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COMPARATIVE FRACTURE RESISTANCE OF COMPOSITE VENEERED POLYETHER ETHER KETONE CROWNS WITH CERAMIC AND COMPOSITE VENEERED ZIRCONIA CROWNS

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ABSTRACT

Objectives: The objective of this study was to evaluate and compare the fracture resistance of Polyether ether ketone veneered composite crowns with composite and ceramic veneered zirconia crowns.

Material and Method: Thirty readly prepared ivory teeth of mandibular right first molar with standardized reduction of (1.5mm for occlusal reduction and 1.2mm for axial reduction with 6 degree convergence angle) with a circumferiential shoulder finish line with rounded angles were fitted in acrylic resin blocks. Full contoured crown wax pattern was made on the readly prepared ivory teeth using inlay wax, then a silicon index for the crown was made to standardize the crown and the veneering layer thickness for all groups. The prepared ivory teeth were scanned and crowns substructures were fabricated using the CADCAM milling process for different groups as follow, (G1): Zirconia substructure veneered with composite (n=10). (G2): Zirconia substructure veneered with ceramic (control group n=10). (G3): BIOHPP/PEEK substructure veneered with composite (n=10). Crowns of the three groups were stored in distilled water for 24 hours at 37°C, then subjected to thermocycling for 10,000 cycles (5-55ºC) with a 30-s dwell time, 20 seconds transfer time, then subjected to mechanical stressing in chewing simulator with maximum vertical load of 10 kg with cyclic frequency of 1.7 Hz for 240,000 cycles, load was applied occlusally with a custom-made load applicator [steel rod with flat tip (20x25mm) attached to the upper movable compartment of the machine. Crowns fracture resistance were tested using the universal testing machine by applying a load with a 4.2 mm diameter steel ball at a crosshead speed of 1 mm/min occlusally in the middle of the crown central fossa and the maximum load causing crown fracture was recorded in newton.

Results: One-way ANOVA test showed a high statistically significant difference (F=, 17.404, P <0.001) between different studied group as regard fracture resistance with the highest mean value was recorded for crowns fabricated with PEEK frame work veneered with composite crowns.

Conclusion: Crowns constructed from PEEK substructure and veneered using composite gave highly significant results than the other two groups. All groups gave comparable results withstanding the fracture forces beyond the maximum masticatory biting force.

KEYWORDS: Fracture resistance, PEEK, Zirconia, Ceramic, Composite resin, CAD/CAM.

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INTRODUCTION

The increasing demand of the public mandated the increase in esthetic fixed prosthetic materials specially Yttria partially stabilized tetragonal zirconia (Y-TZP) due to their favorable mechanical and optical properties. [1,2]

However, clinical survival rates evaluation of the posterior esthetic all-ceramic crowns fixed dental prostheses and their impact of those systems on failure modes [3,4] has revealed that the strength of all-ceramic Bi-layered crowns depends on the core as well as the veneer material, whereas a bilayer crown system with a strong Y-TZP core veneered porcelain tends to show early failure. They have several manufacturing drawbacks such as multiple manufacturing steps, inadequate toughness of the veneer material, and inconsistent bonding between veneer layer and coping [5].

Veneering porcelain fracture have been reported to be the commonly forms of failures in Y-TZP-based restorations [6]. Moreover, porcelain veneering on zirconia cause excessive wear of the opposing dentition, as reported by studies that found showed significant abrasion more antagonistic tooth wear than other restorations [7].

The Brinell hardness of ceramics makes them abrasive material, causing wear of the opposing teeth. While Composite resins are favorable because of its excellent physical, optical, mechanical properties, ease of handling and ability to be bonded to the tooth structure [8.9].

Composite veneered metal crowns have recorded the highest durability and longevity in service against other types of crowns like metal-ceramic crowns. Moreover, opposing enamel abrasion because of the veneering ceramic layer is another drawback of this combination that could be solved by veneering with composite resin as stated by some authors [10].

