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Original Research Article

Retention of All Ceramic Crown Preparation with Two Different Tapers Luted by Two Different Cements

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ABSTRACT

Background: The popularity of all ceramic restorations has increased recently due to superior esthetic appearance. Zirconium oxide all ceramic material constructed using CAD/CAM technology demonstrates one of the most successful systems that are used nowadays. Retention is very important factor to prevent dislodgement of prosthetic restoration and ensures the restoration longevity.
Objectives: The aim of this study was to evaluate the retentive strength of zirconia crowns luted using two different luting agents on two different preparations.
Material and methods: A total of 20 extracted non carious premolars teeth were collected and prepared using standardized technique. The prepared teeth were divided into two equal groups based on the degree of preparation taper, group I: all ceramic crown preparation were done with (5-10°) degrees and group II: all ceramic crown preparation were done with (15-20°) degrees taper, then every group was further subdivided into two equal subgroups according to cement type (Polycarboxylate and adhesive resin cement). Zirconia crowns were constructed. Retention of the crowns was measured using universal testing machine.
Result:

- Cements with (5-10°) taper exhibited higher retentive strength value than cements with (15-20°) difference were statistically significant.
- Regarding the types of the cement, there was no statistical significant difference between retentive stress values of subgroups.

Conclusion:

- Teeth prepared with 5-10° taper greatly improved the retention values than teeth prepared with 15-20° taper with both cement types.
- Adhesive resin cement exhibited better retention values than polycarboxylate cement for both preparations taper.

Key words: Zirconia, all-ceramic, polycarboxylate, resin, retention

INTRODUCTION

All-ceramic crowns have been used over the last years as alternative prosthetic materials for PFM crowns to overcome their esthetic problems.

All-ceramic crowns and bridges have become more popular for the restoration and coverage of prepared teeth due to better esthetic quality and metal-free structure. [1]

The zirconium oxide as core material for all-ceramic restorations possesses a good chemical and dimensional stability, high mechanical strength and toughness and a young's modulus similar to that of stainless steel. [2] Based on these material properties, it is expected that restorations made with a zirconium oxide core are able to withstand the high occlusal stresses occurring during function. Moreover, extensive all-ceramic restorations exceeding the limit of four-units are within reach. [3]

For many years, zirconia ceramics have been used for numerous industrial applications, as well as for hip prosthesis. Only recently have dental companies developed applications for fixed prosthodontics by formulating zirconia all-ceramic systems. [4]

With the advances in the materials and technology, different techniques have been developed to produce dental restorations including CAD/CAM systems.

The use of prefabricated blocks and standardized scanning and milling procedures minimized the influence of the dental laboratory technician in the production process and result in higher quality restorations. [5] The use of CAD/CAM technology spurred a whole new generation of ceramic substructures consisting of zirconium dioxide. Several manufacturers (Lava, 3M ESPE; Procera Forte, Nobel Biocare; and Cercon, DENTSLY) introduced crown-and-bridge frameworks milled from blocks of presintered yttrium-stabilized zirconium dioxide blocks. The oversized milled frameworks were then sintered for 11 hours at 1500°C providing excellent fit with 900 MPa to 1300 MPa of flexural strength. Other manufacturers (Everest, KaVo, DC-Zirkon, Precident DCS) milled fully sintered zirconium dioxide blocks so, that the shrinkage factor was removed and a superior marginal fit was obtained. [6] Both fabrication methods provide a framework with sufficient flexural strength, allowing them to be used for multi-unit posterior bridges.

Lithium disilicate re-emerged in 2006 as a pressable ingot and partially crystalized milling block (Cerec for chairside and inLab milling units for laboratories). The flexural strength of the material was found to be more than 170% higher than any of the currently used leucite-reinforced ceramics. Thus, this ceramic material can be milled or waxed, and then pressed to full contour and subsequently stained. Another option allows for cutting the crown back, followed with layering with different specially designed apatite ceramic glass. The layering ceramic has the same basic components as natural tooth enamel.

CAD/CAM milling of a framework (zirconium dioxide or metal), a full-contoured crown (lithium disilicate at chairside or in the laboratory), or an implant abutment has opened the market for digitized restorative dentistry.

