# Advantages of Using Acrylic and Metal-composite Crowns in Mandibular Single Implant Restorations – FEA Study

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*To determine if acrylic or composite resins are favorable choices for the single crown on implants. It was performed a FE Analysis using the IBM Autodesk Inventor 2014 for a single 3.75x8mm mandibular implant, a straight titanium abutment, three crowns (acrylic, metal-composite and metal-ceramic) and a type III bone with a 1mm cortical component. For the implant, the maximum stress was 178.7MPa (acrylic crown), 96.38MPa (metal-composite crown) and 86.17MPa (metal-ceramic crown). For the abutment, the maximum stress was 312.4MPa (acrylic crown), 140.8MPa (metal-composite crown), and 121.5MPa (metal-ceramic crown). For the retainer screw, the maximum stress was 75.67MPa (acrylic crown), 33.66MPa (metal-composite crown), and 34.64MPa (metal-ceramic crown). For the metallic component of the crown, the maximum stress was 248.7MPa (metal-composite crown), and 207.1MPa (metal-ceramic crown). For the aesthetic component of the crown, the maximum stress was 28.93MPa (acrylic crown), 22.45MPa (metal-composite crown), and 28.13MPa (metal-ceramic crown). For the cortical bone, the maximum stress was 62.74MPa (acrylic crown), 37.63MPa (metal-composite crown), and 40.3MPa (metal-ceramic crown). For the trabecular bone, the maximum stress was 7.147MPa (acrylic crown), 4.995MPa (metal-composite crown), and 4.973MPa (metal-ceramic crown). For the metal-composite crown, the stress distribution in the trabecular bone is more uniform, comparing to the acrylic crown, which is an advantage. For the metal-ceramic crown the stress distribution in both bone components is similar as for metal-composite crown. The safety factor shows that there is no risk of plastic deformation, nor for acrylic or for the composite resins. The composite resin on Cr-Ni alloys is still the best material for the single implant crown. The acrylic resin and ceramics on Cr-Ni alloys proved a similar resistance to stresses.*

*Keywords: acrylic crown, metal-composite crown, single implant, FEA*

Currently, implant-prosthetic treatment is becoming more and more popular and has a very high rate of success [1-3]. However, either possible errors in surgical technique or occlusal and anatomical factors (as the quantity and quality of the alveolar bone or soft tissue inflammation-periimplantitis) can cause an immediate or delayed failure of this type of treatment. There are a high number of situations in which patients show no evident clinical reason to justify this failure [4]. The delayed failure of the implant-prosthetic treatment occurs if the implant is subjected to excessive occlusal forces through the prosthetic superstructure [5]. Among complications that may occur are: the loss of the osseointegration, the fracture of the prosthetic restoration, of the retaining screw, of the abutment or even of the implant and the loss of the screw, especially in single implant-prosthetic restorations [6-8]. Given these findings, researchers' concerns are focused on the optimal choice of materials and restoration methods in order to ensure the long-term success of this kind of therapy. There are numerous *in vivo* and *in vitro* studies that are trying to guide the dentists in selecting the optimal aesthetic and functional crown material, so the forces that occur in mastication and affect the bone surrounding the implant to be as weak as possible, thus the risk of complications being lowered [9-12]. The aim of this study was to determine if plastic materials like acrylic or composite resins are favourable choices for the single crown in case of mandibular implant-prosthetic restoration.

## Experimental part

*Materials and methods*

For this study we selected the clinical situation of a single implant-prosthetic restoration in the mandibular molar area; we used a 3.75x8mm implant, a straight titanium abutment and three types of dental crowns: acrylic, metal-composite and metal-ceramic. We evaluated a type III bone with a cortical component of 1mm thickness. Our *in vitro* study is using the finite element analysis and the IBM Autodesk Inventor 2014 software. We elaborated three 3D models that match each type of restoration using for modelling the dental implant its geometrical characteristics and the geometry and dimensions of a mandibular molar crown made by the technician in the laboratory; the dimensions of this crown were 12mm mesio-distal and 8.5mm cervico-occlusal. The thickness of the metal for both the metal-ceramic and metal-

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| Material | Young's modulus (GPa) | Poisson ratio |
|---|---|---|
| Composite | 16.6 [14] | 0.24 [14] |
| Acrylic | 2.4 [14] | 0.35 [14] |
| Ceramic | 67.2 [15] | 0.28 [16] |
| Titan | 114 [17] | 0.33[15] |
| Cr-Ni | 172 [18] | 0,3 [18] |
| Cortical bone | 13700 [19] | 0.3 [19] |
| Trabecular bone | 1600 [19] | 0.3 [19] |

**Table 1**
MECHANICAL STRESS CHARACTERISTICS

composite crowns was considered 0.5mm; the maximum thickness of the aesthetic component was considered 1.5mm and the minimum thickness 0.5mm (in the central fossae). The thickness of the acrylic crown was considered to be 2mm. We considered that the osseointegration of the implant was complete, a strong bonding existing between the implant and the bone.

