

The Fracture Resistance of Three Different Ceramic Materials Used To Fabricate Endocrown Restoration After Thermomechanical Aging

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ABSTRACT

Background: Endocrown is the one of minimal invasive option restoring the endodontic treated molar and alternative to full coverage that cover occlusal, labial and proximal portions of the tooth have developed as less invasive and highly esthetic restoration. **Objective:** The current research aimed to assess the fracture resistance of pressable modified polyether ether ketone (Bio-HPP PEEK), Pressable Lithium disilicate glass-ceramic (IPS e.max) and Pressable Zirconia reinforced lithium disilicate (Zr/LDS) (VITA AMBRIA) Endocrowns after thermomechanical aging. **materials and Methods:** Thirty mandibular molars were prepared for butt-joint endocrowns. The molars were divided into three equal group, each containing ten molars (n=10). One group constructed from a pressed (Bio-HPP PEEK), while the second group was comprised of a pressed (IPS e.max) and third group of (VITA AMBRIA). Each final restoration was cemented to the matching tooth that had been prepared. The specimens underwent 120000 cycles of thermomechanical aging. A universal testing machine was utilized to measure the resistance to fracture. **Results:** There is statistical differences were found between the three types of ceramics regarding fracture resistance of each one after thermomechanical loading.. **Conclusions:** Endocrowns fabricated from modified Bio-HPP PEEK, exhibit a superior ability to withstand fractures compared to restoration made from IPS e max and VITA AMBRIA.

Keywords: Root canal treated tooth, Endocrowns, Fracture Resistance, IPS e max, modified PEEK, Zirconia Reinforced LDS.

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1. INTRODUCTION

In the concept of restorative dentistry, there is a big discussion on the best way to restore endodontic treated molars and possessed significant crown damage. The most common reasons for a decrease in root canal treated molars fracture resistance include decay, trauma, extant restorations, wide cavity preparation, and tooth tissue waste^(1,2). Additionally, the biomechanical alterations in the tooth tissues^(1,3).

Research and previous study indicate that utilizing posts to take the place of coronal tooth structure can make the crowns that go over them stay in place better., but it may also weaken the tissues of the remaining teeth and raise the possibility of an unintentional root fracture⁽⁴⁾. According to the literature, molars restored with endocrowns shown superior fracture resistance and good clinical performance in comparison to molars repaired with fiber posts and traditional crowns^(3,5).

However, the improvements in dental materials, the progress observed in areas such as bonding materials, along with digital design and production methods, has enabled the creation of better dental repair options. These contemporary methods focus on conserving more of the sound tooth structure and aim to eliminate problems following procedures, exemplified by options like Endocrown restorations^(3,6). An endocrown represents a single-piece restoration option; it encompasses the biting surface of a tooth, reaches down into the central space that once held the pulp, and recreates both the occlusal surface of the tooth and its inner compartment⁽⁷⁾. Endocrown employs adhesive cementation for micromechanical retention and axial walls for macro-mechanical retention^(6,8). Endocrowns are recommended when there

is enough tooth surfaces, particularly enamel, a short crown, and a small interocclusal space. In addition to situations involving root complexities like calcification or dilacerated shape⁽⁸⁾.

The success rate of endocrown restorations depend on a lot of key aspects, such as choosing the right cases, carrying out the required preparatory steps, choosing the appropriate bonding substance, and also the choice of ceramic material⁽⁹⁾. The kind of material used ceramic or hybrid one has a significant factor on an endocrown's functionality⁽³⁾.

Because of its exceptional mechanical and physical properties, which include good aesthetics, translucency, low heat conductivity, sufficient strength, biocompatibility, wear resistance, and chemical durability, dental glass-ceramics are very appealing to both dentists and patients. One member of the glass ceramic family is IPS e.max CAD. It is well-known for its numerous uses, wide variety of processing choices, and high strength of 530 MPa. It is appropriate for the effective fabrication of partial and full coverage restorations.⁽¹⁰⁾

Lithium disilicate ceramics that are strengthened with zirconia (Zr-LDS), suitable for use in for of ingots for pressing technique, have become available commercially thanks to studies focused on creating innovative restorative substances designed to offer exceptional mechanical strength and pleasing appearance. To improve the levels of resistance, fillers made of tetragonal zirconia are integrated into a crystalline element, which is made up of tiny, rounded, and somewhat elongated particles containing lithium metasilicates and lithium orthophosphates distributed uniformly throughout a glassy structure. The formation of LDS particles occurs after going through a process of crystallization⁽¹¹⁾.

