Comparative Investigation of the Fracture Strengths of Crowns of Three Different Non-metal Materials

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Summary

The demands of patients for high aesthetics during reconstructive prosthetic procedures accelerated the development of new materials and technology. Forces acting in the post-canine part of the dental arch amount to ≥ 500 N, and thus the material used for fabrication of the restoration must withstand such forces. The aim of this investigation was to study the resistance to fracture of three non-metal materials: 1. ceromer (Targis, Ivoclar-Vivadent), 2. ceromer reinforced with fibre reinforced composite (Targis/Vectris, Ivoclar-Vivadent), and 3. non-metal ceramic system (IPS Empress 2, Ivoclar-Vivadent). Eighteen identical crowns were fabricated from each type of material on a plaster model of a polished natural second lower premolar, according to the manufacturer's instructions. The same tooth was used for fabrication of a metal model on which crowns were placed in the universal testing device ZWICK. The compressive plate was modified with a pin 7mm in diameter, which acted with force on the occlusal surface at an angle of 180˚. Force was applied up to the first sign of fracture, and the amount recorded.

Half of the samples prior to the examination were thermocycled 1000x for 20 seconds at temperatures of 2˚C and 55˚C with 40 second intervals between immersion of the tempered sample. The mean value measured of the amount of force up to fracture for non-thermocycled samples amounted to 577.8 +/- 113.4 N for crowns of ceromer, 923.3+/- 229 N for crowns of ceromer and fibre reinforced composite, and 1208.9 +/- 161.8 N. for crowns of non-metal ceramic. Significant difference was determined by Mann-Whitney U test between all three materials ($p < 0.05$) for the amounts of loading up to fracture of the samples. Thermocycling did not significantly reduce the amount of force up to fracture of the sample. The investigation determined that all three materials are satisfactory for fabrication of permanent restorations in the area of the masticatory centre, as all withstand force greater than 500 N.

Key words: *fracture strength, crowns, ceramic, fibre reinforced composites, ceromers.*

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Introduction and aim

The increasingly frequent demands of patients for highly aesthetic dental prosthetic restorations accelerated the development of new materials and technology. During the 1980s metal ceramic became the material of choice for fabrication of fixed prosthetic restorations because of its good mechanical and aesthetic characteristics (1). The metal base of such restorations is overlaid with an opaque layer, followed by layers of ceramic, resulting in a completely aesthetic effect. With regard to economics the fabrication of a metal base and its overlaying with ceramic requires a significant amount of time, and exceptional knowledge and skill of the technician, which represents significant cost during the production of the restoration. Recent investigations of construction materials for fabrication of crowns and bridges have concentrated on non-metal systems, such as all-ceramic and fibre reinforced composites (2-8). These aesthetic materials have weaker mechanical properties than metal ceramic systems and limited indicative application (9-13). Systems of glass ceramic, ceromer and fibre reinforced composites, because of their easy fabrication, improved mechanical properties and high aesthetics are used for the fabrication of crowns and bridges of smaller spans, particularly in the frontal segment of the dental arch (24, 25). In the case of systems with glass fibre reinforced composites and ceromers, the reinforced composite is a translucent, aesthetic material, which replaces metal in the system and forms the bearing base for ceromer, which is basically organic polymer with a high percentage of inorganic filler (85%). The fillers are ceramic grains which offer mechanical resistance (1).

Investigations to date have demonstrated that the strength of non-metal restorations decreases considerably when exposed to ageing in the physiological conditions of the oral cavity (14, 15). The average magnitude of masticatory forces in the lateral region of the dental arch is 500 N, and therefore all materials for fabrication of restorations in this area must withstand the above or greater loading in clinical application (17).

The aim of this investigation was to examine and compare fracture strengths of crowns fabricated from three different types of non-metal materials: ceromer, ceromer with composite reinforcement with glass fibres and all-ceramic.