A high strength indirect composite resin veneering on zirconia substructure has been proposed as an alternative veneering method to porcelain veneering system [11]. Another advantage of using composite resin veneering is the reduction by 15% in stresses when compared to porcelain or gold alloy [12]. Moreover, the fracture resistance of monolithic composite resin crowns was comparable and not significantly different from those of monolithic all-ceramic crowns as reported by previous study [13] however, the study was carried out with monolithic composite crown without zirconia substructure.

The bonding between zirconia and the composite resin is a crucial factor that may take part in the mechanical behavior of this combination as a result of differences in chemical and mechanical properties of both materials. Polyetheretherketone (PEEK) is a recently introduced material which is a thermoplastic polymer composed of aromatic backbone molecular chain, interconnected by ketone and ether functional groups. It melts at a temperature around 343°C, with modulus of elasticity that ranges from 3 to 4 GPa, that is close matching to that of dentine structure, and composite. (14) Due to these promising physico-mechanical properties, PEEK shows some advantages to traditional alloys and ceramic dental materials.

The study of the mechanical behavior of composite veneered PEEK has not yet been investigated. Hence crown failure usually occurs under complex types of stresses. Therefore, the objective of this study was to evaluate and compare the fracture resistance of Polyether ether ketone veneered with composite crowns versus zircon crowns veneered with composite and ceramic.

Aim of the work:

The objective of this study was to evaluate and compare the fracture resistance of Polyether ether ketone veneered composite crowns with composite and ceramic veneered zirconia crowns.

MATERIAL AND METHODS

Materials

Materials used in the current study are listed in (Table.1)

TABLE (1) Materials used in the study:

Materials	Composition	Manufacturer
Readymade prepared ivory teeth	inorganic formula $Ca_{10}(PO_4)_6(CO_3)\cdot H_2O$ (collagen matrix ,mineral component)	Nissin Dental Products INC, Kyoto, Japan.
Polyether ether ketone (PEEK)	Polyetheretherketone (PEEK) infiltrated with ceramic fillers with grain size 0.3 to 0.5 μm	Bredent GmbH, Senden, Germany.
Silicon index	Elite HD+ Putty soft normal set Additional silicon elastomeric impression material.	Zhermack, Bovazecchino, RO, Italy
Zirconia block	Yttria-stabilized zirconia blanks (VITA YZ)	Vita Zahnfabrik, Bad Säckingen, Germany
Ceramic veneer	Kiss veneering porcelain	Kiss veneering porcelain (DeguDent GmbH, Hanau-Wolfgang. Germany),
Composite resin	Visio-lign	Brendent GmbH, Senden, Germany.
PEEK Primer	Visio-link	Brendent GmbH, Senden, Germany.
Zircon Primer	MKZ Primer	Brendent GmbH, Senden, Germany.
Adhesive luting cement	self-adhesive (RelyX Unicem)	3M ESPE, St Paul, MN, USA)

Thirty ready prepared ivory teeth representing the mandibular right first molar (Nissin Dental Products INC, Kyoto, Japan) were fixed along their long axis in custom made acrylic resin blocks using survayor [15]. The prepared teeth had standardized reduction of 1.5mm occlusal reduction. 1.2 mm axial reduction and a circumferiential shoulder finish line with rounded angles with 6 degree of tapering. Samples were distributed into three groups each counting 10 samples based on the type of the restoration included in the current study.(Table. 2).

Substucture designing and fabrication:

Group 1 and 2 (zerconia veneered crowns)

The mounted prepared teeth surfaces were scanned using (Q700 Scanners, 3Shape, Copenhagen, Denmark) for CAD/CAM processing. Using CAD software (Dental System, 3Shape, Copenhagen, Denmark), crowns substracture were designed with 0.5 mm thickness (Figure.1) using a cutback technique and milled out of Yttria-stabilized zirconia blanks (VITA YZ) for samples of both Group1 and Group 2 using Cerec CAD/CAM milling process, all 20 zirconia substructures for group 1 and 2 were sintered at 1530°C in a high-temperature furnace (ZYRCOMAT 600 MS, VITA Zahnfabrik, Bad Säckingen, Germany) for 2 hours. following the manufacturer's instructions.

