Marginal Fit Evaluation of Zirconia and Polyetheretherketone Inlay Retained Fixed Partial Dentures Fabricated with CAD-CAM

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ABSTRACT

Purpose: The purpose of this study was to compare marginal fit of Zirconia and Polyetheretherketone (PEEK) inlay retained fixed partial dentures (IRFPD) fabricated by using a computer-aided design and computer-aided manufacturing (CAD-CAM) system. **Materials and Methods:** Sound Mandibular second premolar and mandibular second molar were selected to simulate a clinical situation of a missing mandibular first molar and embedded in an epoxy resin (master model). Both teeth received a standard preparation of IRFPD with respect to all-ceramic preparation design parameters. The master model was duplicated into 18 epoxy resin models for standardization during testing procedure, and 18 IRFPDs were fabricated with CAD-CAM system and divided into 2 groups according to materials type (n=9); Group 1: 3-mol yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP), Group 2: PEEK. Marginal Discrepancy of all bridges was tested before and after cementation with RelyX U200 self-adhesive resin cement (SARC) by using an optical digital microscope with the aid of an image analysis system. **Results:** Significantly lower marginal gap values were obtained in Zirconia group before and after cementation in comparison to PEEK group. There was also a significant increase of marginal gap after cementation in both groups, with higher mean in Zirconia group. **Conclusion:** The margins of IRFPDs performed well with recommended bonding protocols for both materials and present a viable treatment option for replacing a missing single posterior tooth. Both materials presented clinically accepted results of marginal discrepancy less than 120 μm. Further studies simulating clinical conditions are needed to understand how they perform in function.

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INTRODUCTION

Various treatment modalities are available to replace missing posterior teeth; metal- ceramic, all ceramic, direct or indirect fiber reinforced composite fixed partial dentures (FPDs), the conventional removable prosthesis and the implant supported restorations. Implant supported restorations are a more conservative approach to single-tooth replacement. However, this line of treatment has its own limitations, which sometimes makes FPDs the only available choice [1].

FPDs require considerable reduction of tooth structure; therefore, some patients and clinicians are reluctant to use it especially in healthy, young dentition with large pulp chambers [2]. The IRFPD enables the original tooth anatomy to be reproduced while allowing for functionality, aesthetics, and preservation of the tooth structure making IRFPD a valid therapeutic option to replace a single missing tooth.

The increasing demand for esthetic restorations that can also serve as durable long-term restorations capable of withstanding the patients' masticatory forces and adapting to the oral environment coincided with the introduction of ceramic optimized polymers (Ceromers), fiber-reinforced composites (FRC) technology and all-ceramic systems; including ceramics with a high content of glass particles (i.e. lithium disilicate, glass-infiltrated zirconia or alumina), and high strength ceramics (densely sintered zirconia/alumina polycrystals) and Zirconia. Leading to the potential for fabrication of metal free restorations with high durability and good esthetics [3].

A clinical option was introduced using monolithic zirconia in fabrication of IRFPDs. It was concluded that CAD-CAM monolithic zirconia IRFDP allows a minimally invasive approach for single-tooth substitution, and thus can be used as an alternative to a full-coverage FDP or an implant-supported crown [4,5].

A new material group of high-performance polymers which was recently introduced for fabrication of fixed partial dentures is BioHPP (High-Performance Polymer). BioHPP is based on ceramics-strengthened polyetheretherketone (PEEK). It has been used successfully in human medicine for more than 30 years as an implant material (finger prostheses, intervertebral discs and hip joint prostheses. It offers excellent biocompatibility and has a bone-like flexibility which makes it ideal for use in implant-supported dental prosthetics (Off-Peak Effect) as the chewing forces are cushioned [6]. Thanks to strengthening with special ceramic filler, optimized mechanical properties of BioHPP have been created for dental use in the crown and bridge area [7].

The accuracy of restoration's margins is an important parameter in the success of extra and intra coronal restorations. Marginal and internal gap size can influence longevity, wear, discoloration, leakage, degradation of the luting agent, and the ability of the restoration to withstand loading [8,9].