We assumed an oblique masticatory force of 162N with an 8 degree angle from the long axis of the tooth, decomposed in a vertical force of 160N and a tangential force of 23.5N [13]. The vertical force was applied on the mesio-lingual cusp and the tangential force was applied bucco-lingual. The finite element analyses consisted in meshing the 3D models and obtaining the discrete models. In table 1. are presented the mechanical stress characteristics for all the materials of the implant-bone-prosthetic restoration. The discrete model of a 3.75x8mm implant with an acrylic crown had 22661 nodes and 12667 elements. For the model with the metal-ceramic crown we used 27796 nodes and 15517 elements, and for the metal-composite 27783 nodes and 15548 elements.

## Results and discussions

For the acrylic crown restoration, the simulation of applying the masticatory force generates on the components of the implant-prosthetic restoration a maximum von Mises stress value of 178.7MPa in the implant, 312.4MPa in the abutment, 75.67MPa in the retaining screw and 28.93MPa in the acrylic crown (fig.1). The maximum stress in the crown is located at its cervical level, this being the risk area for fracture; also, high solicitations for the acrylic crown are located at the occlusal level, where the forces are applied. The level and stress distribution recorded in the bone surrounding the implant have influence the prognostic of the implant-prosthetic treatment. Both bone components are unequally solicited, the greatest von Mises stress being recorded in cortical (62.74MPa) (fig.2). In the trabecular bone the maximum stress value is 7.147MPa (fig.3). The force distribution shows that the bone surrounding the implant's neck it's subjected to the maximum stress, therefore the bone resorption occurs at this level.

For the metal-composite crown restoration, the simulation of applying the masticatory force generates on the components of the implant-prosthetic restoration a

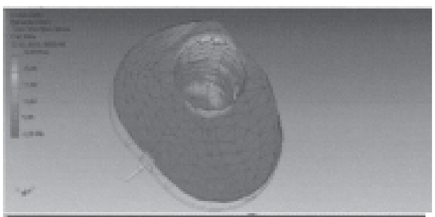

Fig. 1. The von Mises stress in the acrylic crown

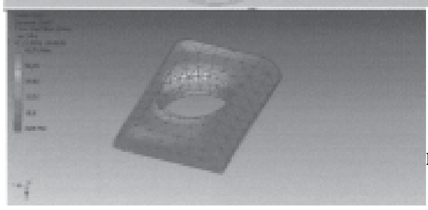

Fig. 2. Von Mises stress in cortical bone (implant-prosthetic restoration with acrylic crown)

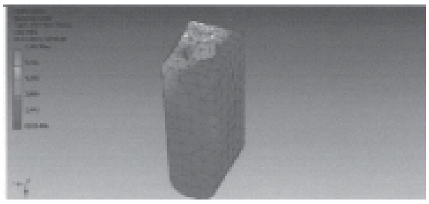

Fig. 3. Von Mises stress in trabecular bone (implant-prosthetic restoration with acrylic crown)

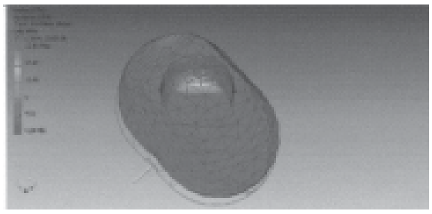

Fig. 4. The von Mises stress in the composite component of the metal-composite crown

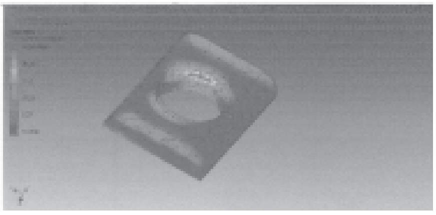

Fig. 5. Von Mises stress in cortical bone (implant-prosthetic restoration with metal-composite crown)

