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INFLUENCE OF SHOULDER AND CHAMFER MARGINAL DESIGN AND TYPE OF CEMENT ON FRACTURE RESISTANCE OF ZIRCONIA CROWNS. AN *IN VITRO* STUDY

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Abstract

One of the major problems of all-ceramic restorations is the possibility of their fracture under occlusal force in posterior region. The aim of the present *in vitro* study was to compare the effect of two marginal designs (shoulder and chamfer) and two types of cement (phosphate and glass-ionomer) on the fracture resistance of zirconia crowns.

The stainless steel dies prepared with two different designs (shoulder and chamfer) were used as premolars. 20 zirconia copings with a wall thickness of 0.6 mm were fabricated for each type of preparation and cement. After cementation by two different types of cement (phosphate and glass ionomer), they were loaded on Universal Testing Machine until fracture. Obtained data were analyzed by the Student's t-test.

The mean values of fracture resistance of copings cemented with phosphate cement for shoulder and chamfer preparation were 899 ± 19.7 N and 617.14 ± 25.9 N, respectively. The mean values of fracture resistance of copings cemented with glass-ionomer cement for shoulder and chamfer preparation were 799 ± 31.6 N and 522.43 ± 20.9 N, respectively. Statistical analysis revealed significant differences between the groups.

Based on the results of this study, both marginal designs had sufficient fracture resistance, which are higher than the physiological masticatory force in posterior region. Both can be used, but since the fracture resistance of chamfer preparation is significantly higher than the shoulder preparation, and the phosphate cemented copings showed significantly higher resistance than the glass-ionomer cemented ones within a same type of preparation, chamfer preparation in combination with phosphate cement are recommended for zirconia based restorations from mechanical point of view.

Key words*: Zirconia, Tooth preparation, Fracture resistance, Cement.*

1. Introduction

During life, teeth as well as the other tissues and organs are subject to changes of physiological and pathological nature.

Because teeth do not have the ability to self-renewal of lost or altered tooth structure, it is necessary to compensate by conservative or prosthetic means. Metal-ceramic and all-ceramic crowns are choice of fixed-prosthetic rehabilitation. In the past 40 years, metal-ceramic preparations have been the gold standard in fixed prosthodontics. But the progress of science and technology, the need for high aesthetics and biocompatibility, and even more the need for materials with high tensile strength and resistance to mastication pressure allow the development and use of all-ceramic systems, both in front and in the posterior region. Full ceramic supra-structures are usually made of glass-ceramics with high hardness, polycrystalline oxide ceramics infiltrated with glass- monolithic polycrystalline aluminum (Al_2O_3) and zirconium oxide (ZrO_2) ceramics.

The most representative ceramic material today (with exceptional strength and fracture resistance) is zirconium-oxide ceramics, which enable a revolution in dentistry with the use of CAD/CAM technology.

However the fracture resistance of all-ceramic systems is one of the main problems in the posterior region. It is highly associated with the following factors: microstructure of all- ceramic materials, type of preparation, shape and thickness of the preparation, surface processing errors, direction and position of the applied force, the way of cementing, the modulus of elasticity of the components, conditions of storage before loading. The type of preparations as an important factor in fracture resistance of all-ceramic crowns was elaborated in many scientific papers from several scientists.

Sadan *et al.*, [1], proposed that both of these types of finishing lines are considered to be adequate for the tooth. But Di Lorio *et al.*, suggested that the shoulder margin could improve the biomechanical performance of single crown alumina restorations [2]. De Jager *et al.*, discovered that for long lasting restorations in posterior region it is advisable to make a chamfer with collar preparation [3]. Cho *et al.*, found out that the fracture strength of chamfer finishing line (0.9 and 1.2 mm) was greater than 1.2 mm rounded end shoulder and 1.2 shoulder finishing line [4]. Potiket *et al.*, suggested that a 1 mm deep shoulder finishing line with a rounded internal line angle has good fracture strength for the natural teeth restored with all ceramic crowns [5]. Rammersberg *et al.*, discovered that a minimally invasive 0.5 mm axial chamfer tooth preparation has the greatest stability for posterior metal free crowns [6].

The aim of the present in vitro study is to examine the influence of shoulder and chamfer marginal design and type of cement used on fracture resistance of zirconia crowns.

2. Materials and Methods

2.1 Abutment preparation

Stainless steel abutments were used for the purpose of this *in vitro* study, representing *in vitro* premolars in posterior region. Total of 40 abutments, each with total angle of convergence (TAC) of 12^0 were made using a CNC machine and according to the preparation design were divided into 2 groups (Figure 1):

- Group A - 20 abutment with shoulder preparation and TAC of 12^0.
- Group B - 20 abutment with chamfer preparation and TAC of 12^0.