Zirconia (ZrO_2) is a polymorphic material that has three allotropic forms (monoclinic, tetragonal and cubic phases) which are stable at a different range of temperatures. The tetragonal grains of zirconia, which are normally stable at high temperatures, can be retained at room temperature by adding metal oxides, such as ceria (CeO_2) or yttria (Y_2O_3). Nevertheless, the tetragonal grains may transform into monoclinic as a result of externally applied stresses exerted by grinding and sandblasting. The tetragonal to monoclinic phase transformation exhibits a 4% volume expansion which creates compressive stresses at the crack tip. These compressive stresses must be overcomed by the crack in order to propagate, explaining the greater fracture toughness of zirconia compared to conventional dental ceramics. This phenomenon is called “transformation toughening. [7]

The use of zirconium oxide all-ceramic material has increased in recent years due to excellent physical properties and optimal biocompatibility. [8,9] Zirconium oxide all-ceramic material demonstrates optimal material properties such as high fracture resistance, enabling its use with posterior fixed partial dentures (FPDs). Zirconium oxide crowns and FPDs can be cemented conventionally, as recommended by the manufacturers due to high fracture resistance. [10-11]

Densely sintered high purity zirconium-oxide ceramics have been recently added to the line of CAD/CAM products. Its clinical use as core material in dental prosthesis has advantages including favourable optical characteristics and mechanical properties. [12,13]

The success of these all-ceramic aesthetic restorations depends, among other factors, on the achievement of high retention and optimum marginal fit after cementation. [14,15]

Crown retention is one of the important parameters in the success of all ceramic crowns. The main importance of crown retention is to prevent removal of the restoration along the path of insertion or long axis of the tooth preparation.

Dental materials for the luting agents of indirect restorations like crowns and bridges mainly have three requirements: to fill the space between the restorative material and the prepared tooth, to enhance the retention and prevent dislodgment of restorations and to provide adequate aesthetic appearance for the indirect restoration. [16,17]

There are many dental cements used in cementation of crowns and bridges.

Cements can be classified as follows: liners and bases, temporary (provisional) cements and permanent cements. Permanent cements like: Zinc Phosphate Cement, Zinc Polycarboxylate Cement, Glass Ionomer Cement, Resin Cements, Resin-Modified Glass Ionomer (RMGI) Cements, Adhesive Resin Cements and Hybrid-Acid-Based CaAl/Glass Ionomer.

Conventional cements and resin cements can be used efficiently to bond the tooth structure to all- ceramic restorations. [18] Yet resin cements are more preferred as it provides ultimate aesthetics with low solubility in oral environment, high bond strength, superior mechanical properties, a better marginal seal, together with high retention. In addition, resin cements are available by several manufacturers and in different polymerization types and shades. [19-21]

The polycarboxylate cement is an acid-base reaction cement. The powder is composed of mainly zinc oxide. It may also contain stannous fluoride, which improved the strength. The liquid is composed of polyacrylic acid or copolymer of acrylic acid and other unsaturated carboxylic acid. Fluoride release by the cement is a small fraction (15-20%) of that released from materials such as silicophosphate and glass ionomer cements. The compressive strength, (55 MPa) is lower than zinc phosphate cement.

One of the most important requirements of prosthodontics crowns and bridges is achieving the maximum integrity of the replacement restoration without marginal opening or loosing of contact between the tooth crown surfaces. [22] The retention of full coverage restorations is a function of tooth preparation that depends on many factors such as tooth geometry, axial taper, height to width ratio, position of finish line, surface area and surface roughness. [23,24] However, the adhesive luting cements which bond to the tooth surface and the restoration has the role for increased crown retention and resistance. [25,26]

Traditionally, The success of crowns retained on a cavity preparation has been attributed not only to mechanical properties of the cement but also to the design of the cavity to achieve excellent adaptation between the restoration and the prepared tooth. [27]

Many studies found that the dental cements and degree of the tapers affected crown retention and resistance. [28,29]

