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MARGINAL GAP AND INTERNAL FIT OF LITHIUM DISILICATE INLAY, ONLAY AND ENDOCROWN RESTORATIONS FOR ENDODONTICALLY TREATED MAXILLARY PREMOLARS: AN IN VITRO STUDY

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ABSTRACT

Aim: assessing the internal fit and marginal gap distance of inlays, onlays, and endocrowns as final restorations for maxillary premolars that have had endodontic treatment.

Methods: In this investigation, 33 maxillary premolars were used. For the endodontic treatment, access cavities were made with #2 round burs and tapered stones. Using gutta-percha and a modified single-cone approach, all canals were obturated after being prepared to size 35 with a 4% taper. Based on the cavity design preparation, the teeth were then randomized into three groups (n = 11 per group): Group A was prepared for endocrowns, Group B was prepared for onlays, and Group C was prepared for inlays. The restorations were fabricated using an IPS e.max Press (EP 3010, Ivoclar Vivadent AG). After thermocycling, the replica technique was used to evaluate the internal and marginal fits of the restorations. Data was analyzed for normality, and statistical evaluation was conducted using ANOVA followed by Tukey

Results: Onlays had the smallest marginal gap both before and after thermocycling, whereas endocrowns had the smallest gap following cementation. All three groups did, however, show slight variations within clinically acceptable ranges. When it came to internal discrepancy, the onlay group had the highest value (186.6±26.4), followed by the inlay group (143.21±14.19), and the endocrown group (103.65±13.73). A statistically significant difference between the groups was found ($P < 0.05$).

Conclusion: Endocrown restorations outperformed inlay and onlay restorations in terms of internal fit and marginal gap, under the constraints of this investigation. All three restoration types—endocrown, inlay, and onlay—had marginal and internal fits that were within clinically acceptable ranges, nevertheless.

Recommendation: For maxillary premolars that have had endodontic treatment, endocrown is the recommended restoration in terms of the marginal gap and internal fit.

KEY WORDS: Endocrown, Onlay, Inlay, Endodontically treated premolars, Marginal gap, Internal fit, Microleakage.

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INTRODUCTION

Numerous factors impact the outcome of endodontic treatment, among which, proper case selection and the quality of the final coronal restoration are two important factors that together with the quality of the endodontic treatment itself can greatly influence the overall treatment prognosis[1] .

A number of factors can contribute to the failure of a root canal treatment, with coronal microleakage identified in numerous studies as a significant cause. It creates a pathway for bacteria—the primary adversary of endodontists—to re-enter the root canal system or multiply to an infectious level, potentially leading to post-treatment disease [1–3].

Restorative requirements vary in different tooth types and the clinical circumstances. In the past, it was commonly believed that all teeth required posts, cores, and crowns following endodontic treatment. However, advancements in adhesive dentistry over the last three decades, along with the exceptional performance of modern adhesive systems, have revolutionized this approach. Today, adhesion provides sufficient retention without relying on the agressive procedures previously needed for macro-retention. [6].

Conservative restorations include inlays, onlays, overlays, and endocrowns. Among these, inlays are the most conservative, as they do not cover any cusps. Onlays cover at least one cusp, while overlays cover all cusps. Endocrowns, in contrast, integrate the post, core, and crown into a single unit, creating a monoblock restoration. They utilize the full depth of the pulp chamber to maximize bonding surface area, thereby enhancing stability and strength.[7]

Despite the significant advancements in retention, strength, and fracture resistance achieved with modern adhesives, other factors continue to influence the retention and durability of bonded restorations. The marginal gap and internal fit of various bonded restorations, including endocrowns, have been extensively studied, with their importance emphasized in numerous research studies [4–6]. The accuracy of the internal and marginal fit is one of several aspects that affect the longevity of indirect restoration. The chemical, physical, and mechanical properties of the luting cement can deteriorate over time due to poor marginal fit, which can lead to microleakage, recurrent cavities, discoloration, and ultimately restoration dislodgement.

Meanwhile, internal fit plays a key role in establishing the thickness of the cement layer, which is required to achieve a strong bond between the tooth substrate and the restoration [4–7].