The height of coronary part of abutments was 7 mm, while the width of the cervical part of the preparations was 5 mm. The depth of chamfer preparation was 0.8 mm. To avoid the appearance of sharp edges abutments were further processed. The axial walls were 12^0 convergent.

2.2 Zirconia framework fabrication

Scanning of the abutments was performed using a scanner (Everest Scan, KaVo, Biberach, Germany). Zirconia copings with settings of: wall thickness of 0.6 mm and virtual cement layer of 35 µm were processed from zirconia disks type KaVo Everest ZS using CAD/CAM machine (Everest KaVo, Biberach, Germany).

The check for the good fitting of copings to the abutments was made by visual inspection using a magnifying glass and coating of the abutments with red lipstick and setting the copings over the abutments without the use of force. Inside surfaces of the copings with red lipstick traces were corrected using a diamond borer and water spray to protect the zirconia restoration from damage of overheating. This procedure was repeated until we got the ideal fitting of copings to the abutments. To make sure this position it correct, it was checked by at least three examiners.

Furthermore, the zirconia copings were conventionally cemented over the metal abutments using glass ionomer cement (Aqua Meron, Voco GmbH, Germany).

2.3 Cementation with phosphate and glass-ionomer cement

In the present study, the zirconia copings were tested without any veneering material. This was because several studies have indicated that neither the

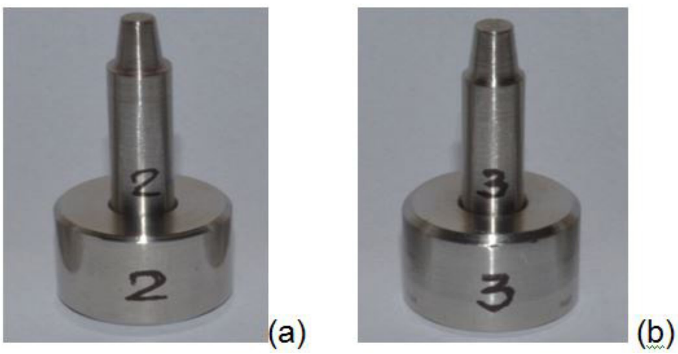

Figure 1. Abutments with (a) shoulder and (b) chamfer preparation

veneering porcelain nor the thickness of the veneering porcelain had a significant effect on the compressive load to failure of all-ceramic crowns [7, 8, and 9].

The copings filled with cement material (phosphate and glass-ionomer cement) were placed over the abutments and vertical force of 50 N for a period of 10 min was applied to complete the binding of the cement (according to the manufacturer's recommendations) (Figure 2).

Figure 2. Cemented zirconia copings

Samples before being tested were placed in a water bath (distilled water) at a temperature of 37 ^{0}C and held for 24 hours before loading, to simulate the conditions in the oral cavity.

2.4 Fracture load test

The test loading of the samples was performed on universal testing machine (Uniframe Controls) (Figure 3).

Figure 3. Universal testing machine Uniframe Controls

Each abutment was first placed in a cylindrical pad also made of stainless steel with a hole of Ø7 mm (as root of abutment) and a depth of 10 mm to provide a vertical position. Placed alike, the abutment was laid down on a horizontal fixed platform of the universal machine. The application of force was performed with vertical movable part of the machine that finishes with 30 mm diameter disc for smooth deployment of the power load.

Application of force was performed by the vertical axis of abutment. The speed of the vertical movement of the clip was 0.5 mm/min. The initial applied force was 30 N. The copings were loaded with continuously increasing force until the occurrence of a fracture visible to the eye. For the purposes of testing, from the digital display of the testing machine the following data was readed and recorded: breaking forces, fracture time and displacement of the piston of the testing machine to the moment of fracture. The maximal force to produce fracture was recorded in Newtons (N) (Figure 4).

Figure 4. Fracture on zirconia copings after applying the load

3. Results and Discussion

The mean values of fracture resistance of zirconia copings with shoulder preparation cemented with phosphate and glass-ionomer cement were 617.14 ± 25.9 N and 522.43 ± 20.9 N, respectively (Table 1, and Figure 5).

Table 1. Fracture resistance of shoulder edge zirconia copings depending on the type of cement

Descriptive Statistics			
Type of cement	Shoulder preparation, TAC = 12°		
	N	Mean ± SD	Min ÷ Max
Phosphate	20	617.14 ± 25.9	576 ÷ 650
Glass-ionomer	20	522.43 ± 20.9	480 ÷ 541

Legend: *Analysis of variance; F = 227.18; $p < 0.01$.

