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Evaluation of Marginal Fit and Fracture Resistance of Zirconia Implant Abutment Supporting Two Types of Metal Free CAD/CAM Restorations

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ABSTRACT

Purpose: To evaluate marginal fit as well as fracture resistance of zirconia implant abutment supporting two types of metal free CAD/CAM restorations. **Materials and methods:** Twenty ready-made ZrO_2 abutments resembling lower first premolar squeezed and stabled to its conforming titanium dummy implants were implanted in epoxy resin blocks. Samples were divided into two groups in relation to the material utilized for the fabrication of the copings; group (I) (n=10): zirconia copings, group (II) (n=10): breCAM.BioHPP copings. All copings were machined using CAD/CAM system. Samples were exposed to a fatigue procedure for 20,000 cycles. Marginal fit was determined using digital stereomicroscope. Fracture resistance was registered using universal testing machine. The samples were overloaded till last fracture occurred and load at fracture was documented. Analysis of data was examined using accessible software programme (SPSS 18). **Results:** BreCAM.BioHPP copings, group (II), registered a statistically significant higher mean vertical marginal gap value (122.08±25.05μm) in addition to higher mean failure load value (2828.47±735.4N) compared to zirconia copings, group (I) (27.06±3.2μm) (416.06±22.16N) respectively. **Conclusions:** Material type used for the fabrication of the copings influences marginal fit and fracture resistance. Zirconia coping samples showed higher marginal fit and lower fracture resistance than breCAM.BioHPP coping samples.

KEYWORDS

breCAM.BioHPP, marginal fit, fracture resistance.

INTRODUCTION

An osseointegrated implant has become an expectable treatment decision for replacing single tooth in esthetic area with high grade of success [(1)].

With increasing number of patients who need highly esthetic restorations, tooth colored ceramic implant abutments have been introduced such as zirconia implant abutment, even after; it has been extensively protracted for clinical use [(2)].

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Digitalized technology like computer-aided design / computer-aided manufacturing (CAD/CAM) is known to yield dental restoration that is standardized and is able to take the place of already existing exciting casting method [3]. For example, zirconia polycrystalline that has premium esthetic and biocompatible restoration [4]. Moreover, it is characterized by a specific property that is stress-induced transformation toughening mechanism which improves fracture toughness, strength and reliability of zirconia restoration. So even in the posterior regions, it is used for fabrication of frameworks for crowns and fixed partial dentures [4].

Currently, to manufacture dental frameworks, novel polymeric restoration has been introduced like as polyetheretherketone (PEEK) that is the extreme applied polymer in the dental area [5]. It is accessible in uniform blocks for CAD/CAM machinery that is characterized by superior properties than manually processed polymeric materials [5]. It is great temperature thermoplastic material includes keto group and ether group [6]. Some materials can be added to PEEK to be modified to improve its properties for instance carbon fibers (carbon fiber reinforced/ CFR-PEEK) and ceramic micro-particles fillers (Bio-HPP) [7].

BioHPP (High Performance polymer) which contains filler particles from ceramic (about 20%) with grain volume (0.3µm -0.5µm) discrete in PEEK polymer matrix. Owing to the very small grain volume of the ceramic particles, constant homogeneity can be manufactured which accounts for the excellent mechanical properties of these materials enabling it to be used as a viable alternative to ceramic restorations[7]. In addition to its excellent mechanical properties, it is characterized by excellent biocompatibility, perfect wear resistance with perfect polishing possessions. Modulus of elasticity which approximates 4-GPa considered the key benefit of this material which remains similar to bone. It decreases the forces transmitted to the restoration and later to implant bone interface accordingly due to it acts as a stress breaker[8]. However, this restoration is not suitable for monolithic esthetic restorations due to its greyish-brown color, hence veneering is critical [9].

Accuracy of marginal fit for any restoration and its strength are important to guarantee its clinical success. Failure of any restoration may result from enlarged marginal inconsistencies that expose the luting material to the oral atmosphere, resulting in cement degeneration, caries and marginal discoloration [10]. To endure functional stresses in the oral cavity, restorations with superior strength have been introduced as the clinical outcome and durability for any materials is reliant on their capability to endure utilized occlusal stresses without being broken [11].

Since BioHPP is newly introduced in prosthodontics, there have not been sufficient researches on this material compared to zirconia. Therefore, there was a feeling of necessity to compare them, hence this study was undertaken.

