The Effect Of Different Preparation Designs And Cement Type On The Fracture Resistance Of All-Ceramic Cantilever Anterior Fixed Partial Dentures

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Abstract: Aims: the aim of this study was to evaluate in vitro the effect of different preparation designs and cement type on the fracture resistance of all-ceramic cantilever anterior fixed partial dentures. **Material and methods:** 30 all ceramic zirconia cantilever bridges were constructed and divided according to retainer design into three main groups (10 bridges each). Each group was further divided according to the type of cement: Resin cement and glass ionomer cement. The fracture resistance of all-ceramic cantilever anterior fixed partial dentures was measured. **Results:** Under non-axial loading, the full coverage retainer provided the best fracture resistance, Three quarter retainer design provides least fracture resistance, No significant difference between resin or glass ionomer cementation.

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Keyword: fracture resistance, all ceramic bridge, preparation design, cement type.

1. Introduction

Due to the increasing interest in esthetics and the high concerns about the toxic and allergic reactions to certain alloys, patients and dentists have been looking for metal-free tooth colored restorations. Several patient reports concerning the replacement of avulsed primary, congenitally missing teeth, or permanent missing incisors were published. The three unit fixed partial dentures, single implant supported crown restorations and resin- bonded fixed partial dentures are the treatment modalities recommended for the replacement of a missing lateral incisor.

Modifications in tooth preparation designs, and thus different restoration designs were recommended, but there are still very few studies that evaluated their effect on the fracture strength of all ceramic restorations. The cantilever fixed partial denture (FPD) is a fixed restoration that has one or more abutments at one end while the other end is unsupported. This unique arrangement accounts for the prime disadvantage: the creation of a Class I lever system. Many dentists have noted a high incidence of damage with these restorations; consequently, some are reluctant to prescribe cantilever FPDs for patients. (1)

For patients with reduced dentition, treatment with fixed cantilever restorations is a favorable alternative to treatment with removable partial dentures. Patient treated using cantilever prostheses showed better functional conditions, better oral hygiene, less caries, and less of a need for dental and prosthetic treatment than patients with removable partial dentures. (2, 3)

In recent studies, attention has been given to causes of failure of cantilever restorations. Distinction was made between biologic causes such as caries, root fracture, endodontic and periodontal problems, and technical causes such as loss of retention or prostheses fracture. (4)

In general the following can be concluded from these studies; Caries and endodontic problems are the main causes of failure, (5-7) the frequency of technical failure is higher when the restorations have a non-vital abutment tooth, (6, 7) multiplication of the number of extension units increases the risk of technical failures, (7) and a healthy supporting periodontium and a strict recall are a prerequisite for favorable long term results. (8)

A further key factor in the performance of cantilever FPDs is the number of abutments. The creation of a “super abutment” by splinting abutments together may limit the forces transmitted to the abutment adjacent to the pontic. However, “double abutting” in the provision of cantilever FPDs has a number of disadvantages, including the involvement of an additional tooth in the prosthesis and possible periodontal complications. (9)

All ceramic crowns have become a dependable treatment modality. As a result, there is interest in expanding this modality to all-ceramic bridgework. All ceramic can be used when the cantilevers length is not more than the mesio-distal dimension of a premolar tooth and metal ceramic restorations can be used in longer situations. [10]

Zirconia is a polymorphic material that occurs in three temperature-dependant forms that are: monoclinic (room temperature to 1170 °C), tetragonal (1170 °C–2370°C) and cubic (2370°C – up to melting point). The tetragonal-to-monoclinic phase (t-m) transformation occurs below 1170°C and is accompanied by a 3-5% volume expansion which causes high internal stresses. This transformation is reversible and begins at 950°C on cooling, unless stabilizing oxides are added. [11, 12]

When stabilizing oxides such as magnesia, ceria, yttria and calcium are added to zirconia, the tetragonal phase is retained in a metastable condition at room temperature, enabling a phenomenon called transformation toughening to occur. [13]

Yttrium-oxide (Y2O3 3% mol) is added to pure zirconia to control the volume expansion and to stabilize it in the tetragonal phase at room temperature. This Yttrium-oxide partially stabilized zirconia (Y-TZP) has high initial flexural strength (900 to 1200 MPa) and fracture toughness (9 to 10 MPa x m1/2). Tensile stresses at a crack tip will cause the tetragonal phase to transform into the monoclinic phase with an associated 3-5% localized expansion. The volume increase creates compressive stresses at the crack tip that counteract the external tensile stresses and retards crack propagation. In the presence of higher stress, a crack can still propagate. The toughening mechanism does not prevent the progression of a crack it just makes it harder for the crack to propagate. [14, 15]

Advances in CAD⁄CAM technology has made it possible to more readily use zirconia in dentistry. [15] There are two types of zirconia milling processes available: soft-milling and hard-milling.