The occurrence of a marginal gap might have serious clinical consequences, generally resulting in a shorter lifespan for the restoration. Such gaps can result in gingival irritation, cement deterioration, microleakage, and cavity formation. Considering improvements in prosthetic dentistry, maintaining completely accurate margins remains difficult, and little deviations are typically unavoidable, leading to both biological and mechanical difficulties. Microleakage is the term used to describe the entry of bacteria, fluids, and other substances through a defect or gap between a dental restoration and the tooth structure. This can result in adhesive failure, recurrent caries, pulpal damage, or even failure of endodontic treatments. Secondary caries, in particular, is a significant clinical concern, as it can develop beneath a crown restoration and severely compromise the long-term success of the dental procedure. To enhance the durability of the repair, it is crucial to minimize the marginal gap. [8–10].

An improper internal fit can result in increased cement thickness, affect the restoration's retention, reduce its resistance to fractures, and ultimately lead to an unsatisfactory fit. The margins of inlay/onlay restorations are exposed to mechanical, physical, and thermal stresses, necessitating proper internal and marginal adaptation[11].

The current study aimed at evaluating the internal fit and marginal gap of inlay, onlay, and endocrown restorations in endodontically treated upper premolars. The null hypothesis posited that the different restoration designs wouldn't affect the marginal gap or internal fit of inlays, onlays, and endocrowns when applied to root canal-treated upper premolars.

MATERIALS AND METHODS

Ethical approval and sample size

The protocol of this in vitro study was approved by the ethical committee at the Faculty of Dentistry, Egyptian Russian University (#FD-ERU-REC17). An effect size of 0.7992273, obtained from the study by Merrill et al [12] with a type I error of 0.05 and a power of 0.98, was considered when calculating the sample size. To find a significant difference between groups in terms of internal fit and marginal gap distance, 33 samples were required.

Selection and preparation of samples

The study utilized thirty-three extracted, fully formed maxillary premolars. After disinfection by a 15-minute soak in sodium hypochlorite (NaOCl), teeth were sterilized by autoclaving. Each tooth was examined under 12x magnification using a Zumax dental microscope (Zumax Medical Co., Ltd., Jiangsu, China) to identify and exclude any surface defects, caries, or cracks. Only teeth with mature, straight roots without any signs root resorption or calcifications were included in the study.

All teeth underwent endodontic treatment, beginning with access to the pulp chambers using size 2 round burs and fine tapered, round-ended stones. The accurate working length was obtained by inserting a #15 K-file (Micro-mega, France) up to the root apex, then subtracting 1mm from its length. Mechanical preparation was performed using Edge File X7 (EdgeEndo, USA) rotary files, up to a #35, 4% taper. The torque and rotation speed were set at 250 g/cm and 400 RPM as recommended by the manufacturer. During the preparation, 2.5% sodium hypochlorite (Clorox Co., 10th of Ramadan, Egypt) was used to irrigate the root canals. Smear layer was removed at the end of instrumentation using a sequence of 5 ml 2.5% NaOCl, 5 ml distilled water, and 5 ml 17% EDTA (Cerkamed, Pawłowski, Poland). The canals were then dried and filled using modified lateral compaction with resin sealer (AH Plus, Dentsupply/Sirona) and matching #35, 4% master cones. A #25 stainless steel spreader was employed to create space for auxiliary cones to ensure optimal adaptation in the coronal part of the canal. The teeth were stored for one week in 100% relative humidity at 37°C to allow for complete setting of the endodontic sealer.

All teeth were prepared with a standard MOD cavity using tapered diamond burs (6-degree taper) at high speed, ensuring a minimum remaining wall thickness of 2 mm on the buccal and lingual sides, and a 3-mm depth for the horizontal pulpal floor. The proximal boxes were prepared with an isthmus depth of 2 mm. The lingual and buccal axial walls were shaped to be divergent. The supragingival margin of all preparations was positioned 1 mm above the cemento-enamel junction. For the onlays, a 90-degree butt joint margin was created, along with a 2-mm reduction of both the palatal (functional) and buccal (nonfunctional) cusps. [13].