MATERIAL AND METHODS

Ethical considerations:

The present study was revised and confirmed through Research Ethical Committee (REC) of the Faculty of Dental Medicine for Girls, AL-Azhar University, under code: 21-08.

Sample size determination:

To determine the numeral of sample size utilized in the current study, independent t test was utilized to compare the effect of different coping restorations according to previous studies [12, 13]. A total number of sample size is 20 (10 in each group), it is sufficient to detect an effect size of 1.44, with a power (1-β error) of 0.8, using a two-sided hypothesis test and a significance level (α error) 0.05 for data. For sample size determination, G power programme form 3.1.9.2 was used.

Procedure methodology:

To conduct the current study; twenty ready-made ZrO_2 abutments (Reactive implant direct, USA.) with circumferential 1 mm thickness chamfer finish line, 9mm length, 4.3 mm diameter, 0 angulation and 2 mm collar height on behalf of lower first premolar was squeezed and stabled to its conforming titanium dummy implant (Nobel Biocare,USA.) with 13 mm length, 4.3 mm platform diameter and 4.7 mm body diameter at 35 Ncm as said by the manufacturer's recommendations. Afterward, a specific specimen holder was utilized to stable all sample in vertical situation using epoxy resin (CMB. International, Egypt). The modulus of elasticity of embedding resin nearly 12 GPa approaches that of human bone 18 GPa [14].

Samples' Grouping:

All samples (n=20) were distributed into two groups according to the material utilized for fabrication of copings; group (I) (n=10): zirconia copings, group (II) (n=10): breCAM.BioHPP copings. All copings machined using CAD/CAM system.

Construction of the copings:

Construction of zirconia copings, group (I):

For milling ten zirconia copings, CAD/CAM Roland apparatus (DWX50 Roland DG Corporation. Japan) was used using CAD/CAM zirconia block (zircon – biostar, Germany), according to the subsequent procedure: each zirconia abutment was covered with light reflecting powder (Okklean, Dental Future Systems, DIAMON, Germany) and held on the tray of the scanner (Optical 3D Scanner Activity 850, Germany) for taking optical impression. Information was transported to the software linked to the milling apparatus to onset designing. The parameter values required for designing the CAD framework were selected. The thickness of coping was attuned at 0.5mm, whereas 30mm was selected as the width of cementing gap [10]. Milling of zirconia disc was then initiated. After that the milled coping were lastly sintered following manufacturer instructions.

Construction of breCAM.BioHPP copings, group (II):

Ten BioHPP copings were constructed from breCAM.BioHPP blanks (Bredent, Germany) using the same processes and systems utilized for zirconia copings.

Checking complete seating of all copings in both groups were done after they were fabricated by settling them on their corresponding abutments using USB Digital steromicroscope (Scope Digital Stereo Microscope, China) (x = 45) (Fig. 1).

Cyclic loading process:

Individually each sample underwent 20,000 cycles utilizing universal testing machine (Model 3345; Instron Industrial Products, Norwood, USA). Samples were attached on the inferior immobile compartment of machine individually. At the mid of the occlusal surface of the coping, a metal rod with round head (3.6 mm diameter) attached to the superior mobile compartment of the machine was applied. The samples were exposed to a gradual rising in compressive load (1mm/min).

Testing procedure:

Assessment of vertical marginal discrepancy:

Digital stereomicroscope was utilized to assess the marginal fit through calculating the vertical gap space between finishing line of the zirconia abutment and coping margin at immovable exaggeration of 90X. The assessment was recorded at four points on all axial walls with five repetitions at each point.

Assessment of fracture resistance:

Individually sample was separately attached on the inferior immobile compartment of a universal testing machine (Model LRX-*P*lus, Lloyd Instruments, Fareham, UK) with a weight cell of 5 kN –then held in place by tightening screws. The superior plate of the machine including a metal rod (5.6 mm diameter spherical tip) was fixed straight above the occlusal surface of sample. To guarantee even force spreading and diminish of the transporting of local force peaks, a sheet from tin foil was located among the load applicator and the sample. Samples were exposed to a gently rising in vertical load (1 mm/min) till fracture occurred as shown in (Fig.1). Load was noted in newton (N). All fractured samples were inspected utilizing magnification lens (X=15) to evaluate the mode of failure. Mode of failure was allocated in relation to the following types; Type (C): Fracture/cracking of copings. Type (A): Fracture/cracking of zirconia abutment. Type (I): Fracture of dummy implant. Type (S): Fracture/bending of connecting screw.

