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Marginal Adaptation and Fracture Resistance of Resin Nano-Ceramic and Zirconium Dioxide All Ceramic Restorations

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Abstract

Purpose: This *In vitro* study investigated the marginal adaptation and fracture resistance of Zirconium Dioxide and Resin Nano Ceramic CAD-CAM restorations (Lava Ultimate Restorative, 3M ESPE) consisting of 80% ceramic and 20% composite resin with nano technology.

Materials and methods: Twenty extracted maxillary first molars were selected and prepared according to previous studies. Cerec 3 crowns were fabricated from optical impression and luted using Scotchbond Universal Adhesive and Rely X Unicem,3M ESPE. Marginal adaptation was evaluated and measured for all specimens then fracture resistance (N) was measured using a universal testing machine parallel to long axis of tooth till failure. The mean loads of failure of each group were statistically compared using ANOVA p<0.001.

Results: Marginal adaptation of group 1:68.90μ, group 2:80, 60μ (p=0.14). Fracture resistance of group 1:1483 N and group 2:1952N (p<0.001).

Conclusions: Zirconium Dioxide restorations showed significantly higher marginal discrepancy than Resin Nano Ceramic, fracture resistance of Zirconium Dioxide is significantly higher than Resin Nano Ceramic restorations.

Introduction

Marginal adaptation is one of most important criteria for long term clinical success of dental restorations [1]. The presence of marginal discrepancies exposes the luting agent to the oral environment. The larger the marginal discrepancy and the subsequent exposure of the dental luting agent to oral fluids, the more rapid the rate of cement dissolution and microleakage [2]. These marginal irregularities facilitate the adherence of oral bacteria along with percolation of food, oral debris and other substances to finally cause plaque retention, which in turn causes changes in the distribution of the subgingival microflora, thereby leading to periodontal disease [3] and secondary caries [4].

Several authors have attempted to determine what constitutes clinically acceptable marginal openings that are not visible to the naked eye and are undetectable with a sharp explorer. For CAD-CAM generated restorations, the approximate acceptable marginal gap discrepancies are less than 90 μm [1].

Marginal gap measurement has been defined as vertical marginal discrepancy, horizontal marginal discrepancy, overextended margin, underextended margin, seating discrepancy and absolute marginal discrepancy. Today, there is no standard method available for measuring the marginal fit. The most common method is to measure the distance directly under a microscope after sectioning the embedded specimens [5].

The marginal discrepancy depends on the fabrication stage [6], type of CAM system [7,8], number of units in substructure [9], location of tooth, tooth preparation design [10], material stiffnes [11], type and thickness of the luting cement [12], and presence of a luting cement [13].

In CAD-CAM systems it is possible to program the software so additional space can be provided to accommodate for the cement, potentially influencing the internal and marginal fit values [14].

The success of a full crown restoration depends on several factors. One of the most important factors is the marginal adaptation [15,16].

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All types of ceramic restorations are becoming more popular every day. The use of zirconium dioxide- based ceramics (ZrO_2) in combination with CAD/CAM technology makes esthetic and fracture resistant restorations with excellent marginal adaptations available to all clinicians [17-19].

The Lava all ceramic system (3M ESPE, Seefeld, Germany) comprises a CAD/CAM procedure for the fabrication of all-ceramic crowns and fixed partial dentures for anterior and posterior applications. The system uses tetragonal polycrystalline zirconia partially stabilized with yttria (Y-TZP=yttria tetragonal zirconia polycrystals). Traditionally, coping fabrication is performed by scanning the model using the optical Lava Scan (3 M ESPE) [17,19,20].

The evolution of dental materials and technologies advances dentistry by helping clinicians provide patient with indirect restorations fabricated chairside. CAD/ CAM restorations created and placed using the Trifecta Method from 3M ESPE (eg., Lava Ultimate Restorative, Scotchbond Universal Adhesive and Rely X Ultimate cement)can be more efficient to produce because the firing step is eliminated ,cementation and adhesive application procedures are simple [21].

Lava ultimate restorative system eliminates many of the drawbacks associated with traditional dental ceramics by combining resin and nano-technologies.

Nano ceramic particles are embedded in a highly cross-linked resin matrix (80% wt Nano ceramic and 20% wt resin) [21].