Sreeramulu et.al collected 40 freshly extracted non carious human premolars teeth that were mounted and prepared for full coverage crowns with 4 degrees overall taper. They compared and evaluated the retentive strength of four different luting agents. It was shown that the mean stress and force required to remove the crowns from the tooth structure was 6.17 (± 0.39), 5.57(±0.25), 5.15(± 0.34), and 4.24 (±0.31) MPa for the adhesive resin, resin modified glass ionomer, glass ionomer and zinc phosphate cement groups, respectively. [30]

Sajjan Chandra Shekar, et.al. evaluated the best advisable taper and cement for maximum retention. Eighty extracted human maxillary premolar teeth with sound surfaces were selected and randomly divided into five different taper groups (0°, 3°, 6°, 9° and 12°). The crown preparations were achieved by graduated customized device. Crowns were cast with Co-Cr alloy; metal copings were luted with glass ionomer and zinc phosphate cement. Retention was measured (MPa) by using universal testing machine. Glass ionomer cemented 0° and 12° taper group showed increase in retentive strength (p = 0.003 hs), when compared to zinc phosphate cement. 9° and 12° group showed decreased retentive strength (p = 0.001 vhs) when compared with 0° taper group. No significant difference was found between 0° and 3° and 6° group. The choice of cement for crowns prepared within this ideal range (0°-6° taper) might be of limited clinical significance. 3° and 6° taper with zinc phosphate or glass ionomer cement were shown to be ideal for maximum retention. [31]

The aim of this study was to compare the retention of all ceramic zirconia crowns cemented with zinc polycarboxylate and resin cement in standardized preparations made with two different tapers.

Subject:

A total of 20 extracted non carious human premolars was collected then cleaned from debris and stored in normal saline. The roots of the selected teeth was notched for retention and embedded along their vertical alignment in an auto polymerizing acrylic resin (Acrostone, acrostone dental factory, Egypt) with the cement-enamel junction positioned 1mm above the top of the acrylic resin. The teeth were divided into two equal groups according to the degree of tapers: group 1: all ceramic crown preparation was done with (5-10°) degrees taper (Fig.1) and group 2: all ceramic crown preparation was done with (15-20°) degrees taper (Fig.2). Each group was subdivided into two equal subgroups according to luting agents, subgroup A crowns were cemented with zinc polycarboxylate cement and subgroup B crowns were cemented with resin cement.

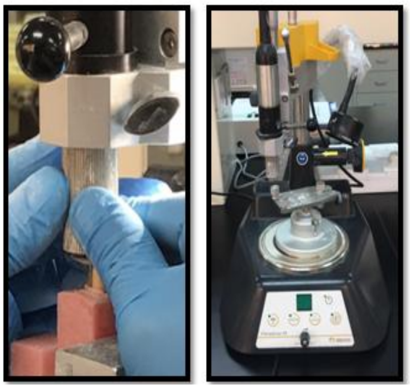
(Figure1): Tooth preparation with (5-10°) degree taper
(Figure 2): Tooth preparation with (15-20°) degree taper

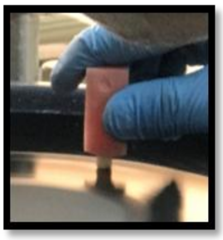
(Table 1): Organization of study groups

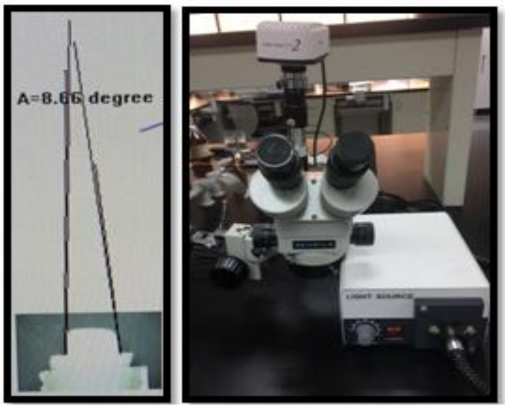
Groups	**Group I**		**Group II**	
	5 – 10° degrees		15 – 20° degrees	
Subgroups	**Subgroup A**	**Subgroup B**	**Subgroup A**	**Subgroup B**
	Zincpolycarboxylate 5 samples	Resin cement 5 samples	Zincpolycarboxylate 5 samples	Resin cement 5 samples
Total	20 samples			

Standardized teeth preparation:

Full coverage all ceramic crown preparation were done using PARASKOP M milling machine (Fig.3), the occlusal surface was prepared parallel to the floor (Fig.4).