Analysis of data was examined using SPSS 18 (Statistical Package for Scientific Studies) for Windows using unpaired Student's t test for two independent samples. *P*-value less than 0.05 were revealed significant.

RESULTS

I- Results of marginal fit (vertical marginal gap distance "μm"):

BreCAM.BioHPP copings (group II) registered a statistically significant higher vertical marginal gap distance mean value (122.08±25.05μm) compared to zirconia copings (group I) (27.06±3.2μm), (p=0.001). However both restorations are within clinical accepted range. (Table 1).

II- Results of fracture resitance (failure load "N"):

BreCAM.BioHPP copings (group II) registered a statistically significant higher mean failure load value (2828.47±735.4N) compared to zirconia copings (group I) (416.06±22.16N). (Table 1).

III. Mode of failure analysis:

On inspection of fractured samples, it was observed that all (20) samples of both groups were fractured completely type (C). All zirconia abutments type (A) survived after fracture load test in zirconia copings, group (I) while they were fractured completely in breCAM.BioHPP, group (II). Dummy implants type (I) and connection screws type (S) survived after fracture load test in both groups.

Figure (1) Assessment of fracture resistance under universal testing machine till fracture occurred.

Table (1) *Comparison of mean value of marginal fit "μm" and fracture resistance "N" in both groups (independent t test).*

	Groups	Mean±SD	Difference				t value	P value
			Mean	SD	C.I. lower	C.I. upper		
Marginal gap "μm"	zirconia	27.06±3.20	-95.02	11.30	-126.00	-64.05	8.41	0.001*
	breCAM.BioHPP	122.08±25.05						
Fracture resistance "N"	zirconia	416.06±22.16	-2412.4	329.03	-3325.3	-1499.5	7.33	0.002*
	breCAM.BioHPP	2828.47±735.4						

*Significance level p≤0.05, *significant* *C.I.: 95% confidence interval*

DISCUSSION

Dental implants are the treatment modality that is used for rehabilitation of both esthetics and proper function of lost teeth in completely and partially edentulous patients with high rate of survival [15].

Pure titanium is the basic material used as an implant abutment since it is well recognized as biocompatible and has high mechanical properties. However, it compromises the esthetic outcomes due to the metallic gray colors of these abutments that can still luster out of the mucosa [16]. So that, zirconia implant abutment that has excellent esthetic have been recommended to overcome the main problem of titanium abutment and improve gingival discolorations for patients who have thin soft tissue when they used titanium abutment [17]. Because zirconia has better physical properties, low plaque accumulation and high strength properties; zirconia has been introduced for applications in implant dentistry [2].

Biocompatibility, esthetic results and mechanical properties for occlusal bites is considered as requirement for any material used in prosthetic dentistry [18]. Zirconia restoration is considered as the one of all-ceramic materials that delivers promising mechanical and esthetic properties to be appropriate for mainly restorative situations particularly as framework design [19].

A lengthier treating period and erode of the instrument is the result of treating fully-sintered zirconia owing to its eminent strength[20]. So, treating of pre-sintered zirconia is mostly conducted which lead to a linear shrinkage by 20–25 % due to the restoration must submit to the final sintering afterward the treatment which affects the fit of zirconia restoration [21]. In addition, zirconia with highly elastic modulus of (210 GPa) would not be considered the absolute best choice for framework over implant abutment prosthesis, though the fact that there is no material can fulfill the whole criteria of success [22].

To obtain optimum chemically unchanging condition and high long-lasting in mechanical resistance such as fatigue, bending and tension, bioHPP has been familiarized as a dental CAD/CAM material [23]. The low elastic modulus (4 Gpa) of this material which is close to that of bone result in homogeneous distribution of load, prevention of stress concentration and minimal stress shielding effect on the bone [11].

Addition to previously illustrated, for proper selection of framework material, it is necessary to know to what extent this material would have better marginal fit and can withstand masticatory forces without fracture, thus both forces had to be studied.

Hence, evaluating marginal fit as well as fracture resistance of zirconia implant abutment supporting two types of metal free CAD/CAM restorations (zirconia versus Bio HPP) was the target of the present study.