Lava ultimate resin nanoceramic with low modulus of elasticity lower than brittle glass ceramic materials and porcelain fused to metal veneering porcelain that allowed absorption of chewing forces and decrease stresses falling on restoration, this is especially advantageous for crowns over implant [21]. The present *In vitro* study aimed to make a comparison between Resin Nano-Ceramic and Zirconium Dioxide All Ceramic Restorations regarding marginal adaptation and fracture resistance.

Materials and Methods

Twenty extracted human first maxillary molar teeth with no caries or anatomical defects were used in this study. After soft tissue removal, the teeth were stored in 5% formal/saline for 2 hours then cleaned and transferred to distilled water to prevent desiccation during storage. The average bucco-palatal and mesio-distal mean widths were 10.71 ± 0.63 mm and 9.30 ± 0.55 mm, respectively. Teeth falling below or above size limits were excluded.

The roots of teeth were embedded parallel to the long axis of the teeth into self-cure acrylic resin (Acrostone, WHW Plastics, East Yorkshire, UK) up to 2 mm below cement-enamel junction (CEJ) using rings. The teeth were randomly allocated into 2 groups (n=10). For each tooth an impression was made using a heavy body polyvinyl siloxane impression material (Imprint, 3M ESPE), which was sectioned and used as an anatomical guide during tooth reduction.

All samples were prepared to receive all ceramic crowns by the author. In both groups, preparations were performed with the following characteristics in common: anatomic occlusion reduction 2 mm, 6°axial convergence, axial reduction of 1.0 to 1.5 mm and a finish line located 0.5 mm above CEJ. The finish line for all samples were 1 mm wide 90°. Flat end tapered diamond burs (Axis modified shoulder No.847 KR, Axis Dental, Kerr Corporation, Copell TX) were used.

Impressions of each tooth were made with a polyether impression material (Impregum Penta medium and Impregum soft, 3M ESPE). A light– body impression material was injected around the tooth preparations and then inserted in custom made trays of regular body material. After the impression, the prepared teeth were stored in a fresh 10% formaldehyde solution. Master dies were fabricated with type 4 dental stone (Elite Rock Fast, Zhermack, Badia Polesine, Rovigo, Italy) prepared by an automatic vacuum mixer following the proportions indicated by the manufacturer. After fabrication, all models were sent for production of copings and all ceramic restorations (Figure 1). According to previous studies, copings were designed according to the following manufacturer s instructions: 0.5 mm wall thickness, a 0.35 mm reinforcement of the restoration edge and a 0.2 mm space for cement initiated at a distance of 1.2 mm from the coping of the margin and increased to 0.05 mm at a distance of 2.3 mm from the margin of the coping, then layers of veneering material were added and glazing finished the manufacturing process.

Evaluation of marginal adaptation

Copings and crowns were placed on their teeth and the margins of each coping and crown were evaluated using a dental explorer (EXD 11/12, Hu-Friedy Chicago, IL) and magnification loupes with a power of 2.5 X (Task Vision, Chery Hill. NJ) to perform an initial clinical evaluation.

Measurements of marginal adaptation

To measure the marginal adaptation, we used the criterion proposed by Holmes et al. [22], defining absolute marginal discrepancy as the distance from the edge of the crown to the edge of the finish line. Measurements of marginal discrepancies were made at five equidistant points on each of the four axial walls.

Finally crowns were cemented on the prepared teeth using resin composite cement (Rely X Unicem, Applicap, 3M ESPE). Finger pressure was initially applied for 2 minutes, excess cement

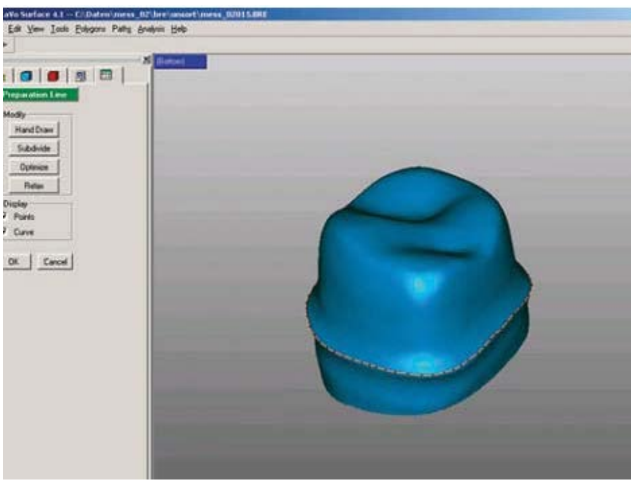


Figure 1: Designing CAD-CAM restorations.

was removed and pressure was applied again for an additional 5 minutes. Then thermocycled (5000 cycles, 5° to 55°C; dwell time: 60 seconds, transfer time:12 seconds) then stored at 37°C in distilled water for 24 hours before testing.