MATERIALS AND METHODS

Sample size calculation

A power analysis was designed to have adequate power to apply a two-sided statistical test of the research hypothesis (null hypothesis) that there is no difference between both tested groups. According to the results of Pilo, R., et al. an effect size (d) of (1.47) was calculated and by adopting an alpha (α) level of 0.05 (5%), and a beta (β) level of 0.20 (20%) i.e. power=80%; the predicted sample size (n) was found to be a total of (18) samples i.e. (9) samples per group [10]. Sample size calculation was performed using G*Power version 3.1.9.4

To conduct the present study, 2 freshly extracted human teeth (1 sound mandibular 2nd premolar and 1 mandibular 2nd molar), were selected. The teeth were thoroughly cleaned using an ultrasonic cleaning device, dried gently and stored in 0.1% thymol solution at room temperature.

Ethical approval for the use of extracted human teeth was obtained in accordance with guidelines from research ethics committee of faculty of dental medicine (Girls' Branch), Al Azhar University (18-027).

Model Construction:

A master model, formed of a 2nd mandibular premolar and a 2nd mandibular molar embedded in an epoxy resin block with 11 mm inter-abutment distance representing missing mandibular 1st molar, was constructed according to the following procedure:

Putty consistency of Zeta plus (3M ESPE, Seefeld, Germany) was mixed and placed in the premolar-molar region of a pre-fabricated plastic dental arch (Elbanna, Alexandria, Egypt). By the aid of a dental surveyor (Surveyor B2, Bio-Art, São Carlos, Brazil), the teeth were embedded into the impression mix in a parallel position and at the same occlusal level. After rubber base setting, the mandibular 1st molar was removed, the area filled with wax, and an edentulous contour was made. An occlusal index was taken by putty consistency rubber base. The mandibular 2nd premolar and 2nd molar were removed from the plastic dental arch and placed into their corresponding positions in the index. The index was then boxed with remodeling wax and sealed. Afterwards, epoxy resin (Crystal Clear Epoxy Resin, East Coast Resin. USA) was mixed following manufacturer's instructions and poured into the boxed index on a vibrator to remove any air bubbles. After complete setting, the boxing was removed, and the rubber base index was separated from the epoxy resin model and the model was checked for any defects under a magnifier.

Teeth Preparation:

The teeth were prepared according to the standard preparation guidelines for class II inlay with general principles for ceramic inlay restoration, with the aid of a Centroid milling machine (CNC, Milling machine, USA). The Occlusal cavity measurements were (3±1 mm/ 4±1 mm) buccolingually and (5±1mm/7±1mm) mesiodistally for the premolar/ molar abutments, respectively. The depth was adjusted at 2 mm measured from the central groove. The proximal cavity was extended with flared buccal and lingual walls (4mm/5mm) for the premolar/molar abutments, respectively. The proximal box measured 4mm in length and 1.5mm in depth. Occlusal divergence angle was set at 10°-12°. Cavo-surface margins were finished in butt joints with no bevels. Internal line and point angles were rounded.

Model Duplication:

A half-arch impression was made for the master model with prepared teeth using polyvinylsiloxane impression material. After setting and separation from the master model, the impression was inspected for any tears or defects, which if observed the impression was retaken. Dental epoxy resin material (Die epoxy type 8000 system, American dental supply Inc.) was blended according to the manufacturer's instructions and was poured into the half-arch impression on a vibrator to remove any air bubbles and checked for any defects after setting. The procedure was repeated to obtain 18 epoxy resin models accurately similar to the master model to ensure standardization during testing procedure.

Samples' Grouping:

The constructed models (n=18) were randomly divided into 2 groups (n=9) according to material type: Group (1): 3Y-TZP Katana STML (Kuraray Noritake Dental Inc, Tokyo, Japan), Group (2): Juvora PEEK (Straumann AG, Basel, Switzerland).