(Figure 3): PARASKOP M milling machine
(Figure 4): Preparation of occlusal surface
(Figure 5): Measuring of tapered angle by MEJI microscope

The tapered angle was measured by using MEJI microscope (Tested to comply with FCC and CE standards) with camera model INFINITY2-3C (color) (Fig.5).

Zirconia crown construction:

Zirconia crown was constructed using CAD/CAM machine, teeth were scanned using Cercon eye scanner (DeguDent Gm b H, Germany) .The design of the crowns was designed using the CAD software (DeguDent Gm b H, Germany). The crowns were milled using Cercon Brain milling machine (DeguDent Gm b H, Germany) (Fig.6).

(Figure 6): Design of the crown using Cercon CAD/CAM

Crown cementation:

Zinc polycarboxylate:

- Mix ratio: One spoon of powder and one drop of liquid
- Mixing (30 seconds): using spatula and mix until creamy consistency is reached.

Total etch resin cement:

- Using bonding agent then, activates the tube and the mix is exited through the tip.

The luting agents were mixed as per the manufacturer's instructions. A thin layer of the luting agent was applied to the inner surface of the crown with a plastic instrument and the crown seated on its respective preparation by finger pressure. The excess cement was removed from around the margins with a sharp probe and cotton roll. Then samples were stored in distilled water for 24 hours.

(Figure 7): Universal testing machine
(Figure 8): Tensile load test

Retention test (pull-out test):

A tensile load with pull out mode of force was applied via universal testing machine (Fig.7) at a crosshead speed of 0.5 mm/min. A tensile load was applied to separating the crowns from the prepared teeth (Fig.8) The force at dislodgment was recorded.

Statistical analysis:

Statistical analysis was performed by Microsoft Office 2013 (Excel) and Statistical Package for Social Science (SPSS) version 17. The comparison between means were tested using t-test and one way ANOVA test to assess effect of taper degree and cement over retentive stresses. Data were presented as mean and standard deviation (SD) values. The significant level was set at $P \leq 0.05$.

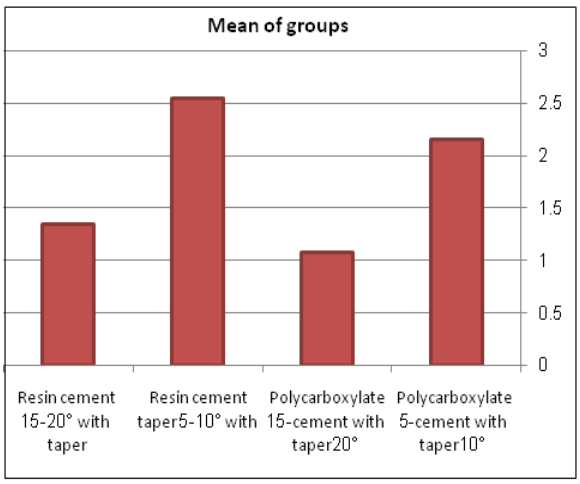
(Table 2): Composition and manufacture of materials

Material	Composition	Manufacture
Zinc polycarboxylate	Zinc oxid Polyacrylic acid	Medental
Total etch resin cement	Glass reinforced composite	Coltene/Whaledent
Yttria partially stabilized zirconia	Zirconium oxide Yttrium oxide 5% Hafnium oxide 3% Aluminum oxide , Silica oxide 1%	DeguDent ,Germany

Table 3: Descriptive statistics of the four tested groups

	PC (5-10°) taper	RC (5-10°) taper	RC (15-20°) taper	PC (15-20°) taper
Maximum	241.9	412.5	412.5	145.1
Minimum	194.1	131.5	110	62.24
Mean	215.7	255.7	135	107.2
SD	17.7	108.7	20.6	32.1

PC: polycarboxylate cement
RC: resin cement



(Figure 9): mean of groups

With respect to (Figure 9) the mean results showed that:

- The highest mean retentive value was resin cement with (5-10°) taper.
- The second highest mean retentive value was polycarboxylate cement with (5-10) taper.
- The third highest mean value was resin cement with (15-20°) taper.
- The last mean retentive value was polycarboxylate cement with (15-20°) taper.