To conduct the present study, titanium dummy implants were used that has the same features of titanium implant used clinically. However, dummies are non-sterile, that's why they are used in scientific researches on casts and models. To simulate the situation of an osseointegrated implant, selected dummy implants were embedded in epoxy resin blocks as the young's modulus of epoxy resin is similar to that of jaw spongy bone [24]. Moreover, to control thickness during the manufacture process and allow standardization of the mechanical possessions of the restorative materials, CAD/CAM technology was selected [3].

The restoration success reliant on its marginal fit. Luting degeneration, recurrent caries as well as discoloration of restoration margin diminishes with an ideal marginal fit[25]. To investigate marginal exactness, countless procedures have been suggested; inspecting the margin directly with exterior measurements has the benefit of being non – invasive technique so useful in clinical practice to investigate marginal fit precision. Vertical marginal gap measurement using digital stereomicroscope was selected to conduct the present study as it is the maximum regularly used method to measure the fit restoration accuracy[26].

In addition, marginal gap distance was measured underneath a stationary weight of 5 kg to confirm a standardized seating force during measurement. Vertical marginal gap distance measurements were carried out in this study without cementation of the frameworks to the abutments as it was previously known in the literature that cementation process contributed to higher marginal discrepancy (27).

The clinically permissible extreme marginal opening has been informed to remain 120 µm, even though there is no clinically recognized net criterion for marginal fit (28). Some studies reported values between 40 and 120 µm(28,29). 200-300 µm was reported as wider marginal discrepancy in other studies (30, 31). Based on these proposals, two metal free CAD/CAM restorations (zirconia and breCAM.BioHPP) were assessed in the current study are clinically appropriate with respect to marginal accuracy.

Regarding material type used on registered vertical marginal gap distance mean values, table (1), breCAM.BioHPP copings (group II) registered statistically significant higher vertical marginal gap mean value (122.08±25.05µm) compared to zirconia copings (group I) (27.06±3.2µm) which are in agreements with previous studies (10,32). This is attributed to the zirconia is polycrystalline material which differ in structure than breCAM.BioHPP material which is semi crystalline comprises a quantity of fillers entrenched in resin ground that lead to superior marginal gap compared to zirconia material.

Though, the results of the present investigation are in differences with former investigation that reported that zirconia restoration is less accurate in margin term compared to breCAM.BioHPP restoration(33). The authors clarified their result to be due to the presence of the sintering process during the fabrication of zirconia that affect the fit of restoration which imprecise estimation of shrinkage that happened through the sintering procedure in the final step (34).

Fracture resistance of restorative materials is significant to expect both the clinical service and failure rates. In addition, in order to examine sample behavior under clinical like conditions to simulate artificial aging, all specimens were exposed to dynamic loading as materials would undergo subcritical cracks during chewing (35).

The fracture resistance test indicates the force (in`Newtons) at which the sample fails. The mean fracture resistance for zirconia copings and breCAM.BioHPP copings in the current study were reported to be (416.06N) & (2828.47N) respectively. Regarding material type used on the recorded fracture resistance mean values, breCAMBioHPP copings (group II) registered statistically significant higher fracture resistances mean value (2828.47±735.4N) than zirconia copings (group I) (416.06±22.16N) which are in agreements with previous studies (4, 32). This is attributed to the low-temperature degradation property of zirconia that limited its long-term stability and is a brittle material that cannot tolerate tension (32).

Though, the results of the present investigation are in differences with former investigations that reported that zirconia restoration recorded superior fracture resistance than breCAM.BioHPP restoration(12,36,37) which is related to specific material properties (38,39).

The current study was not free of restrictions; vertical marginal gap distance was recorded solely and horizontal gap was not inspected. The veneering process exclude in this study which might affect the final marginal accuracy. In addition, final result of marginal fit may affect by cementation process that is not performed here.

CONCLUSIONS

Inside the restriction of the current study, the subsequent points might be concluded:

1. Material type is a major issue which affects their marginal fit and fracture resistance.

2. Marginal fit for the both groups were within the acceptance range.
3. Zirconia copings showed superior marginal fit than breCAM.BioHPP copings.
4. BreCAM.BioHPP copings showed superior fracture resistance than zirconia copings.

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RECOMMENDATIONS

Supplementary studies are essential to:

- Investigate the outcome of zirconia versus breCAM.BioHPP coping design with different modifications such as anatomical core design on the chipping resistance.
- Subjecting samples to thermal cyclic condition to have more close estimation of the restoration clinical performance.
- Extending the outcomes of the in vitro studies to the clinical level ought to be encouraged.

CONFLICT OF INTEREST: None.

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