IRFPDs fabrication:

Nine Zirconia IRFPDs were fabricated according to the following procedure: Each constructed model was sprayed with light reflecting powder (Occutec, Scanspray, USA), and secured on the tray for taking the optical impression. The fully anatomical IRFPD design was designed according to the manufacturer's directions and

software recommendations (Exocad GmbH, Darmstadt, Germany) including; a virtual cement space of 50 μm was set 0.5 mm short of the margins, modified ridge-lap pontic and 4x4 mm^2 connector dimensions with rounded 0.6 mm radius of curvature at the gingival area. Data was sent to a 5-axis milling machine Roland DWX50 (Roland DG Corporation. Japan) to fabricate the bridges using a 14mm blank. Afterwards, the bridges were placed on their occlusal surface inside the ceramic sintering tray, which was filled with sintering beads and then sintered in the HTC furnace (High-Temperature with program Control Unit), according to manufacturer instructions. Nine PEEK IRFPDs were constructed from a PEEK blank (12mm) using the same procedure and system for scanning, designing and milling.

Cementation procedure

Before cementation, the restorations were tried in on the abutment teeth to check for proper seating. Surface treatment of epoxy resin models was performed by sandblasting the fitting surfaces with 50μm Al$_2$O$_3$ at 2 bar pressure for 10 seconds at 10 mm distance. The internal surfaces of inlay retainers of Zirconia and PEEK IRFPDs were abraded with Al$_2$O$_3$ (50 μm at 2 bar pressure /50 μm at 4 bar pressure respectively) at a 10 mm distance for 15 seconds using a special holder to standardize the distance.

The cementation was done using RelyX-U200 SARC (RXU200; 3M ESPE, Seefeld, Germany) according to manufacturer's recommendations. The resin cement was dispensed onto the fitting surface of the IRFPDs, which were slowly seated on the abutment teeth using adequate finger pressure allowing excess cement to seep out. The excess cement was removed by sharp scaler after 2 seconds of curing using a sharp dental explorer, then immediately placed under a loading device of 10 Kg. Light curing of 40 seconds from each side was done and the IRFPD was left in place for 5 minutes to ensure complete polymerization of the resin.

Marginal Accuracy test

The marginal gap width pre- and post-cementation was measured with a digital image-analysis system using digital photographs acquired with optical digital microscope at a fixed magnification of 50X (fig. 1). Marginal gap was expressed in pixels; thus, system calibration was performed to convert the pixels into absolute units of micron by comparing a ruler with a scale. The marginal gap was measured at 22 measuring locations in each IRFPD at an approximately constant interval along the margins of the restoration.

Statistical analysis

Numerical data was represented as mean and standard deviation (SD) values. Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Independent and paired t-test were used to analyze inter and intragroup comparisons respectively. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.0.3 for Windows.