PEEK refers to a linear, partially crystalline thermoplastic substance that has an aromatic foundation connected through ether and ketone functionalities, exhibiting exceptional resistance to chemical reactions. Adjustments involving the addition of different substances were implemented in PEEK with the aim of enhancing its physical strength and durability. The creation of prosthetic dental restorations is made possible by High-Performance Polymer (Bio-HPP PEEK) which is a modified PEEK with 20% ceramic⁽¹²⁾. The ceramic filler has grains that are between 0.3 and 0.5 μm in size. This extremely small grain size makes it possible to create a uniform structure with enhanced strength and abrasion resistance⁽⁷⁾. Furthermore, the Bio-HPP PEEK material has the advantage of shock absorbing qualities alongside considerable resistance to compression. This is attributed to the presence of an extra ketone component within its structural composition. Consequently, it ensures the level of mechanical resilience necessary for enduring the biting forces applied to the teeth⁽¹³⁾.

The hypothesis of this current study is that there is difference of fracture resistance between three tested materials

2. MATERIALS AND METHODS

Sample preparation

In all, thirty human mandibular molars were extracted and gathered for periodontal study. Teeth with comparable mesiodistal (10 ± 1 mm) and buccolingual (9 ± 1 mm) diameters, whole root development, and estimated shape of crowns were chosen. The teeth were inspected for inclusion to make sure they were free of visible cavities, fracture lines, fissures, and indications of interior or exterior resorption of the root. The teeth spent 10 minutes submerged in a sodium hypochlorite (NaOCl) solution to disinfect them after the debris was removed with an ultrasonic scaler. They were then stored in purified water at 37°C before they were needed.

After evenly applying a consistent 0.2 mm layer of dental wax melted (Cavex, Holland) over the immersed area of the roots, extending 2 mm beneath the cemento-enamel junction (CEJ) all the way to the root apex, a block of self-cured acrylic resin (Acrostone, England) was used to fasten each tooth. Once the self-curing acrylic resin blocks were completely set, the tooth was removed from its block. The wax was then eliminated, and light body silicone (Ghenesyl, LASCOD Spa, Italy) was put by injection surrounding the roots to mimic the periodontal ligament membrane.

Endocrown tooth preparation

Assisted by dental surveyor (Bego PARAFLEX, D 28339, Bremen), a single, skilled clinician prepared the tooth to provide a more consistent preparation and minimize human error. The dental surveyor was equipped with a slow-speed straight hand piece (Strong Traus AT-II, Saeshin Precision Co., Korea) and an adaptor (Intensive SA, H 2003, Montgognio, Switzerland). A periodontal probe was used to standardize all measurements⁽¹⁶⁾.

To uniformly lower the occluso-gingival height a thin, blue, permanent marker pen was used to mark sides that are distal and mesial at a distance of 3 mm coronal to the CEJ utilizing a calibrated periodontal probe. The horizontal incision was made using abrasive discs to start the occlusal preparation process. To gain access to the pulp chamber for root canal therapy a round bur was used to create the internal hollow of the coronal part surface. Next step was a conventional butt-

joint margin with an axial wall thickness of at least 2 mm. A standardized tapered stone (Elite dental stone, Zhermach, Italy) was used to prepare the cavity's interior axial walls and eliminate any possible undercut inside the pulp chamber. This resulted in a cavity with an 8° occlusal divergence, Maintaining 4 mm of the intracoronal cavity and 2 mm of the tooth structure from the pulp chamber floor to the butt joint's occlusal platform using flowable composite .

Endodontic treatment

Following the determination of each tooth's working length using #10 K-files (MANI, Italy) and using rotating files (NITI ROTARY FILES, ROGIN DENTAL, China) driven by a rotary machine (COXO, C-Smart-1, China), the root canal instrumentation was finished using a periapical radiograph. During the preparation phase, EDTA and 5.25% NaOCl were used to irrigate the canal. After that, absorbent paper tips were used to dry the root canals. Gutta-percha tips covered in a resin-based sealant (ADSEAL®, META BIOMED) were employed to close off root canals. Following the application of a thin coating of a flowable resin composite and dental adhesive bonding agent to the pulp chamber floor, it was allowed to completely cure. To prevent drying out, every specimen was stored at 37°C in a little jar containing distilled water that has been coded.