Material and method

A specimen of the second lower premolar for all three types of non-metal crowns was produced by circular rounded step and all transitions on the surfaces of the stumps were rounded. The thickness of the bur for the specimen was 1.2 mm and the specimen was smoothed with a polisher 1.4 mm thick. Impression of the specimen tooth was made by the addition of silicone (STD EXPRESS, 3M-ESPE) using the method of double simultaneous mixing. Three identical copies of the stump were cast in wax from the impression (Miling Dark Blue wax). The wax objects were cast from cobalt-chrome alloy Wiron 99 (BEGO). Plaster casts of the stump were then made by means of the elastomer impression (Fuji - Rock, GC). On the basis of the plaster casts three groups of 18 crowns each were fabricated from ceromer (Targis), ceromer and fibre reinforced composite (Vectris) and glass ceramic (IPS Empress 2), material of the firm Ivoclar-Vivadent, Schaan, Liechtenstein. Prepolimerisation of each layer of Targis material during fabrication of the ceromer crowns lasted for 20 seconds using a Targis Quick lamp. Final polymerisation of crowns in the Targis power apparatus lasted for 25 minutes. During fabrication of crowns from the Targis/Vectris system the Vectris material was shaped on the stump in a VS1 device and treated by grinding, sanding and cleaning. The layers of the Targis material were prepolimerised and finally polymerised as for the ceromer crowns. Final treatment of the crowns was performed in accordance with the manufacturer's instructions. Crowns in glass ceramic were modelled from white wax, placed in a kivete? and cast according to the manufacturer's instructions. After opening the kivete, sanding and cleaning was performed in a Special Jet Medium device under pressure of 1 bar. Layers of ceramic were then deposited on the prepared crowns, and the final temperature for firing of the ceramic was 770ºC.

The loading pedestal was constructed of steel alloy as a component part of the universal testing device used in the investigation. Thus the device for loading the samples was modified. The pedestal was shaped like a plate with a serrated lower part which was fixed to the lower jaw of the universal testing machine. The upper part of the pedestal contained a groove for securing the cast of the polished tooth with a transversely inserted screw for tightening. The upper part of the modified loading device contained a circular disk 35 mm in diameter and 20 mm thick which on one side secured the pin for loading and on the other secured the upper jaw of the universal testing device by a thread. In all measurements the diameter of the pin amounted to 7 mm.

Half of the samples of each type of material were subjected to thermocycling by Kappert's method. The samples were thermocycled in baths with normal water 1000 x, for 20 seconds. The temperature of one bath was 2 +/- 0.8ºC, and the other 55 +/- 0.8ºC. The temperature of the samples was checked with a thermostat every 10 minutes during the thermocycling process. The time interval between baths was 40 seconds, because of tempering the samples. The prepared samples were examined for resistance to fracture in a ZWICK ZD universal testing device.

Computerised statistical analyses of data of the obtained results of the investigation were performed by means of the programme packet SPSS for Windows 10.0.

Results

Results were divided into three groups based on the type of fabrication material. Each group had two sub-groups, one thermocycled and one without thermocycling. In the group of crowns of Targis material, which were not thermocycled, fracture force ranging from 400 to 795 N was recorded, which represents minimal and maximal values of fracture force. The group of non-thermocycled crowns of the Targis/Vectris system withstood the effect of fracture forces ranging from 610 to 1250 N. The group of crowns of IPS Empress 2 material, which were not thermocycled withstood fracture forces ranging from 940 to 1370 N (Table 1). In the group with thermocycled samples crowns of Targis material withstood fracture forces ranging from 250 to 770 N, which represents minimal and maximal values of fracture force. Thermocycled crowns of the Targis/Vectris system withstood fracture forces ranging from 580 to 920 N, while IPS Empress crowns of the same group of thermocycled samples withstood fracture forces ranging from 680 to 1450 N (Table 2).

Statistically significant difference was determined by Man-Whitney test ($p < 0.001$) between the examined materials. Statistical comparison of pairs of materials after thermocycling revealed statistically significant difference in fracture strength: a) between the Targis material and Targis/Vectris system ($p = 0.009$), b) between the Targis material and IPS Empress 2 of the ceramic system ($p = 0.003$). No statistical significant difference was determined between the Targis/Vectris system and the system of IPS Empress 2 ceramic ($p = 0.072$).

Statistical analysis of pairs of material, without the influence of thermocycling revealed statistically significant difference in fracture strength: a) between the Targis material and Targis/Vectris system ($p = 0.003$), b) between the Targis material and IPS Empress 2 of the ceramic system ($p = 0.003$), and between the Targis/Vectris system and IPS Empress 2 ceramic ($p = 0.018$). Statistical analysis of the relations of the amount of fracture strength within the groups of materials thermocycled and those not thermocycled did not show statistically significant difference: a) for the group of samples and Targis material ($p = 0.93$), for the group of samples and Targis/Vectris ($p = 0.44$) and for the group of IPS Empress 2 system ($p = 0.16$). The mean value of fracture strength in the group without thermocycling was: Targis crowns 577.8 +/- 113 N, Targis/Vectris system 923.3 +/- 229 N, IPS Empress 2 system 1208.9 +/- 161 N. The mean value of fracture strength in the thermocycled group was: Targis crowns 557.8 +/- 162 N, Targis/Vectris system 779.4 +/- 102 N and for IPS Empress 2 of the ceramic system 1041.1 +/- 266 N. Significant difference (in fracture strength?) was determined between crowns fabricated from ceromer Targis material and those fabricated from the Targis/Vectris system, and between ceromer material and ceramic system. No statistically significant difference in fracture strength was found between crowns of Targis/Vectris and IPS Empress 2 system (Figure 1).