Fracture resistance test

All specimens were mounted in a jig that allowed loading with long axis of the roots in a universal testing machine (Instron S 500 R England) with cross head speed of 1 mm/min.

All crowns were loaded until catastrophic failure occurred and the testing machine automatically recorded the fracture force (Newton) (Figures 2,3 and 4). Fracture patterns were then evaluated for all specimens with an electron microscope (Figures 5 and 6) (Leica EZ 4 D, Bensheim, Germany).

Statistical methods

SPSS package version 17.0 IL Chicago was used for data analysis. Mean and standard deviation, median and range described study variables in tables and Graphs 1 and 2. Non

Figure 2: Fracture test of specimen.

Figure 3: Fracture of Zirconia specimen with fragment.

Figure 4: Fractured RNC specimen without fragment.

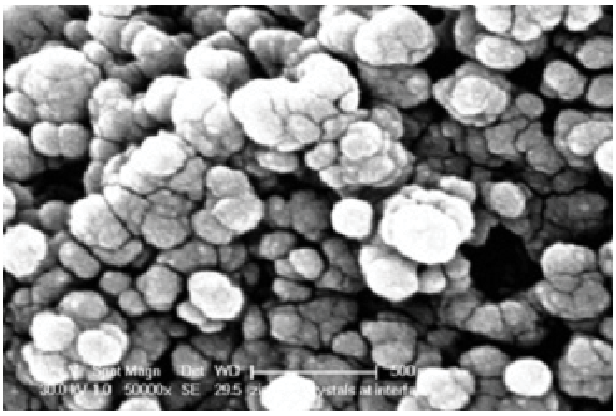


Figure 5. SEM showing intergrain porosity of RNC specimen (x 50.000).

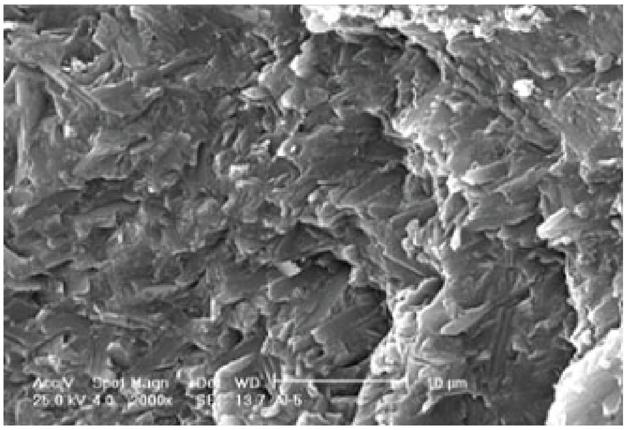
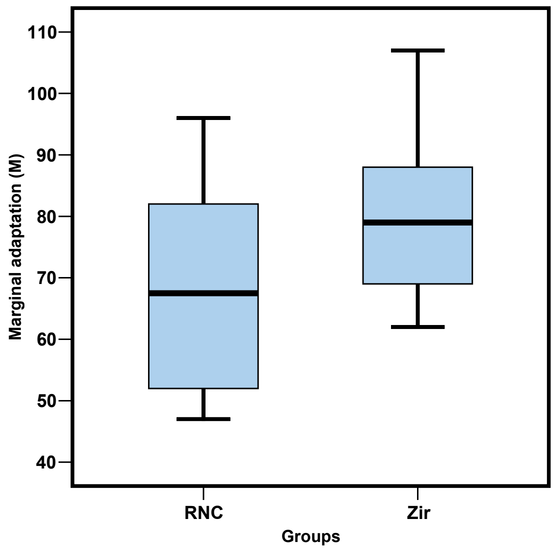


Figure 6: RNC specimen with remnants of composite (x 2.000).

