surface of the prepared cap prior to the application of ceramic, d) crown on a stump for resistance tests

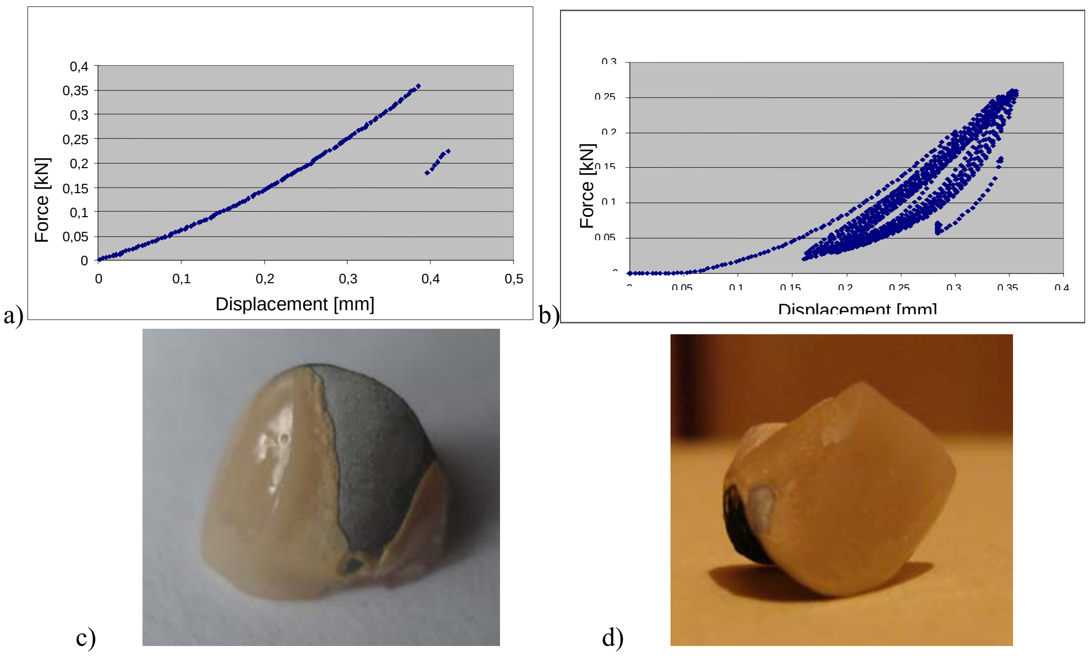

Fig. 5. Crowns reacting in resistance test: a) compression, b) low cycle fatigue, c), d) typical damage in crowns [20]

CONCLUSIONS

From the obtained results it may be concluded that the finite elements method successfully models dental crown tensions.

The structural FEM finite elements method analysis makes it possible to state that the damages appearing in the around-neck zone have been caused by an unfavourable distribution of tensions. Various coefficients of the thermal expansion of crown components causes the padded layer of porcelain to be in tensile state due to the existence of remaining tensions [21, 22]. Those tested interdependencies, however, have not yet found practical application in the development of the manufacturing technology of highly resistant metal-ceramic crowns that could be compared with whole ceramic crowns based on technologies of manufacturing zirconium oxide or aluminium oxide ceramic.

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