The bonding of zirconia substructures should be based on both micro-mechanical and chemical bonding since the micro-mechanical retention supports chemical bonding and if bonding is based only on chemical compounds some de-bonding might happen in moist environments.

Airborne-particle abrasion has been shown to be a good method for cleaning and roughening the zirconia surface after clinical try-in procedures, since the contamination with saliva is known to decrease the bond strength. [16, 17] Tribochemical silica coating is a system where a silica layer is formed on the surface of zirconia ceramic by airborne-particle abrasion with silica coated alumina particles. MPS silane can be used on the surface of silica coated zirconia substructure and efficient chemical bonding can be achieved. However, tribochemical silica coating seems to produce durable bonding with some zirconia ceramics, whereas silica coating particles do not provide adequate bond to the surface of denser zirconia ceramics. [18]

Several factors affect fracture resistance such as modulus of elasticity of the supporting substructure, properties of the luting agent, loading condition, surface roughness, residual stress, artificial aging, tooth-preparation design and restoration thickness. [19]

2. Material and Methods

A right maxillary lateral incisor was removed from the upper arch of an acrylic typodont*.the socket of the upper lateral was closed by pink modeling wax to stimulate an edentulous area of missing lateral incisor bounded by maxillary right central and canine acrylic teeth.

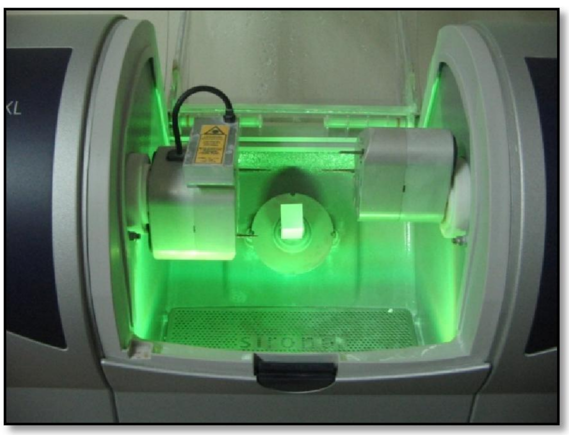
Three identical maxillary right canine acrylic teeth were selected from the refill teeth of the typodont. Each tooth was prepared to receive a different all ceramic retainer design; a full coverage, three quarter and a modified three quarter all ceramic retainer (fig 1).

Figure 1: abutments preparation

A total of 30 all ceramic zirconia cantilever bridges were constructed and divided according to retainer design into three main groups (10 bridges each). Each group was further divided according to the type of cement: Resin cement and glass ionomer cement.

The tests specimens were constructed using the inlab system, which was compromised acquiring an optical impression with the Cerec -3 acquisition units, designing the restorations with the inlab 3.1X software and finally milling bridges in the inlab MC XL milling unit.

When inLab restoration data have been captured, a dialog box appeared where the material we want to use for milling the restoration can be chosen. VITA YZ cubes with appropriate size were selected from the dialog box. The restorations would be milled with an oversize of approx.25%to be shrunk subsequently to



by grinding. If any necessary minor adjustments were needed, they were done by high speed diamonds under copious coolant, and then a thermal treatment (regeneration firing) of the substructure was done in order to reverse any phase transformations which may have taken place at the surface. Any micro cracks which have arisen cannot be regenerated.

Predrying temperature was 500°C.heating up was 5 minutes to reach a firing temperature of 100 °C at a rate of 100°C/min. the holding time was 15 minute without vacuum(fig3).