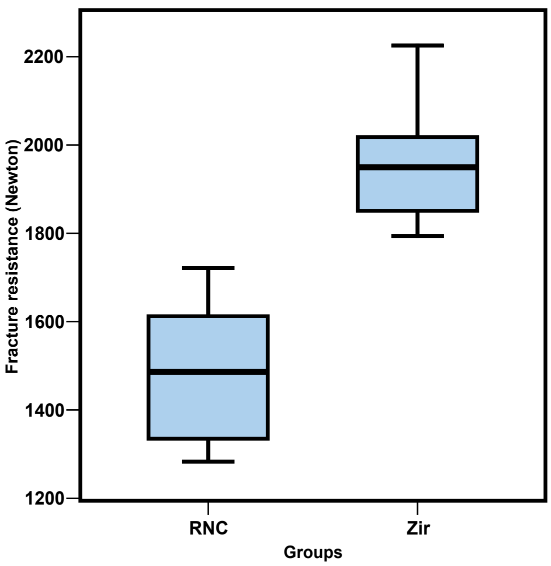
parametric t-test compared independent groups and p value was set significant at 0.05 level.

Results

Table 1 shows the mean and standard deviation of the fracture



Graph 1: Mean marginal adaptation of different restorations (Microns).



Graph 2: Mean fracture resistance of different restorations (Newtons).

	Groups	N	Mean	SD	p value
Marginal adaptation (Microns)	RNC	10	68.90	17.96	
	Zir	10	80.60	15.76	0.14
Fracture resistance (Newton)	RNC	10	1483.30	146.82	
	Zir	10	1952.70	135.35	< 0.001

Table 1: Showing Marginal adaptation and Fracture resistance of restorations.

forces (Newtons) and marginal adaptation (Microns) for all test groups. Mean failure force for groups were as follows: group 1: 1483 N and group 2:1952 N. Mean marginal adaptation for group 1:68 M and group 2: 80 M.

Discussion

In the present study, maxillary molars restored with two different types of all ceramic restorations were used to determine their resistance to fracture under simulated occlusal load.

Zirconium Dioxide showed a higher resistance to fracture than Resin Nano Ceramic restorations, this is attributed to the very high modulus of elasticity of Zirconium Dioxide due to densely sintered yttria-tetragonal zirconia polycrystal (y-TZP) and its ability to prevent crack propagation [23].

It is possible to predict fracture resistance of a substance from the strength between individual bonds between the atoms in the material, the values of strength obtained by such a prediction are typically 10% of modulus of elasticity. The interatomic or intermolecular forces of the material are responsible for the property of elasticity [24,25].

In vitro assessment provides useful information to aid manufacturers and researchers in choosing materials for prosthetic restorations before their introduction to the clinical setting [12].

In this work, attempts were made to simulate standard clinical procedures; however, this is not a substitute for the complex oral environment. While *In vitro* testing might be limited in its ability to predict clinical survival [26,27].

Resin Nano– Ceramic restorations recorded better marginal fit than Zirconium Dioxide, this might have been a result of differences in composition but both systems demonstrated acceptable marginal discrepancies *In vitro* below 120 µ [28].

Marginal fit plays an important role in the clinical success of ceramic restorations since great marginal discrepancy lead to more dental plaque retention, recurrent caries and bone resorption [29].

In another study, the mean marginal gap was 35µm for zirconia copings, 63 µm for crowns which were veneered by using pressing technique [30].

A study indicate that close attention should be paid to the preparation procedure of zirconia-based crowns and bridges by CAD-CAM process ,with the aim of obtaining smooth surfaces, because a strong effect of surface roughness on the mechanical strength was observed [28].

Exposure of ceramic materials to mechanical stress and moisture results in low-temperature degradation and artificial aging has an adverse impact on the mechanical properties of zirconia material, moreover the phase of zirconia could be transformed from tetragonal to monoclinic [31].

Consisting of 80% ceramic and 20% composite resin with nano-technology, the resin nano-ceramic is neither a resin composite nor a pure ceramic but a combination, demonstrating a non brittle and fracture resistant nature. Because of its elastic modulus similar to dentin, masticatory forces are absorbed, decreasing restorative stress [31].

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

1- Zirconium Dioxide restorations showed significantly higher marginal discrepancy than Resin Nano-Ceramic.

2- Fracture resistance of Zirconium Dioxide is significantly higher than Resin Nano –Ceramic restorations.

3- Both Zirconium Dioxide and Resin Nano-Ceramic all ceramic restorations demonstrated acceptable clinical range of marginal discrepancies (below 120 μ) and fracture resistance (above 950 N).

Conflict of interest

No conflict of interest.

Source of support

MSA University provided lab facility.

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