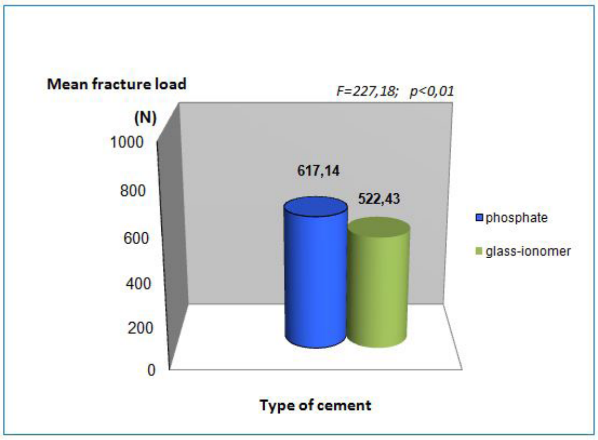

Figure 5. Mean fracture load of zirconia copings with shoulder preparation

The Students's t-test revealed a statistically significant fracture resistance of copings with shoulder preparation cemented with phosphate cement than the copings cemented with glass-ionomer cement (p < 0.01).

The mean values of fracture resistance of zirconia copings with chamfer preparation cemented with the same two types of cement (phosphate and glass-ionomer) were 899.0 ± 19.7 N and 799.0 ± 31.6 N, respectively (Table 2, and Figure 6).

Table 2. Fracture resistance of chamfer edge zirconia copings depending on the type of cement

Descriptive Statistics			
Type of cement	**Chamfer preparation,TAC=12°**		
	N	**Mean ± SD**	**Min ÷ Max**
Phosphate	20	899.0 ± 19.7	871 ÷ 923
Glass-ionomer	20	799.0 ± 31.6	752 ÷ 832

Legend: *Analysis of variance; F = 93.44; p < 0.01.

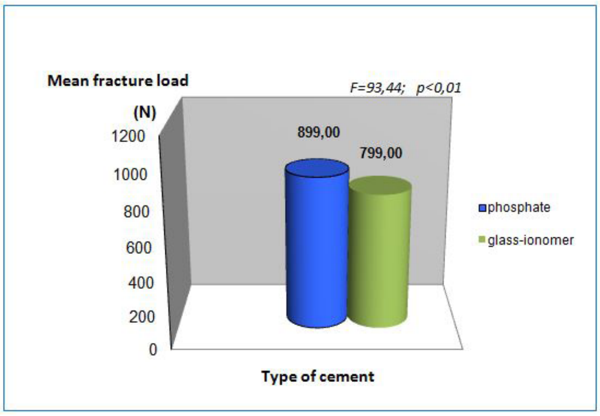

Figure 6. Mean fracture load of zirconia copings with chamfer preparation

The Students's t-test revealed a statistically significant fracture resistance of copings with chamfer preparation cemented with phosphate cement than the copings cemented with glass-ionomer cement (p < 0.01).

In the past 40 years, the majority of restorations contain metal which brings about toxic, chemical and allergic affects. The difference between their color and that of the natural tooth is another problem. Most people prefer tooth-colored crowns. All-ceramic crowns have esthetic and biocompatibility. Initially they were used in anterior region and in recent years such restorations have been used in posterior region [10].

One of the major problems of the all-ceramic restorations is their probable fracture against the occlusal and lateral force [11, 12, 13, and 14].

The mean breaking loads of all the examined preparation designs were well above the clinically required strength for zirconia. The fracture resistance of the zirconia in this study is higher than the physiological maximum of the masticatory forces in posterior region of 500 N with natural dentition [15, 16, 17, and 18].

Tinschert *et al.*, state that all-ceramic restorations for posterior region can be accepted as therapeutic choice only if their minimal fracture resistance is 500 N [19].

In this study, zirconia frameworks without porcelain veneering were loaded until fracture. As the effect of the veneering material on the breaking strength for zirconia-based restorations is still debatable, the copings were not veneered with porcelain [7, 8]. Additionally, it is noteworthy that while it is possible to achieve equal frameworks with standardized dimensions it is almost impractical to harbor such an expectation for veneered crowns. This is because veneering porcelain is applied by dental technicians and therefore human errors are inevitable at this step in the working procedure.

According to Scherrer and de Rijk [20], increasing the elastic modulus of the supporting material resulted in increased fracture strength. In this study, the elastic modulus of the supporting metal die was 200 GPa, which was superior to that of dentin at 12 GPa. If natural teeth were used as the supporting model, the fracture strength of the copings might have been lower [21, 22].

Results of the present study concurred with the study of Cho *et al.*, which found out that the fracture strength of chamfer finish line was greater than rounded end shoulder finish line [4].

4. Conclusions

- Based on the results of this study, both marginal designs had high fracture resistance, which are higher than the physiological masticatory force in posterior region.

- Both can be used, but since the fracture resistance of chamfer preparation is significantly higher than the shoulder preparation, and the phosphate cemented copings showed significantly higher resistance than the glass-ionomer cemented ones within a same type of preparation, chamfer preparation in combination with phosphate cement are recommended for zirconia based restorations from both mechanical and periodontal point of view.

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