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Marginal and Internal Adaptation Evaluation of Endo-Crown Restorations Fabricated with Different Impression Techniques

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Aim: This in vivo study aimed to evaluate the marginal and internal adaptation of endo-crown restorations made using various impression procedures using clinical and cone beam (CBCT).
Materials and Methods: Forty Patients with endodontically treated lower first molar were chosen for this research from the Fixed Prosthodontics clinic at Tanta University's Faculty of Dentistry. 2 mm occlusal reduction, axial preparation with 7-degree total occlusal divergence with 3 mm pulpal floor depth were made to all teeth. Each specimen was randomly assigned to one of two groups: the group I served as the control which received endo-crown restorations made by conventional impression. The other group (group II) received restorations made by digital impression. After one week of cementation of Vita Enamic endo-crowns to specimens, internal adaptation was evaluated using CBCT. USPHS criteria were evaluated at baseline ,6 months and 1year. Independent t-test and Chi-square test were used for statistical analysis once data was collected, collated, and organized.
Results: Regarding the internal adaptation measurements, group II has higher statistically significant internal adaptation than group I (P=0.000). Regarding marginal adaptation evaluation, a significant difference between both groups was found in favor of group II, p=0.008 after 6 months while p=0.037 after one year.
Conclusion: Impression techniques for Vita Enamic endo-crown fabrication affects marginal and internal adaptation to natural prepared tooth. Digital impression technique is highly recommended to be used during impression taking for endo-crowns rather than conventional impression.

Keywords: Endo-Crown Restorations, Impression Techniques, Internal Adaptation, Marginal Adaptation

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Introduction

Dentists have long faced the difficulty of rehabilitating teeth that have undergone endodontic treatment yet have sustained significant coronal damage. [1] Dowels and cores are advocated to retain conventional restoration through macro-retention means. [2] New treatment alternatives have been made possible, nevertheless, thanks to developments in adhesive dentistry and a greater focus on minimally invasive principles. An updated and practical substitute for the traditional resin composite or ceramic endo-crown full-crown coverings.[3] Endo-crown has the advantage of being minimally invasive preparation achieving maximum tissue conservation. It can be used with dilacerated, calcified or short roots that are not indicated for post and core. Moreover, it provides good esthetic and better mechanical performance with less cost and time compared to conventional dowels.[4,5]

A biomimetic restorative approach has been adopted in dentistry attempting to imitate tooth structure. [6] Hybrid ceramics represent a notable category of CAD/CAM materials crafted for this objective. Their distinct composition involves the alteration of ceramics to yield a biomimetic material possessing physical characteristics akin to dentin and enamel, while maintaining the robustness inherent in conventional ceramics. Furthermore, they offer the benefit of conserving tooth structure, as they can be milled into thin layers tailored to the clinical context, thereby facilitating minimally invasive to non-invasive procedures without compromising their mechanical attributes. [7]

A crucial part of making fixed dental prostheses is making an impression.[8,9] Various techniques can be employed to take impressions, with one of the most prevalent being the conventional impression technique. Despite its widespread use for transferring information from the patient's mouth to the dental laboratory when fabricating indirect restorations, this technique is associated with numerous errors that hinder its accuracy. Factors contributing to inaccuracies include incorrect tray selection, insufficient adhesive application, inadequate control of salivary and hemorrhagic fluids, patient discomfort, and several other variables. [10] To minimize these errors, direct intraoral scanning for prepared teeth preparation has been introduced using intraoral digital scanners. Studies have indicated that the advantages of intraoral scanners are their high level of efficiency, their ability to alleviate patient discomfort, their reduced risk of impression distortion, and the accuracy of their marginal and internal adaptation. For indirect repairs to be successful in the long run, this specific adjustment is vital. [7, 10]

The evaluation of internal and marginal adaptation has made use of several methodologies, such as direct view technique using digital microscope, scanning electron microscope, the micro-CT scan, impression replica, cross-sectioning technique and cone beam computed tomography. [11] The most cutting-edge investigative tool now available is cone beam CT, which allows for a non-invasive assessment of the internal adaptation of indirect restorations. In contrast to micro-CT, which exposes patients to radiation, clinical and cone beam (CBCT) enables accurate examination of gap and internal fit measurements without radiation exposure. [12] Accordingly, this clinical study's null hypothesis was that different impression techniques don't affect marginal nor internal adaptation of hybrid ceramic Endo crowns on clinical and radiographic prospects.