TABLE. (2) Samples grouping and subgrouping

Zerconia substructure veneered crowns (20 crowns)		BIOHPPPeek Substructure (10 crowns)
(G1) composite veneered	(G2) Ceramic veneered	(G3) veneered with composite (10 crowns)
10 samples	10 samples	

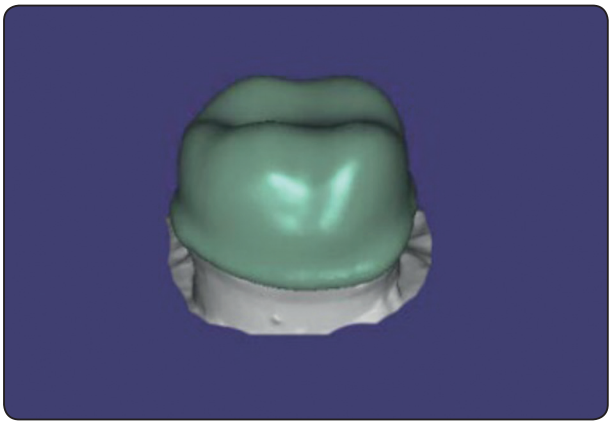

Fig. (1)

Group 3 (BIOHPP / PEEK veneered crowns)

The substructure for samples of group 3 were designed the same way as in group 1 and 2 with the same thickness of 0.5 and milled out of BIOHPP / PEEK blocks in Cerec CAD/CAM milling.

Substructures surface treatment:

Group 1 (zirconia veneered with composite)

The zirconia substructure was treated by airborne-particle abrasion using 110 µm Al_2O_3 particles at 2 bar pressures for 10 seconds from a distance of 3 cm at 45° degree to the surface. Substructures were cleaned in an ultrasonic path for 1 minute and vigorously cleaned with air water spray then dried with oil free air. A thin coat of a MKZ Primer (Brendent GmbH, Senden, Germany) was applied using a brush to the pre-treated zirconia substructure surfaces. Allow the material to react for 30 seconds.

Group 2 (Zirconia veneered with Ceramic)

The zirconia substructure was treated by airborne-particle abrasion using 120µm Al_2O_3 particles at 4 bar pressures for 20 seconds from a distance of 10 mm perpendicular to the surface. Substructures were cleaned in an ultrasonic path for 10 minutes and then dried with oil free air.

Group 3 (PEEK veneered with Composite)

crown frameworks were blasted with 110 µm under 2-3 bar pressure at a distance of 3cm, then cleaned with alcohol moistened Bruch. A special adhesive was applied on the treated PEEK surface using (Visio-link) in thin layer and polymerized for 90 seconds in a special light curing chamber of (bre. Lux power Unit) at wave length of 370nm-400nm.

Crown dimension standardization:

To standardize the test crowns samples dimension, a full contoured crown was waxed up using blue inlay wax over the die. Silicone matrix was made over the waxed crown using Putty Soft Regular Set additional silicon elastomeric impression material (Zhermack S.p.a, Via Bovazecchino, RO, Italy) to make a negative replica of the crown dimensions to produce a standardized thickness of the veneering overlay. (Figure. 2)

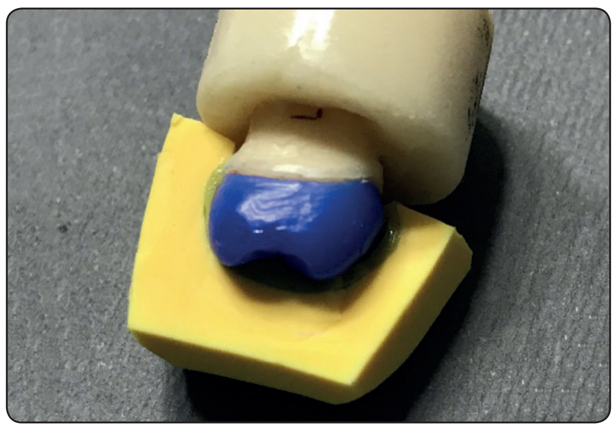

Fig. (2)