Each tooth in the Endocrown group was occlusally reduced by 2-mm. Then, using a tapered stone with a rounded end to remove undercuts, we set up the pulp chambers with a 10-degree coronal divergence. The preparation was oval-shaped and 4-5 mm deep from the cavosurface edge, as checked by a graduated periodontal probe, with no additional drilling into the canal. The internal line angles were smoothed with a finishing stone. Impressions were made with vinyl polysiloxane elastomer (EliteHD+, Zhermack/Italy).

The cast was scanned via an extraoral scanner (Medit T500,Seongbuk-gu, Seoul, Korea) to digitize the dies then data were then transmitted to a software program (EXOCAD, Matera 2.4. exocad GmbH, Darmstadt, Germany) and then circumferential margin were determined. Following the successful milling of the CAD wax restorations, the wax patterns were meticulously detached from the CAD/CAM disc with a carbide bur, and any surplus sprue was trimmed to enhance the surface quality of the wax restorations. Each wax specimen was subsequently attached to a wax sprue and positioned onto the pressing ring base following the manufacturer's guidelines. The investment material had been subsequently mixed according to the specified powder-to-liquid ratio and then poured into the ring. The material was permitted to cure, resulting in the formation of the investment mold. The subsequent step included the burnout of the wax, succeeded by the pressing of a molten glass-ceramic ingot into the mold cavity, in accordance with the pressing schedule and temperature parameters established by the manufacturer.

Cementation procedures

Each restoration's fitting surface was treated with 8% hydrofluoric acid (Bisco Porcelain Etch) for 20 seconds, rinsed with water, and dried with air free of moisture. Next, the etched ceramic surface was brushed with Porcelain Silane BisCem (Bisco, United States) for one minute and then thoroughly dried, as per the manufacturer's instructions[14,15].

As directed by the manufacturer, all teeth were selectively etched (enamel only) using Scotchbond (3M ESPE) Etchant. After applying the etchant for 30 seconds, it was thoroughly washed with an air stream for 15 seconds and then air dried.

Cementation was performed using Total Cem resin cement (Itena, France). The cement was applied directly to every surface of the restoration using auto-mixing tips. The luting cement was then allowed to flow from all sides of the restoration as it was carefully placed onto the prepared tooth. After proper seating, any excess cement was carefully removed using a hand scaler before the restoration was light-cured (700 mW/cm2, Elipar2500) for a total of 100 seconds (20 seconds per surface) [15].

Thermal cycling procedures for laboratory testing of dental restorations

All teeth were artificially aged using thermal and mechanical aging (TCML) in a masticatory simulator (Esetron Smart Robotechnologies, Ankara, Turkey) after cementation. For six months of clinical use, 5,000 cycles of thermocycling were conducted. Each cycle included a 10-second lag time and a 25-second dwell duration in each water bath (Robota automated thermal cycle; Bilge, Turkey). A minimum temperature of 5°C and a maximum temperature of 55°C were set [16].

Marginal Gap Measurements

Before cementation, the cervical vertical marginal discrepancies were measured. The internal discrepancies of the samples were evaluated using a replica technique. Each tooth was filled with light-body silicone (Panasil, Kettenbach GmbH & Co. KG, Eschenburg, Germany) using a modified parallelometer, and it was then continuously loaded with 750 g for ten minutes. After the light-body silicone had set, the restoration was taken out. Since light-body silicone could not be removed from the inside of the crown without being distorted, heavy-body silicone was used to stabilize the crown. The duplicates were then precisely divided into four equal segments using a razor blade (No. 15c).

Two opposite parts were chosen to assess the inside fit out of the four sections taken from each replica. Six internal measures were obtained for each coping by measuring the pulpal floor, axial wall, and occlusal surface in each portion. Digital microscopy at ×35 magnification was used to measure the light-body silicone thickness of each duplicate. This measurement represented the distance between the preparation's exterior surface and the coping's internal surface.