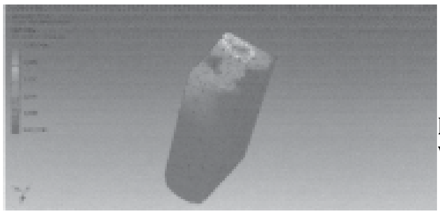

Fig. 6. Von Mises stress in trabecular bone (implant-prosthetic restoration with metal-composite crown)

maximum von Mises stress value of 96.38MPa in the implant, 104.8MPa in the abutment, 33.66MPa in the retaining screw. The two components of the crown are pressed differently, the metallic component being subjected to a maximum von Mises stress of 248.7MPa, and the composite component to a maximum value of 22.45MPa. For the composite component the minimum resistance area is the occlusal surface, in areas where the forces are applied and where the maximum tensions appear (fig.4). The von Mises stress values registered in the bone were of 37.63MPa in cortical (fig.5.), respectively 4.995MPa in trabecular (fig.6.). It can be noticed that the stress distribution in the trabecular bone is more uniform, comparing to the acrylic crown case, which is an advantage.

For the metal-ceramic crown restoration, the simulation of applying the masticatory force generates on the components of the implant-prosthetic restoration a maximum von Mises stress value of 86.17MPa in the implant, 121.5MPa in the abutment, 34.64MPa in the retaining screw. The two components of the crown are pressed differently, the metallic component being subjected to a maximum von Mises stress of 207.1MPa, and the ceramic component to a maximum value of 28.13MPa. The metal-ceramic crown area most exposed to fracture is on the cervical level, where the stress values are the highest from the ceramic component (fig.7.). The two bone components are unequally loaded, similar with the case of the composite material, the highest von Mises stresses being registered in cortical bone (40.3MPa) (fig.8.) comparing to 4.973 MPa in the trabecular bone (fig.9.).

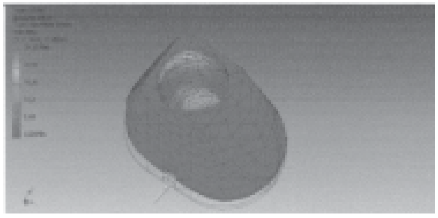

Fig. 7. The von Mises stress in the ceramic component of the metal-ceramic crown

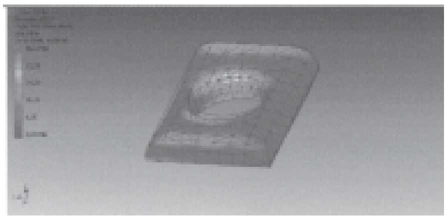

Fig. 8. Von Mises stress in cortical bone (implant-prosthetic restoration with metal-ceramic crown)

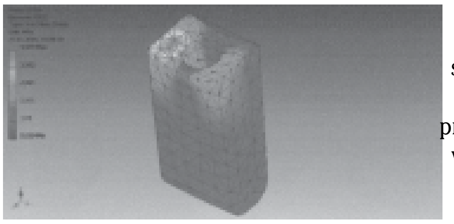

Fig. 9. Von Mises stress in trabecular bone (implant-prosthetic restoration with metal-ceramic crown)

Although, the stress distribution in both bone components, is similar with the one observed for metal-composite crown restoration.

The maximum von Mises stresses on the entire implant-prosthetic restoration have the smallest value (207.1MPa) for the metal-ceramic crown, the highest value (312.4MPa) for the acrylic crown and an intermediary value (248.7MPa) for the metal-composite crown. Even though the metal-ceramic crown seems to be the most advantageous because the maximum values of stresses in the implant-prosthetic restoration are the lowest, this study demonstrates that for the metal-composite crown the stress values in the cortical bone are the lowest which in low quality bone situations represents a real advantage contributing at lengthening the life of the implant-prosthetic restoration. Because of the smaller stress values, the other failure risks like the fracture of the implant, of the abutment or of the screw are much less probable using a metal-composite crown. The risk of plastic deformation of the metallic component of the crown can be avoided using an alloy with improved mechanical characteristics (table 2).

The safety factor obtained for the two plastic components shows that there are no risks of deformation, neither for the acrylic nor for the composite resins, if the occlusal loads are applied as in this study. Moreover, the composite resin is still the best material for the single implant crown. The acrylic resin and the ceramic proved a similar resistance to the developed stresses.

Implant-prosthetic restorations can use plastic materials such as acrylic or composite resins; comparing to metal-ceramic restorations, they have advantages and also disadvantages. A great number of international studies are comparing these three dental materials. In 2010, Hegdec *et al.* found that the acrylic crowns used for implant-prosthetic restorations have some advantages: low price, possibility to be repaired and easy to use when there is a lack of space; in the same study he claims that modern composite resins are convenient because they have similar abrasion resistance with natural teeth [20]. In case of the metal-ceramic implant-prosthetic restorations, the fracture of the ceramic layer is a frequent complication [21,22], and the occlusal contacts that appear during the mandible's eccentric movements can significantly increase the accident rates [23].