This in vivo study aimed to evaluate the marginal and internal adaptation of end-of-crown restorations made using various impression procedures using CBCT.

Materials and Methods

The present investigation was designed as a randomized clinical trial and received ethical clearance from the Research Ethics Committee, Faculty of Dentistry, Tanta University, Egypt (approval no. #R-END-1-22-10). An informed consent was duly obtained from all patients.

This investigation was carried out from July 2022 to September 2023 at the outpatient clinics of the Faculty of Dentistry, Tanta University, Egypt. Prior to commencement, the study objectives were comprehensively explained to potential participants.

Inclusion criteria

Age 18-50 years old, having mandibular first molar teeth with no root fracture, didn't have any signs of failure for endodontically treated tooth clinically or radiographically, was able to return for follow-up exams and evaluations; and, following root canal therapy, the tooth's four coronal walls were at least 3 millimeters intact.

Exclusion criteria

Patient with compromised medical history, teeth with poor prognosis due to severe or active periodontal disease, significant damage to the topmost layer of tissue or the existence of enormous cysts, or even both and difficulty to apply rubber dam for good isolation for bonding the Endo crowns.

Preoperative preparation

Accurate oral examination to the patients, mounted diagnostic casts to each patient, Periapical x-ray for endodontically treated teeth to ensure presence of all successful criteria of endodontic treatment, History from the patient for any complain from the tooth after endodontic treatment and Shade selection record.

Operative phase

2 mm occlusal reduction was made using wheel diamond bur. A tapered diamond bur was used for pulp chamber axial preparation in order to shape the pulp chamber by eliminating all undercuts in access cavity with total occlusal divergence about 7°–10° of tooth axis. The pulpal floor prepared to standardized depth (3 mm) and pulp chamber cavity trapezoidal in shape to enhance restoration stability. Following the manufacturer's instructions, the immediate dentin sealing protocol was carried out by applying one coat of the adhesive (Prime & Bond Active Universal, DENTSPLY) and vigorously rubbing it for 20 seconds. After that, for another 20 seconds, a mild air stream was used to help the solvent evaporate, and then, for another 20 seconds, light curing was applied. Following a 20-second light curing period, the cavity was filled with a bulk-fill flowable resin (Filtek Z350, 3M ESPE Dental Products, St. Paul, USA). To minimize the formation of an oxygen-inhibited layer, post-curing through a clear glycerin gel was performed for an additional 20 seconds. (Figure 1).

Figure 1: Final cavity preparation and immediate dentine sealing.

Grouping

Forty patients aged 18-50 years were selected and divided into: group I (Control group) included 20 patients received endo-crown restorations made by conventional impression. Group II included 20 patients who received endo-crowns made by digital impression.

Impression techniques

For group I, full arch impression was taken by two step impression technique using additional silicon material (Zhermack elite HD+, Putty/Light Body, DENTSPLY, Italy) for both upper and lower teeth. The dental stone used for the casting was Type IV (Shera premium type IV, SHERA, Germany), which was poured to achieve an impression following the manufacturer's instructions. For group II, proper saliva control was obtained using saliva ejector and cotton rolls. The prepared tooth was placed next to the scanner (Trios 3, 3 shape, Copenhagen, Denmark). After capturing sufficient data about maxillary, mandibular teeth and the patient bite, after that, the lab received the transformed scans in standard tessellation language (STL) format.

Provisional restoration fabrication

provisional restoration was made using CAD/CAM PMMA disc (SR Vivo dent CA, Ivoclar digital, Schaan, Liechtenstein) placed over prepared tooth and cemented with eugenol-free temporary cement (Temp-Bond NE, UK). The excess cement was removed using an excavator.

Endo-crown fabrication

For group I, scanning the working cast was made by an extra oral scanner (DOF Freedom HD lab scanner, Korea) after setting of the stone (45-60 min) and separating it from the impression. The design of the restorations was accomplished using ExoCad 2020 software, with a cement gap of 60 µm. Vita Enamic blocks (VITA-Zahnfabrik, Bad Säckingen, Germany) were inserted into a milling machine (Imes-icore CORITEC 350, Germany) to fabricate Vita Enamic endocrowns. For the second group, the digital data obtained from the intraoral scanning process was utilized at the dental laboratory to create virtual models using computer-aided design (CAD) system software. After analyzing the STL files, the design process for the full contour endocrowns was performed with the CAD software. Subsequently, the data were transferred to the computer connected to the milling machine for analysis and initiation of the milling process to fabricate full-contour Vita Enamic endocrowns.