In order to quantitatively and qualitatively assess the gap width, a specific program for analyzing digital images (ImageJ 1.43U, National Institutes of Health, USA) was utilized. Pixels were used to represent all boundaries, dimensions, frames, and measured parameters in the ImageJ program. System calibration was carried out by comparing a known-size object (a ruler utilized in this study) to a scale produced by the ImageJ software in order to translate these measurements into real-world units (i.e., micrometers). [17].

A USB digital microscope (U500x Digital Microscope, Guangdong, China) with an integrated camera was used to take pictures of each specimen in order to determine the Vertical Marginal Gap Distance. The image acquisition setup consisted of a 3-megapixel digital camera positioned vertically 2.5 cm away from the samples. The lens axis was at about a 90° angle to the light source. With a color index close to 95%, eight movable LED lamps provided illumination. After being taken at the maximum resolution (2272 × 1704 pixels), the images were saved to a personal computer that was compatible with IBM and had a fixed magnification of 40X. 1280 × 1024 pixels was the resolution at which the final photos were captured. Each specimen was photographed from the margins, and each image was subjected to morphometric measures using four landmarks spaced equally around the perimeter of each surface. Every measurement was made three times at each location. Each group's mean and standard deviation values were determined once the resultant data was gathered and tallied. After then, the data underwent statistical analysis.

Statistical methods

The mean and standard deviation (SD) are used to illustrate numerical data. The Shapiro-Wilk test and distribution analysis were employed to assess normality. Tukey's post hoc test was utilized following a one-way ANOVA because all of the data were found to be parametric. The significance level for each test was set at $P<0.05$..

RESULTS

Data for marginal gap distance is represented in table (1) & Figure (1&2). Amongst the three groups, onlay had a significantly lower gap distance before cementation and also after thermocycling. While Endocrown group showed the highest gap distance at the same time points. After cementation, on the other hand, the endcrown group had the least gap distance.

Data for internal discrepancy is represented in Table (2) & Figure (3), the highest value was found in the onlay group 186.6 ±26.4 followed by the inlay group 143.21 ±14.19 and the lowest value was in the endocrown group 103.65 ±13.73. Pair-wise comparison revealed a significant difference was among the three groups ($P<0.05$) meaning that, endocrowns had a mean internal discrepancy significantly lower than either inlays or onlyas and inlays had a significantly lower discrepancy value than onlays.

TABLE (1) Mean & SD for marginal gap distance among the groups:

	Endo Crown	Onlay	Inlay	P-value
Before cementation	60.06 ±6.69 ^{b}	43.66 ±5.80 ^{a}	55.59 ±3.12 ^{b}	<0.05
After cementation	52.547 ±1.124 ^{a}	59.113 ±2.104 ^{b}	54.04 ±2.66 ^{a}	<0.05
After thermocycle	71.45 ±6.94 ^{b}	40.57 ±14.10 ^{a}	68.28 ±10.02 ^{b}	<0.05
P-value	<0.05	0.006	0.002	

Means that don't share same letter are significantly different.

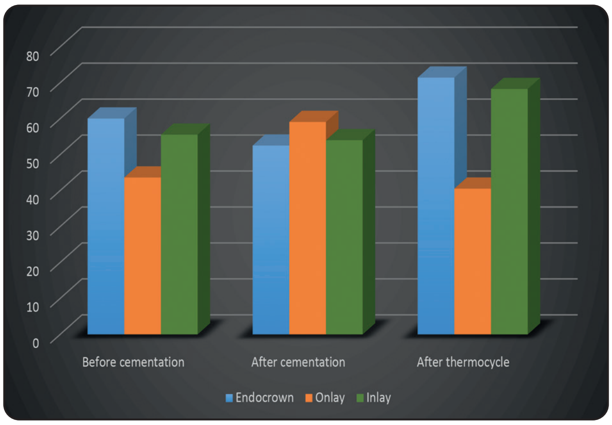

Fig. (1) Histogram representing the mean marginal gap distance before cementation, after cementation and after thermocycling among groups