Endocrown preparation

Following endodontic treatment and tooth preparation, three equal groups of ten molars were divided based on the endocrown restorative material: pressable modified PEEK (Bio-HPP PEEK; Bredent GmbH & Co. KG, Germany), a pressed IPS e.max (Ivoclar- Vivadent) and pressable Zr/LDS (VITA AMBRIA, Vita Zahnfabrik).

In order to ensure a persistent occlusal thickness of 2 mm, Dental CAD software (ExoCAD version 2.3, Germany) was used to digitally create the endocrown wax designs. Wax templates were created via a CAM dental milling apparatus (Roland, DWX-510, Japan), and their fit with the matched tooth was subsequently confirmed.

The mill wax patterns were then spurring, invested, and each endocrown was prepared from each heat-pressed material. The pressing process for IPS e.max, VITA AMBRIA and Bio-HPP PEEK was completed in compliance with each material's manufacturer's directions.

Endocrown cementation procedures

After being ultrasonically cleaned in distilled water for ten minutes, all endocrown samples were left to air dry. 9.5% hydrofluoric (HF) acid porcelain etching gel (9.5% Buffered HF acid gel, BISCO, USA) was used to etch each fitting surface of IPS e.max and VITA AMBRIA endocrowns for 20 seconds. It was then rinsed away with an air-water spray for 60 seconds then silane coupling agent (BISCO, USA) is applied with non threaded brush for 1 minute and air dried. 110 µm aluminum oxide particles were used to air abrade each Bio-HPP PEEK endocrowns fitting surface for 10 seconds at 2 bar of air pressure. The specimen surface and the tip of the sandblasting machine were spaced 10 mm apart.

Prior to primer application, all endocrown restorations were cleaned for four minutes using distilled water in an ultrasonic bath and dried with oil-free compressed air.

The VITA AMBRIA and IPS e.max samples etched fitting part was primed using a porcelain primer (Porcelain Primer, BISCO) that contained silane as a coupling agent. The Bio-HPP PEEK samples sandblasted surface had a thin layer of Visio applied on it (Bredent GmbH & Co. KG, Germany) link primer, which was then polymerized using the light curing unit (LED.D curing light, WOODPECKER, China) suggested by the manufacturer.

A 35% phosphoric acid gel was used to selectively etch the enamel for 15 seconds. It was rinsed off and left to air dry after a 30-second air-water spray. The prepared tooth surfaces were coated with a universal bonding agent (All Bond, BISCO, USA), brushed with a microbrush, allowed to air thin, and then exposed to a light cure for 20 seconds. Dual-cure resin cement (BisCem, BISCO) was utilized for the endocrowns cementation. Every endocrown was placed on its appropriate preparation using a loading machine that applied a straight-line static tension of 5 kg .On each surface, any extra cement was then tack-cured for two seconds, scraped off with a sharp explorer, and light-cured for twenty seconds.

Thermomechanical aging test:

A four stations multimodal ROBOTA chewing simulatorXLIII integrated with thermo-cyclic protocol and controlled by programmable logic was used to perform mechanical aging. Simultaneous vertical and horizontal movements, with alternating immersion in 5°C and 55°C water baths with dwell time of 60 seconds each were used. These test parameters are listed in Table (4). A 10 kg weight was applied, which is equivalent to 98 N of chewing power. Each specimen underwent chewing simulation vertical and horizontal movement for 120000 cycles. This is equivalent to a year of clinical experience ⁽¹⁴⁾

Test for fracture resistance

A computer-controlled materials testing device (Instron, Model 3345; Norwood, MA, USA) equipped with a 5 kN load cell was used to perform the fracture test. The fracture test was carried out using a compressive method of load-delivered occlusal using a steel rod secured to the top removable chamber of the testing apparatus and moving at a crosshead speed of 1 mm/min in order to decrease the transmission of regional force peaks and achieve a uniform distribution of stress. The force applicator on the occlusal surface was a steel rod with a spherical point (8.6 mm in diameter) pointed vertically at the endocrowns central fossa⁽¹⁵⁾.

3. RESULTS

For all groups, the Shapiro-Wilk test in the interest of normality revealed a statistically insignificant difference ($P > 0.05$), representative that both groups' data created from parametric data had a normal distribution.