RESULTS

There were no outliers, as assessed by boxplot of grouped data. The data was normally distributed, as assessed by Shapiro-Wilk's test of normality ($p > 0.05$) and there was homogeneity of variances ($p > 0.05$) as assessed by Levene's test. Before and after cementation, significantly higher marginal gap values were measured in PEEK samples ($p < 0.001$). In samples of both groups, there was a significant increase of marginal gap after cementation ($p < 0.001$). Percentage change of marginal gap after cementation was significantly higher in Zirconia samples ($p < 0.001$). Results of student t-tests were summarized in (table 1). Mean and standard deviation values for marginal gap percentage change after cementation were presented in (fig. 2).
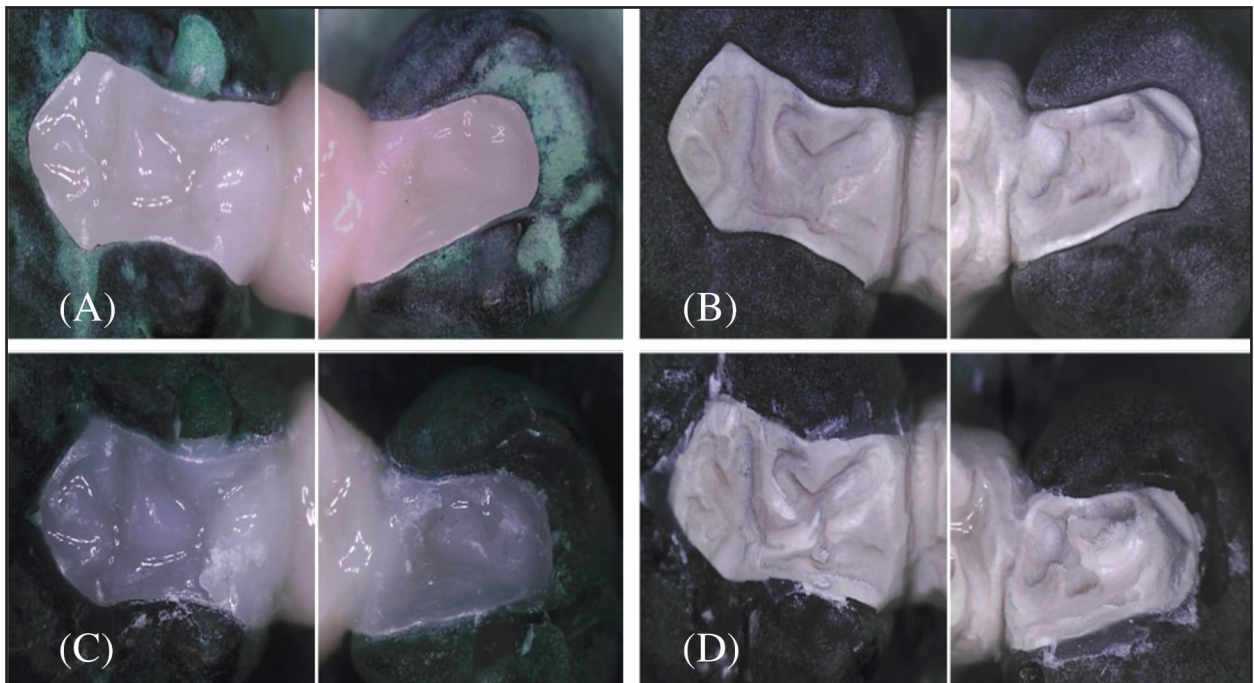
Figure (1) Marginal gap evaluation with a digital microscope (×50) a. Zirconia IRFPD before cementation. b. PEEK IRFPD before cementation. c. Zirconia IRFPD after cementation. d. PEEK IRFPD after cementation.

Table (1): *Summary of student t-test results*

Time	Marginal gap (Mean±SD)		Mean difference [95%CI]	Cohen's d	t-value	p-value
	Zirconia	PEEK				
Before cementation	30.05±1.89[B]	63.58±2.28[B]	-33.53[-36.24:-30.82]	-16.00	-27.72	**<0.001***
After cementation	46.18±1.99[A]	78.05±3.29[A]	-31.86[-35.47:-28.26]	-11.71	-20.28	**<0.001***
Change (%)	54.06±9.05	22.76±2.62	31.3[21.82:40.79]	4.70	8.13	**<0.001***

Means with different superscript letters in the same vertical column are statistically significant different; *significant ($p<0.05$)
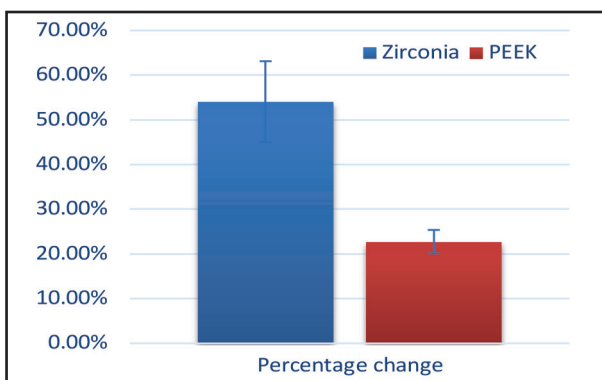
Figure (2) Bar chart showing mean and standard deviation values for marginal gap percentage change after cementation

CONCLUSION

Within the limitations of this in-vitro study on the marginal fit of Zirconia and PEEK IRFPDs, the following conclusions can be drawn:

- The margins of IRFPDs performed well with recommended bonding protocols for both materials.

- All marginal gap values recorded were within the clinically acceptable range of 120 μm, with zirconia presenting significantly better values.

- Further in-vitro and vivo studies are needed to evaluate the marginal integrity of IRFPDs to understand how they perform in function.

CONFLICT OF INTEREST

None declared.

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