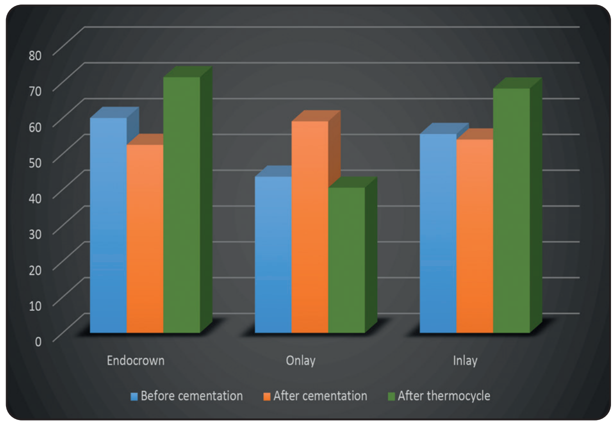

Fig. (2) Histogram representing the mean marginal gap distance before cementation, after cementation and after thermocycling within each group.

TABLE (2) Mean & SD for internal discrepancy among the groups:

	Endo Crown	Onlay	Inlay
Mean ±SD	103.65 ±13.73 [a]	186.6 ±26.4 [c]	143.21 ±14.19 [b]
P-value		<0.05	

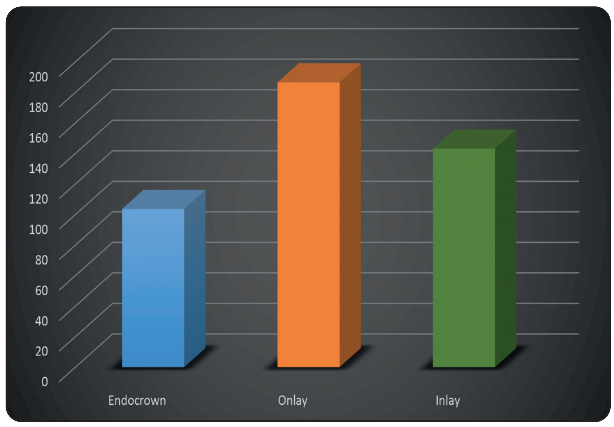

Fig. (3) Bar chart comparing mean internal discrepancy among groups

DISCUSSION

Post-treatment endodontic disease is influenced by various factors. Ng et al. (2008)[18] conducted a systematic review to study factors influencing the outcome of endodontic treatment. The lack of periapical radiolucency, obturation within 2 mm of the radiographic apex, homogenous root canal filling without voids, and an adequate coronal restoration were the four primary characteristics they discovered to be linked to superior treatment outcomes. Therefore, choosing the best restoration and material that satisfies aesthetic, biological, and functional requirements is crucial for guaranteeing long-term success when restoring teeth after endodontic treatment [7]. Among the elements that affect this choice, internal and marginal adaptations are crucial. Numerous factors, including the type of scanner, material and milling machine, the design of the preparation as well as the cement space, and the measurement protocol, were proved to affect the accuracy of the margins and internal fit. [19].

This study explored the effects of different restoration types (inlay, onlay, and endocrown) while maintaining consistency in all other factors across the samples. The null hypothesis was partially rejected.

Because it directly impacts the restoration's lifetime and performance, the precision with which the restoration fits the prepared tooth structure is a critical factor in the success of dental restorations. In recent years, endocrowns have emerged as a promising treatment option, offering a conservative approach to restoring severely damaged teeth. Endocrowns, along with inlays and onlays, are adhesive restorations that utilize the pulp chamber as the main source of retention, providing benefits over traditional crown and bridge treatments [8].

The marginal gap and internal fit of these restorations are crucial factors in determining their clinical success and durability. Research has emphasized the significance of these parameters, as increased marginal discrepancies can result in microleakage, secondary caries, and potential pulpal irritation. Moreover, the internal fit of the restoration plays a direct role in its resistance to fracture and dislodgement [8,20–22].