Finishing of restorations

Following the milling process, the fabricated restorations underwent cleaning in an ultrasonic water bath, followed by drying and polishing using the Vita Enamic Polishing Set (VITA-Zahnfabrik, Bad Säckingen, Germany) in accordance with the manufacturer's instructions.

Cementation of endo-crown restoration

provisional restorations were removed using excavator and teeth were sandblasted using 27µm AL2O3 particles to remove all temporary cement remnants and reactivate the immediate dentine sealing layer. Endo-crown restorations were checked for accuracy. All restorations underwent etching with 5% hydrofluoric acid gel (Vita Enamic etch, Vita Zahnfabrik, H. Rauter GmbH, Bad Sackingen, Germany) for 60 seconds, followed by rinsing with water for 60 seconds and drying with compressed air for 20 seconds. Subsequently, a silane coupling agent (MonoBond N, Ivoclar Vivadent AG, Schaan, Liechtenstein) was applied onto the etched surfaces of the endocrowns and allowed to dry for 60 seconds. A thin layer of self-adhesive radiopaque resin cement (Breeze™, N97E-en-shade Opaceous White) was then applied to the fitting surface of the endocrown, which was subsequently inserted into the tooth with mild finger pressure applied to the occlusal surface. Initial light curing for three seconds was performed, after which the excess cement was removed. Glycerin gel was applied all around the margin to help self-curing of resin cement, then final curing for 40 seconds per surface.(Figure 2)

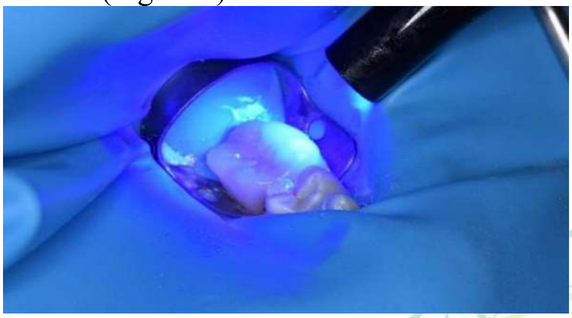

Figure 2: Curing for 40 seconds per surface.

Any occlusal interference detected and removed using articulating paper(40µm) (Bausch Arti-fol^R, Germany). Shim stock was used to ensure occlusal contact with opposing teeth.

Radiographic evaluation

All patients were scanned one week after endo-crowns cementation to evaluate the internal adaptation using CBCT scan (KaVo OP 3D Vision Kavo Dental, Biberach, Germany) with fixed exposure parameters (120 KV, 5mA, 0.125 voxel size) with selecting the same field of view (8Dx 8H cm). All images were sliced at the same plane to ensure standardization using On Demand dental software (On Demand 3D software Seoul, Korea). Measuring the cement gap at the internal part of the endo-crown for both groups was made at selected points (cavo-occlusal (CA) and axio-pulpal transitional angel (APT)).

Clinical evaluation

The patients underwent clinical examination according to the modified United States Public Health Service (USPHS) criteria to evaluate marginal adaptation at baseline (one week postoperatively), 6 months, and 1 year after the intervention (Table 1). [13]

Table 1: Modified USPHS criteria

Category	Rating	Criteria
Marginal adaptation	**A**	Probe, does not catch, smooth margin interface
	B	Probe catches at single spots, slight roughness
	C	Probe catches under 50% of margin length
	D	Probe catches at/over 50% of margin length

Sample Size Calculation

The sample size calculation was done by G*Power 3.1.9.2 (Universitat Kiel, Germany). We performed a pilot study (5 cases in each group), and we found that the mean (± SD) of Value of cavo-surface angle was 1.41 ± 0.46 in group 1 and 0.87 ± 0.60 in group II. The sample size was based on the following considerations: 1.01 effect size, 95% confidence limit, 80% power of the study, group ratio 1:1, and three cases were added to each group to overcome dropout. Therefore, we recruited 20 patients in each group.

Statistical analysis

The collected data was tabulated and subjected to statistical analysis. Numerical variables (radiographic data) were summarized using descriptive statistics, including means and standard deviations. Comparisons between groups for numerical variables were performed using the independent t-test. Nonparametric variables (clinical data) were expressed as frequencies and percentages. The chi-square test was employed to compare nonparametric variables between groups. All statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS version 26).