Discussion

In the group of thermocycled samples the glass ceramic system withstood the greatest fracture force of all the investigated systems, which for IPS Empress ceramic amounted to 1208 N. The determined amount of fracture force also represents the highest value for thermocycled samples in the whole of the investigation. By comparing the present investigation with similar investigations by other authors varying degrees of conformity appear.

The mean value of fracture strength obtained for Targis crowns in the present investigation was 4.3% less than the results obtained by Ku, Park and Yang (16). The mean value in their investigation amounted to 602 +/- 101 N. Kolbeck, Rosentrit & Behr (17) investigated fracture strengths of three-unit inlay bridges from the Targis/Vectris system and obtained mean value of 723 N, which is 27% less than the result of this investigation. The difference in magnitude of the strength can be explained by the different construction of the examined prosthetic restoration (bridge - crown) and the place of loading. Behr, Rosentritt, Latzel & Kreisler (18) determined that fibre reinforcement does not contribute to the hardness of crowns fabricated from ceromer fibre reinforced composite systems.

According to the results of this investigation significant difference in fracture strength exists between Targis crown (ceromer) and Targis/Vectris system (Ceromer/reinforced composite) of as much as 41%. In his investigation Valittu (19) concluded that the effect of fibre reinforcement on crowns fabricated from polyethylene methacrylate results in an increase of fracture strength by 42%, which agrees with the values obtained in the present investigation. Bae, Kim, Hattori et al (20) also concluded that fibre reinforcement contributes to the mechanical properties of composite resin. Kolbeck, Rosentritt, Behr et al (21) examined bridge constructions of ceromer and fibre reinforced composite and obtained average fracture strength of 898 +/- 217 N, which is only 2.8% lower value than in this investigation. Behr, Rosentritt, Ledwinsky & Hendel (22) also examined fracture strength of three unit bridges and obtained mean value of 925 +/- 176 N. Although the investigation was carried out on bridges and not on crowns, their result almost entirely agrees with the values of fracture strength in this investigation.

Yoshinari & Derand (23) examined fracture strength of crowns of leucite ceramic fabricated on premolars and obtained a value of 789 +/- 185 N, which is a 47% poorer result than the result obtained in this investigation. Difference in the magnitude of fracture strength can be explained by the difference in the examined material - leucine/lithium disilicate ceramic. Rosentritt, Behr & Handel (24) examined fracture hardness of inlay bridges from the IPS Empress 2 system. Fracture strength after simulated conditions in the oral cavity of 5 years amounted to 500 N. The significant difference in the obtained results can be explained by the difference in the design of the examined restorations and the place of loading. In contrast to the aforementioned result Kappart (25) obtained fracture strength of 1280 N for three unit bridges from IPS Empress 2 system. His result is 5.8% greater than the result of this investigation. Attia & Kern (26) studied fracture strength of all-ceramic crowns fabricated by the CAD-CAM system. The fracture strength obtained was 715 +/- 105 N, which is 32% less than in this investigation.

Conclusions

Based on the results of this investigation the following conclusions can be made:

1. The highest values of fracture strength were determined in the sample of crowns of glass ceramic, which withstood fracture loading up to 1370 N.
2. The lowest values of fracture strength were determined in the sample of crowns of ceromer material, which fractured at loading of 400 N.
3. The results of the investigation show that the mean value of fracture strength determined for crowns fabricated from ceromer amounted to 577 N, crowns from ceromer reinforced with fibre composite 920 N and for glass ceramic 1208 N.
4. Comparison of the determined values of fracture strength for individual groups of samples before and after thermocycling showed that thermocycling had the least negative effect on crowns from ceromer, reducing their fracture strength by 6.7%.

5. Reduced fracture strength occurred twice as frequently after thermocycling on the sample of crowns of ceromer and fibre reinforced composite by 17.9%, and all-ceramic by 16%.
6. Significantly all of the investigated aesthetic materials had higher mean value of fracture strength than the determined average values of masticatory forces (500 N) for the posterior part of the dental arch, which also justifies their application in this area.