Substructures veneering:

Group 1 (Zirconia-composite Crowns)

The full sintered and treated zircon substructures were veneered to a full crown with the aid and guidance of the formerly fabricated silicon index with visio-lign (Brendent GmbH, Senden, Germany) veneering composite in sequence layers according to manufacturer instruction and light polymerized in bre.Lux power Unit (Brendent

GmbH, Senden, Germany). for 180 seconds with final polymerization period of 360 seconds.

Group 2 (Zirconia-Ceram crowns)

Zirconia substructures of this group were completed to a full contoured crown using the formerly produced silicone index as a guide for standardized crown dimension with the overlaying conventional feldspathic porcelain using (kiss veneering ceramic, (DeguDent GmbH, Hanau-Wolfgang. Germany), following the manufacturers guidelines.

Group 3 (BIOHPP/PEEK veneered with composite).

The formerly surface treated and primed PEEK substructures in group 3 were veneered to a full crown in the same way as in group 1 with the aid and guidance of the formerly fabricated silicon index with Visio-lign composite veneering material (Brendent GmbH, Senden, Germany). in sequence layers according to manufacturer instruction and light polymerized in bre.Lux power Unit (Brendent GmbH, Senden, Germany). for 180 seconds with final polymerization period of 360 then polished to high shine according to manufacturer instruction. Crown samples in the three group were finished and polished to a clinical standard thickness of 1.2 mm.

Samples cementation:

All samples were cemented to their corresponding ivory teeth using self-adhesive luting cement (RelyX Unicem, 3M ESPE, St Paul, MN, USA) with the application of seating forces for 30 N. All cemented crowns were stored in distilled water at room temperature for 24 h before thermal and dynamic stressing.

Samples thermal and dynamic stressing:

All samples of the three groups were then subjected to thermocycling for 10,000 cycles (5-55ºC) with a 30-s dwell time, 20 seconds transfer time. This is corresponding to one year of clinical service. The thermocycled specimens were subjected to mechanical stressing in chewing simulator with maximum vertical load of 10 kg with cyclic frequency of 1.7 Hz for 240,000 cycles, which corresponds to one year of clinical service Load was applied occlusally with a custom-made load applicator [steel rod with flat tip (20x25mm) attached to the upper movable compartment of the machine. [16].

Samples fracture resistance testing:

Samples were mounted and jigged to a universal testing machine (Instron 3365) Crowns fracture resistance were tested by applying a load through a 4.2 mm diameter steel ball at a crosshead speed of 1 mm/min occlusally in the central fossa area (Figure. 4). The maximum load causing crown failure was recorded in newton.

Fig. (3)

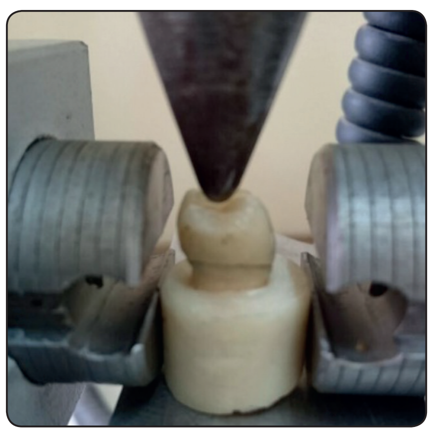

Fig. (4)

RESULTS

The fracture resistance measurements were imported into Statistical Program for Social Science (SPSS) version 21.0. Mean ± standard deviations (SD) of fracture resistance values (N) were calculated and analyzed statistically with descriptive statistics. One-way analysis of variance (ANOVA) test was used to evaluate whether there is a difference in the fracture resistance values between different crown veneered restorations or not. The mean values of fracture resistance and statistical significance are shown in (Table 3) and graphically represented in (Figure 5).