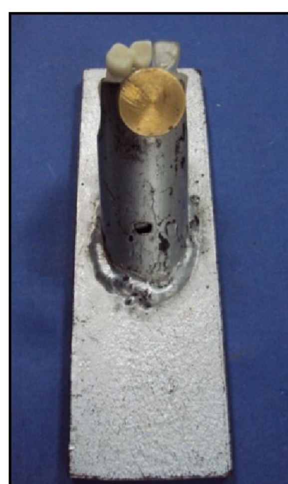


Figure 4: Epoxy cast mounted in custom made jig

Addition polymerization silicon impression material was used for taking impression for each prepared canine tooth after being placed in its socket of the typodont. The impression included the prepared canine tooth, the upper right lateral incisor edentulous area and the upper right central incisor. Impressions were poured after one hour according to the manufacturer instructions with Epoxy resin.

The samples were subjected to lateral loading using universal testing machine. Fracture resistance test was conducted, in order to identify the site and mode of failure for each retainer design under the investigated load direction (fig4).

Load was applied with a custom made load applicator (steel rod with round end 3.4 mm diameter, placed palataly 2mm below the incisal edge of the pontic) attached to the upper movable compartment of the machine until the very first discontinuity resulting from an early crack, debonding or catastrophic failure of bridge and/or die was detected. Then the results were tabulated and statistically analyzed (fig5).

Figure 5: lateral loading (proximal view)

3. Results

The mean values and standard deviation of fracture resistance (N) as function of preparation design and cement are summarized in table (4) and graphically drawn in figure (50).

Table 1: Fracture resistance results (Mean values± SDs) as function of preparation design and cement type

Variables		Cement			
		GIC		Resin	
		Mean	±SD	Mean	±SD
Preparation design	Partial coverage	327.07	23.10	195.58	2.94
	Modified p. coverage	411.11	83.30	334.27	60.58
	Full coverage	336.12	15.11	420.64	57.36

Different letter in the same column indicating statistically significant difference ($p < 0.05$)
*; significant ($p < 0.05$) ns; non-significant ($p>0.05$)

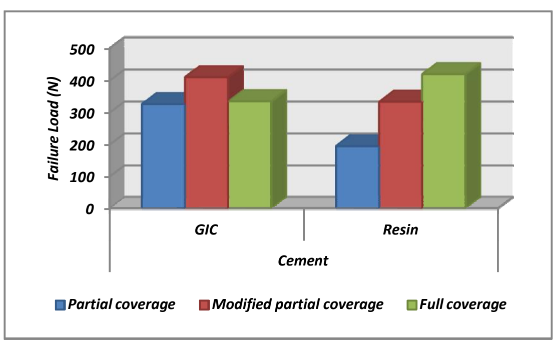


Figure 1: Histogram of fracture resistance mean values as function of preparation design technique and cement type

4. Discussion

This study was performed to investigate the fracture resistance of yttrium stabilized zirconia all ceramic cantilever anterior bridges as influenced by the of preparation design and cement type.

Yttrium stabilized zirconia has been selected because of high initial flexural strength ad fracture toughness. Zirconia has mechanical properties similar to that of stainless steel. Its resistance to traction can be as high as 900-1200 MPa and its compression resistance is about 2000 MPa. [20,21]

In order to produce a ZrO2 core for a prosthetic Restoration. It is necessary to use a computer aided design / manufacturing (CAD/CAM) system that can deal with zirconia and create a fitting framework. Various production techniques have been developed for enhancing the fabrication of consistent and predictable restorations in terms of strength, marginal fit, and esthetics. The Cerec system (Sirona, Bensheim, Germany), was selected since it is the most famous system that has been marketed for several years (since 1986). [20,22]

All ceramic anterior cantilever bridges retainer and the adjacent pontic may be subjected to various forces during function. In this study force directed 45 ° on the palatal surface of the pontic to subject the restoration to torque force to evaluate the résistance, as stresses that affect all-ceramic cantilever anterior bridges during mastication and protrusive mandibular excursions are complex and not usually directed parallel to the long axis of a tooth. [23,24]

Investigating test specimens on human teeth has however a touch of realism, but they are often replaced by the easily available metal alloy or resin materials this is because, such materials in contrast to human teeth ensure that the studies can be carried out using identical tooth dimension. [25] The difficulty in standardizing natural abutment teeth is due to the large variation in their size and condition which depends on their age and individual structure. Investigations that considered the fracture pattern of natural teeth showed a different fracture mode of the extracted tooth compared with teeth in vivo, implying that the dentin thickness remaining after preparation influences the fracture strength. [26]Human and bovine teeth were also avoided because of the variability in their mechanical strengths resulting from material anisotropy and the variable pulp size. [27,28]