A large significant difference between the groups was revealed by the independent t test results. The VITA AMBRIA and IPS e.max displayed a lower fracture resistance mean value, but the Bio-HPP PEEK displayed a significantly greater one (Table 1).

Table (1): Characteristics of three groups' fracture resistance in Newton

	Min.	Max.	Median	Mean	SD	t-value	P-value
PEEK	2654.77	3139.03	2949.71	2969.55	265.23	18.8	.000*
VITA AMBRIA	1437.82	1985.96	1695.37	1667.45	159.50		
IPS e.max	1670.88	2020.71	1750.55	1726.13	186.65		

*, Significant at $P < 0.05$. Min: Minimum. Max: Maximum. SD: Standard Deviation.

Comparison between three groups:

Comparison of fracture resistance between three groups displayed that mean load needed to PEEK's fracture was (2969.55 ± 265.23), while **VITA AMBRIA** was (1667.45 ± 159.50) and **IPS e.max** was (1726.13 ± 186.65) Using independent t-test revealed that there was significant difference between PEEK and other two groups, but there is no significant difference between **IPS e.max** and **VITA AMBRIA**.

4. DISCUSSION

In this investigation, pressable IPS e.max and Zr-LDS (VITA AMBRIA) was used instead of machinable milling to prepare endocrowns since it was found that heat-pressed LDC seemed to age less quickly than milled LDC because the heat-pressed ceramics have longer crystals⁽⁷⁾. Additionally, because they demonstrated superior mechanical qualities and stability over pressed granules, Bio-HPP PEEK pressed pellets were employed in this study. The flexural strength, stability, and dependability of the material for Bio-HPP PEEK restorations are enhanced by pre-pressing pellets in an industrial setting⁽¹⁶⁾.

The fracture resistance of the endocrown material was selected as a test property in the current experiment because it is one of the most important qualities for the clinical performance and longevity of dental prosthesis. It depends on the material's resistance to internal defects that could lead to the spread of cracks⁽¹⁷⁾.

The results of this study show that the mean load that caused the specimen to fail in Bio-HPP was 2969.55N, whereas the lowest load that did so was 3054.77 N. In contrast, the mean loads for zirconia-reinforced LDS (VITA AMBRIA) endocrowns and IPS e.max were 1667.45N and 1726.13N, respectively. This suggests that the maximum load applied to IPS e.max and zirconia-reinforced LDS (VITA AMBRIA) endocrowns was below the minimal load needed to cause modified PEEK samples to fracture. Stresses that are conveyed to the underneath tooth structural complex from the restoration may be lessened by the modified PEEK's increased stress-bearing capacity⁽⁷⁾. These findings were explained by the elasticity modulus and the intrinsic integrated crack avoidance feature of the Bio-HPP PEEK material⁽¹⁸⁾. These findings are consistent with previous studies^(19,20). However, the findings of other investigations contradicted those of our investigation^(21,22).

The result finding of the present research demonstrate that there is significant variation of fracture resistance across PEEK and other two glass materials, this may be explain by the resilient properties of PEEK which act as shock absorber before

tooth destruction during function and biting in contrast to VITA AMBRIA and IPS e max glass ceramic materials which is brittle material with no polymer content and high modulus of elasticity.

Using restorative material with a low elastic modulus, which absorbs more energy from the applied load and sends less energy to the abutment, minimizes the strains imparted to the underlying structure, according to earlier research⁽²³⁾.

Bio-HPP is suggested as a therapy for bruxism patients who are parafunctional because of its capacity in the resistance to severe chewing forces, demonstrate a great resistance to abrasion for opposing and maintain tooth structure without breaking, particularly when cosmetic concerns are not a major goal, according to a previous study⁽²⁴⁾.

The hypotheses of the present study were that there would be significant difference in fracture resistance between modified PEEK and other two materials (IPS e max and VITA AMBRIA) endocrown restorations is accepted, PEEK has high fracture resistance than IPS e max and VITA AMBRIA endocrown restorations but there isn't significant difference between IPS e max and VITA AMBRIA glass ceramic endocrown restorations.

5. CONCLUSIONS

6.

Compared to IPS e max and zirconia reinforced lithium disilicate (VITA AMBRIA) endocrowns, modified PEEK (Bio-HPP PEEK) endocrowns are more resistant to fracturing. But the all tested materials is within clinical acceptance range.

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