The fracture resistance values recorded with the composite veneered PEEK crowns group (G3) were the highest at the level of (1327.18±44.03). N), followed by zirconia veneered with ceramics crowns group (G2) at the level of (1260.52±51.55. N), while zirconia veneered with composites crowns group (G1) showed the lowest fracture resistance values at the level of (1196.94±52.10. N). (Table 4), (Figure 5). A high statistically significant difference was also seen at the level of (F=, 17.404, P <0.001) between different studied group as regard fracture resistance.

"Least Significant Difference (LSD)" Post Hoc test were employed to compare pairs of groups are listed in (Table 4) and graphically represented in (Figure.6).

A highly statistical significance difference at the level of p value is (<0.001) was found upon comparing PEEK substructure veneered composite

TABLE (3): Comparison between all groups as regard fracture resistance using one Way ANOVA

	Group 1 (n=10)	Group 2 (n=10)	Group 3 (n=10)	F	P
Fracture Resistance (N)	1196.94 ± 52.10	1260.52 ± 51.55	1327.18 ± 44.03	17.404	<0.001**

*****; High Statistical Significant Difference***

TABLE (4): Comparison between all groups using post hoc test (Tukey), Dependent Variable: Fracture Resistance

(I) Groups	(J) Groups	Mean Difference	P
Group 1	Group 2	-63.579	0.020*
	Group 3	-130.240	<0.001**
Group 2	Group 3	-66.661	0.015*

*****; High Statistical Significant Difference, *; Statistical Significant Difference***

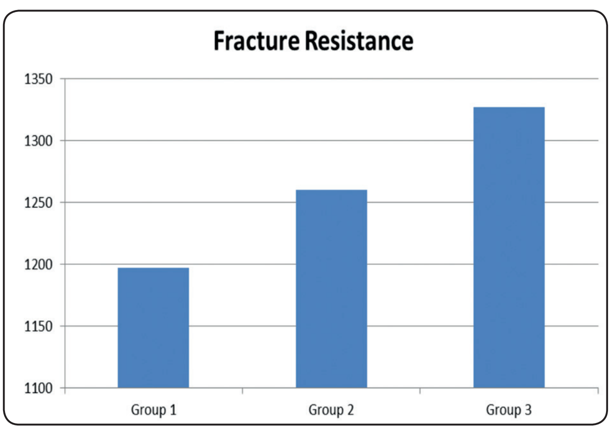

Fig. (5) fracture resistance values between different crowns veneered restorations

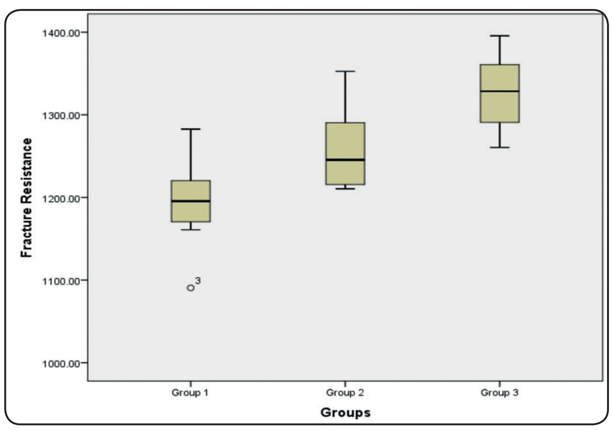

Fig. (6) Fracture resistance of different crowns veneered restorations

(G3) with zirconia substructure veneered with composite (G1). While upon comparing the fracture resistance values of zirconia substructure veneered with composite (G1) with those of zirconia substructure veneered with ceramic (G2), a Statistically significant difference was found at the level of P value = (0.020). also, a statistical difference was found in comparing zirconia substructure veneered with ceramic (G2) with PEEK substructure veneered with composite (G3) at the level of P value= (0.015).