Before cementation the fitting surfaces to be cemented were sandblasted with 50µm Al_2O_3 at a pressure of < 2.5 bar. The dual cure resin cement (G-CEM Capsule) and Chemical cured glass ionomer (GC Fugi I Capsule) were used for cementation of the test specimens without the need for silication and silanization of the surfaces. [20, 29]

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The Effect of Preparation Design

In some investigations, steel or resin dies have been used for fracture testing of all-ceramic crowns and bridges. [30,31] It can be argued that a standard steel or resin die, enforces consistent preparation shape and identical physical quality of the abutments under loading; however, steel or resin abutments do not reproduce the actual force distribution that occurs on crowns cemented to natural teeth. [32]

Rosentritt *et al.* [33]**:** investigated the influence of the abutment material on the fracture resistance of all-ceramic (FPDs) using human, polymer and alloy abutments. The application of the alloy abutments lead to an overestimation of the fracture resistance of the all-ceramic (FPDs). However, studies using resin material for the abutment teeth reported similar fracture forces for zirconia-based (FPDs). [34]

In the present study to better simulate clinical conditions, epoxy resin material are selected as die material on which the test specimens are cemented for investigating their fracture resistance since its modulus of elasticity is similar to the reported modulus of human dentin and bone(18.3GPA). [35,36]

Three preparation designs were investigated during this study. The full coverage, as a standard preparation, that provides the ultimate resistance and retention to restorations. The conventional three quarter preparation, a well suited design for short span anterior bridges as it provides good mechanical and esthetic properties as well as being conservative. [37,38]

The obtained results showed that under 45° load the full coverage resist rotation, the modified partial coverage design exhibited the statistically significant higher mean of fracture resistance than the partial coverage design, this may be due to that, under 45° load, the 2 mm incisal reduction done as a preparation modification had increased the resistance to rotation than that exhibited by the conventional partial coverage design.

This justifies the claim that appropriate crown-preparation design is necessary if retention and resistance of cantilever FPDs are to be maximized. [39,40]

It has been claimed that the tooth furthest from the pontic especially should be extremely retentive to resist dislodgment. [39]

The effect of cement type

Zirconia surface cannot be etched due to the absence of the glassy component in its structure, thus its surface was only sandblasted with 50µm Al2O3 at less than 2.5bar according to manufacturer's instructions to create a roughened surface and increase micro-mechanical retention. [41]

Glass ionomer cement was chosen over other conventional cements because of its bacteriostatic effect through fluoride release properties, chemical adhesion to tooth structure, low coefficient of thermal expansion to maintain that bond and good physical and mechanical properties. [42] Its use is recommended by manufacturer to cement zirconia restorations which have high strength. [43]

Self-Adhesive Resin cement was chosen as it eliminates the need of pretreatment of the abutments. (44) It also contains phosphate monomer which has a high affinity to zirconia and enters into a durable chemical bond with the sandblasted surface of zirconia forming low soluble stable phosphate compounds without the need for silication and silanization of the surfaces. It was dual cured as the thickness of the crown might not allow the light to penetrate through its full thickness. [45,46]

However, there was no significant difference of fracture resistance mean values between resin cement and glass ionomer. [47]

The correlation between preparation design and cement type:

The clinical performance of all-ceramic cantilever FPDs is challenging, because available data for maximum clinical forces and in particular on cantilever FPDs vary widely for cantilever FPDs, maximum local forces between 150N anteriorly and

700N posteriorly were reported. [48] (According to the present study , stress under 45° load they range from 195.5 N to 420.6 N which was well beyond the 150N required [49], predicting promising prognosis of such designs.

In case of full coverage retainer design: resin group recorded statistically non-significant higher fracture resistance mean value (420.64N) than GIC group (336.12N).

In case of Partial coverage group: It was found that GIC group recorded statistically significant higher fracture resistance mean value (327.07 N) than resin group (195.58 N).

In case of Modified partial coverage group: It was found that GIC group recorded statistically non-significant higher fracture resistance mean value (411.11 N) than resin group (334.27 N).

Conclusions:

Within the limitations of this study the following conclusions could be obtained:

1- Under non-axial loading, the full coverage retainer provided the best fracture resistance.

2- Three quarter retainer design provides least fracture resistance.

3- No significant difference between resin or glass ionomer cementation.

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