It is believed that a key factor in assessing the long-term sustainability of ceramic restorations is marginal adaptation, often known as the distance between the finish line and the restoration margin [23]. A significant gap between the tooth and restoration subjetcs the luting agent to the oral environment, which can lead to its dissolution. This leads to microleakage, potentially resulting in secondary caries, bacterial invasion, pulpal damage, and eventual failure of the prosthesis [24]. Additionally, a higher plaque index is directly associated with the presence of a fixed restoration that shows significant marginal fit discrepancies, which can negatively impact periodontal health. Therefore, it is crucial to thoroughly investigate the effects of different restorations on endodontically treated teeth[25].

The marginal gap was assessed at three different stages: before cementation, during cementation, and after thermocycling. Studies that examine the marginal gap by simulating functions like biting or tooth cleaning may uncover significant changes.

The endocrowns had a mean internal gap of 103.65±13.73µm, showing a statistically significant difference in internal fit between the examined groups. The replica technique was used in the current investigation since it was verified for measuring internal fit and marginal integrity as a quantitative and non-destructive method[26]. The null hypothesis, according to which the marginal gap between the tested groups did not differ significantly, was successfully rejected by the replica technique. According to Meshreky et al. (2020)[27] the measured marginal gaps fell within the clinically acceptable limit, which is less than 120 µm. The use of pressing technology in manufacturing the restorations, enabled proper marginal adaptation, which could account for these outcomes. Furthermore, this result was probably influenced by keeping the cement spacing at the lowest permissible value. [17]

The findings of our investigation contradicted the findings of the study by Sağlam et al., 2021 [22] where a marginal gap of 122.49±28.37 mm in E-Max press endocrowns was discovered. The manual procedure of making wax patterns could have produced diverse results. This method is also prone to errors and incorrect handling [17].

Several authors have attempted to establish criteria for determining a clinically acceptable marginal gap. According to Specification #8, issued by the American Dental Association in 1971, a marginal gap between 25 and 40 µm was considered clinically adequate. Achieving this range in a clinical setting is challenging and considerably smaller than the results reported in earlier studies[25]. Christensen discovered that the acceptable marginal gap was frequently impacted by the margin location. According to his findings, the permissible range for supragingival margins is 2 to 51 µm, and for subgingival margins, it is 39 to 119 µm [28]. In another study, Following a thorough in vivo analysis with over 1,000 crowns, McClean and von Fraunhofer proposed that the marginal gap should be less than 120µm.[29] For CAD/CAM restorations, Att et al, on the other hand, suggested a clinically acceptable range of 50–100 µm. [30]. According to Keshvad and Neves, marginal gaps for all-ceramic restorations must be under 100 µm, and ideally less than 75 µm, in order for those restorations to be deemed contemporary and clinically acceptable. [8,31,32].

The literature reports a variety of techniques for evaluating marginal gaps, including micro-CT, sectioning and microscopy, direct microscopy, tactile detection, and the use of silicone fit-checking materials. In this study,

We used silicone materials like Bite Checker and Fit Checker to measure the marginal gap. To determine the size of the marginal gap, the silicone layer is taken off, sectioned, and viewed under a digital microscope once it has completely set [8].

The study demonstrated that the measuring procedure could influence both the marginal and internal values. Recent findings show that marginal discrepancies tend to increase significantly after the cementation process. Following cementation, the vertical margin nearly doubled in size. However, the endocrown group exhibited the smallest gap distance after cementation [19]. However, in Shin et al[33] investigation the discrepancy was either minimized or remained unchanged. Despite the additional space created during cementation, the current findings still appear to remain within a clinically acceptable range.

As an in vitro study, the current research has certain limitations in replicating clinical conditions. Additional research is necessary to investigate the impact of long-term fatigue on restorations.

CONCLUSIONS

Under the constraints of this investigation, Endocrown restorations outperformed inlay and onlay restorations in terms of internal fit and marginal gap. All three restoration types—endocrowns, inlays, and onlays—had marginal and internal fits that fell within the clinically acceptable range

RECOMMENDATIONS

Because of their marginal gap and internal fit, Endocrowns can be recommended as restorations for maxillary premolars that have undergone endodontic therapy. Additionally, more investigation is required to ascertain how new materials, such as hybrid and resin-based ceramics, affect the marginal and internal fit of the three restoration designs studied.

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