DISCUSSION

In this current in-vitro study, the fracture resistance of zirconia-composite veneered crowns was compared with PEEK- composite veneered crowns and the classical combination of zirconia – ceramic veneered crowns.

Changing the veneering layer on Zirconia-based crown with composite instead of ceramics was proposed to overcome some of the disadvantages associated with porcelain veneering for zirconia substructure crowns, combining biocompatibility and strength of the zirconia substructure together with the less abrasive composite veneer and the ease of handling and intra-oral repair is an added advantage of this combination [17]. Fracture resistance of these combination was the issue under reviewing to investigate their structural integrity of such structures by occlusal fracture resistance [18]

Fracture resistance mean values recorded for zirconia veneered with ceramic group were a slightly higher than those recorded for zirconia veneered with composite group, this finding is in agreement with other studies that have concluded that the indirect composite zirconia substructure restorations fracture resistance was comparable to the porcelain veneered zirconia substructure restorations [19]

This could be attributed due to the stresses propagation in different ways depending on the type of materials used as in the case our study between ceramic and composite, that led to higher stress generation at the base of zirconia based crowns under the same occlusal load, the core eventually can initiate crack growth through the veneer layer [20]

Yttrium stabilized zirconium oxide veneered with feldspathic ceramic crown of. 1.5 mm thickness, has recorded fracture resistance values in this study that were comparable with that attained with Zahran *et al*. [21,22]

The lower fracture strength values of both zirconia groups compared to those of PEEK substructure veneered with composite could be related to the effect of aging process on zirconia substructure, because of the slow and uncontrolled transformation of superficial layers of the zirconia from tetragonal-to-monoclinic phase that is in contact with water, that creates surface roughness and formation of microcracks, increasing the possibilities for water ingress causing further phase transformation and consequent loss of mechanical strength [23,24].

In many studies their findings were based on the fact the most of the clinical failures happens in the bilayer veneered restorations mainly in the veneer layer [25]. That also could be because of the physical and chemical structure dissimilarity of both of the adherent materials as was observed in the current study between both zirconia groups with different veneering layering materials (Composite G1 and Ceramic G2)from one side and on the other side the higher results recorded for PEEK substructure group that was veneered with a similarly based polymers composite veneering, that confirms the principle of instead of reducing the possibility of early fracture into eliminating the weak phase between two dissimilar structures (zirconia substructure and composite veneering layer) with similarly based structures (Composite veneering on PEEK substructure).

The findings and the results clarification of the current study is also in agreement with Previous studies analyzing the fracture strength of all-ceramic monolithic crowns indicate a superior performance for the monolithic design over the bilayer ones as a result of eliminating of the interface between core and veneer of two dissimilar structures, which is believed to be the weak link in bilayer systems [26].

The fracture resistance recorded for (G3) (PEEK substructure veneered composite crown) were the highest with a significant difference compared with the other two groups. These results agrees with the findings of Behr et al, [27] who reported the in vitro excellent performance of three-unit fixed restorations fabricated from PEEK during investigation as it greatly exceed the fracture resistance required to withstand the normal masticatory forces (500-600N). [28,29]. This could be explained by the mechanical behavior of BIOHPP/PEEK material as regard to its ideal modulus of elasticity properties that is closer to composite material and dentin that might reduce stress induction at the interface layer at different layers of the crowns [30,31]

CONCLUSION

Results of the current study has drawn the following conclusions.

1) Crowns constructed from a PEEK framework and veneered using light-cured composite gave highly significant results than the other two groups.
2) All groups gave comparable results withstanding the fracture forces beyond the maximum masticatory biting force.
3) Bonding interface between two dissimilar materials is considered the weakest part of the chain that should be eliminated rather than trials to reduce the possibility of early failure.

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