The crowns can be made entirely from any of these three types of materials or they can be fused or deposed on a metallic framework. Other studies show that the aesthetic material used without a metallic framework can influence the bone response to stress in implant-prosthetic restoration. From this point of view, some authors claim that the acrylic resin is the best material to use because of the lowest stress values appeared in periimplantar bone compared to composite or ceramic [10, 15]. According to these findings, Menini et al. (2012) stated that the plastic materials (acrylic and composite resins) used without a metallic framework are superior to all-ceramics when we talk about the absorption of the excessive loads [9].

The type of the aesthetic material influences the outcome of the implant-prosthetic therapy also when is used on metallic framework. Thus, although Teigen (2012) compared the metal-acrylic to metal-ceramic and found that there aren't any advantages regarding the success or the long rate survival of the implant-prosthetic restorations [24]; in 2014, Grando concluded that covering the metallic frame of the crown with ceramics produces a high rigidity of the implant-prosthetic restorations comparing with acrylic [25]. However, in 2014 Priest found in a statistical study that the metal-acrylic implant-prosthetic restorations have very low rate success, having complications such as the fracture or the abrasion of the acrylic component in short time [26]. Also, other authors found that the acrylic component presents a low resistance to abrasion comparing to the composite or ceramics [20]. Furthermore, the acrylic component suffers important colour changes in a very short period of time [21]. Considering these results, we considered that, especially for the long term single unit implant-prosthetic restorations, the metal-acrylic crowns are not such a desirable option, being excluded from our study. Still, the all acrylic crowns can be used as provisional implant-prosthetic restoration

**Table 2**
THE MAXIMUM VON MISES STRESS VALUES

| Crown type | Implant | Abutment | Retainer screw | Metallic component of the crown | Aesthetic component of the crown | Cortical bone | Trabecular bone |
|---|---|---|---|---|---|---|---|
| Acrylic | 178.7 MPa | 312.4 MPa | 75.67 MPa | - | 28.93 MPa | 62.74 MPa | 7.147 MPa |
| Metal-composite | 96.38 MPa | 140.8 MPa | 33.66 MPa | 248.7 MPa | 22.45 MPa | 37.63 MPa | 4.995 MPa |
| Metal-ceramic | 86.17 MPa | 121.5 MPa | 34.64 MPa | 207.1 MPa | 28.13 MPa | 40.3 MPa | 4.973 MPa |

**Table 3**
THE SAFETY COEFFICIENT IN THE AESTHETIC COMPONENT OF THE IMPLANT-PROSTHETIC CROWN

| Aesthetic component | Safety factor (minimum) |
|---|---|
| Acrylic | 2.63 |
| Composite | 13.98 |
| Ceramic | 2.99 |

and have been included in our research. Our results show that using the acrylic resin determines high stresses in the implant-prosthetic complex and in both mandibular bone components, so that the period covered by the provisional restoration should be as short as possible, especially in cases of low quality bone.

Considering the stresses registered in periimplantar bone, other researches shown that plastic materials as composite resins for metal-composite crowns may or may not be superior to the ceramic for metal-ceramic crowns depending on the metal used. Thereby, Assunção (2010) found that the single implant ceramic crowns fused on titanium are superior to the composite pressed on the same framework. Both Assuncao (2010) and Gomes (2011) concluded that if both the composite and the ceramic are used on the same gold alloy there are no differences between the stress values that appear in the bone [27,28]. Gomes added that the stress appeared in the retainer screw is higher for the composite than for the ceramic in both situations (titan and gold alloy). Our study uses the Cr-Ni alloy; for this type of metal, the results regarding the stress values in periimplantar bone and in the retaining screw are better for the metal-composite then to metal-ceramic crown. Low stress values in periimplantar bone are a real advantage, especially in cases of low quality bone, for the long-term survival of the implant-prosthetic restoration. Low stress values in the retaining screw mean a decreasing complication risks, common especially for the single crown implants.

## Conclusions

Using plastic materials as composite resins on Cr-Ni alloys for single implant crowns is more favorable comparing to ceramics regarding the stress values registered in periimplantar bone and in the retaining screw. In this study we demonstrated that there is no risk of fracture for the composite component. The acrylic resin used without metal framework induced high stresses in periimplantar bone, so it can be used in single crowns but only as a provisional restoration for a short period of time.

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