(Table 4): The correlation between four groups

Correlated groups	p-value
Resin cement with (5-10)taper –Resin cement (15-20) taper	0.05*
Polycarboxylate cement with (5-10)taper- Polycarboxylate cement with (15-20)taper	0.002*
Resin cement with (5-10)taper -Polycarboxylate cement with (5-10)taper	0.398
Resin cemnt with (15-20)taper -Polycarboxylate cement with (5-10)taper	2.26

(*): Related to significant difference that's mean the p value ≤ 0.05 in correlation between two groups

- Resin cement with (5-10°) taper exhibited higher retentive strength value than resin cement with (15-20°) difference was statistically significant.
- Polycarboxylate cement with (5-10°) taper exhibited higher retentive strength value than polycarboxylate cement with (15-20°) difference was statistically significant.
- Regarding the types of the cement, there was no statistical significant difference between retentive stress values of subgroups.

DISCUSSION

The hypothesis that the retentive force of Zirconia crown is influenced by the cement type was rejected. However, the hypothesis that the retentive force of zirconia crowns is influenced by the degree of taper of preparation was confirmed. The adequate adhesion between ceramic and tooth structure is one of the requirement for successful function of ceramic restorations over years. Bond strengths are influenced by several factors, one of which is the bonding mechanism. Another factor is the degree of taper of the preparation.

Bonding to zirconia represents a challenge as neither hydrofluoric acid etching nor sinalization result in considerable modification of the surface due to high crystalline content and limited vitreous phase. [32-34] However, sandblasting was verified as the reasonable method to increase the bond strength with zirconia ceramics. [35,36] Due to the high fracture toughness of this high strength zirconia ceramics, the manufacture claims that conventional bonding can be used to obtain satisfactory results which may be comparable to that was obtained with adhesive resin cement.

In the present study, the retentive strength of the two luting agents (polycarboxylate & resin cement) was examined using pull-out test with crown cemented on extracted human teeth. This was done for better simulation of the clinical environment. [37] This testing procedure is considered complex and technique sensitive but postulates real information about retentive performance of the crown. [38] This test was previously recommended in several studies. [39-41]

The abutment teeth were chosen to be of similar size and shape, and the preparation was done using PARASKOP M milling machine for assuring standardized preparation through all the test samples.

Regarding the cement type, the results of this study revealed that the retentive values of zirconia crowns with resin cement (255.7 & 135 N) were higher than the retentive value of zirconia crowns with polycarboxylate cement (215.7 &107.2 N) for the two tapers. However, there was no statistical significant difference between them. The results of the present study were in agreement with those Zidan O and Ferguson GC. and Palacios RP. et. al. Both studies showed the retentive values of the adhesive resins at higher than the retentive values of the conventional cements. [41-42]

Our study supported by Nicola Mobilio et. al. they noticed the composite cement has higher retention than GI. [43]

In 2013, Aleisa et.al studied the retention of zirconium oxide copings using different types of luting agents. The mean copings bond strengths were 440 N, 416 N, and 360 N for resin-modified glass–ionomer cement, self-adhesive resin cement, and adhesive resin cement, respectively. There was no statistically significant difference in mean crown retention between the three cementation groups. [44]

In our study the degree of taper exhibited statistically significant higher retentive values upon using (5-10°) taper preparations than that upon using (15-20°) taper preparations for both cement types.

Our results was consistent with study of Zidan O and Ferguson GC have shown the difference in retention was significant between the 6-degree taper and the 24-degree taper (P<.0001) and between 12-degree taper and 24-degree taper (P=.0178). [42]

It is important to mention that the type of the luting agent and the degree of preparation taper are two critical factors that must be properly chosen for long term clinical success.

CONCLUSION

Within the limitation of this study, the following conclusions were drawn:

1. Regarding the preparation taper, teeth prepared with 5-10° taper greatly improved the retention values than teeth prepared with 15-20° taper with both cement types.
2. As for the types of the cement, adhesive resin cement exhibited better retention values than polycarboxylate cement for both preparation taper.

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