Results

Regarding the evaluation of internal adaptation, an intergroup comparison of the mean values of the cavo-surface angle from the coronal view revealed values of 1.42 ± 0.31 mm and 0.69 ± 0.17 mm for Group I and Group II, respectively. The unpaired t-test indicated a highly statistically significant difference ($p < 0.001$) in favor of Group II (Table 2).

Table 2: Inter group comparison of mean values of cavo-surface angle between two groups

Value of cavo-surface angle				
Groups	**Mean± S. D**	**Min—Max**	**Independent t-test**	
			T	**p-value**
Group 1 (conventional)	**1.42± 0.31**	**1.02—1.92**	6.802	0.000 **
Group 2 (digital)	**0.69 ± 0.17**	**0.43—0.91**		

There is a significant at P-value< 0.05 (*), and highly significant at P-value< 0.001 (**).

Meanwhile, the intergroup comparison of the mean values of the axio-pulpal angle from the coronal view yielded values of 1.64 ± 0.27 mm and 0.69 ± 0.18 mm for Group I and Group II, respectively. Upon applying the unpaired t-test, a highly statistically significant difference ($p < 0.001$) was observed, favoring Group II (Table 3).

Table 3: Inter group comparison of mean values of axio-pulpal angle between two groups

Value of axio-pulpal angle				
Groups	**Mean± S. D**	**Min—Max**	**Independent t-test**	
			t	**p-value**
Group 1 (conventional)	1.64±0.27	1.34—2.02	9.369	0.000* *
Group 2 (digital)	0.69±0.18	0.45—0.91		

There is a significant at P-value< 0.05 (*), and highly significant at P-value< 0.001 (**).

Regarding the clinical evaluation, two independent evaluators assessed the restorations at baseline, 6 months, and 12 months after treatment, according to the modified United States Public Health Service (USPHS) criteria. In Group II, marginal adaptation was rated as 100% score at baseline and after 6 months.

However, after one year of follow-up, the marginal adaptation score was 90% A and 10% B at the same measurement points. In contrast, for Group I, 70% of cases scored A, and 30% scored B at baseline. Subsequently, after 6 months, a decline in marginal adaptation was observed, with 50% scoring A and 50% scoring B, a finding that remained consistent after 12 months of follow-up.

Regarding the statistical analysis of marginal adaptation, the Chi-square test was employed to examine the relationship between durations and scores within the same group, which revealed no significant difference between them. The test was also utilized to assess the difference between groups for each duration individually. At baseline, no significant difference was observed between the two groups. However, after 6 months ($p < 0.05 = 0.008$) and one year ($p < 0.05 = 0.037$), a statistically significant difference was found between the groups (Table 4).

Table 4: USPHS scores and Chi-Square statistics for marginal adaptation from baseline to 12 months

Marginal adaptation						
Groups	**Score**	**Baseline**	**After 6 months**	**After 12 months**	χ^2	**p-value**
Digital group		**N (%)**	**N (%)**	**N (%)**	2.034	0.362
	A	20 (100%)	20 (100%)	19(95%)		
	B	0(0%)	0(0%)	1(5%)		
	C	0(0%)	0(0%)	0(0%)		
	D	0(0%)	0(0%)	0(0%)		
Conventional group	**A**	17 (85%)	14 (70%)	14 (70%)	1.600	0.449
	B	3(15%)	6(30%)	6(30%)		
	C	0(0%)	0(0%)	0(0%)		
	D	0(0%)	0(0%)	0(0%)		
Duration comparison	χ^2 **(P-value)**	3.243 (0.072)	7.059 (0.008*)	4.329 (0.037*)	-------	

There is a significant at P-value< 0.05 (*), and highly significant at P-value< 0.001 (**).

Discussion

The study's null hypothesis was disproved. Digital and conventional groups showed different levels of internal and marginal fit. Digitally designed endo-crowns displayed larger internal and marginal adaptation compared to the conventional designed ones.

Restoration of badly broken teeth with an end-of-crown allows better performance and longevity due to reducing the size of the restoration can mitigate stress concentration on the remaining tooth structure. [1]

Mandibular 1st molar tooth was used in this study for all patients to ensure standardization durinsg the whole study. Molar was recommended for the study more than any other tooth as the surface area for adhesion affect the success of these restorations by several previous studies. [14]

The tooth preparations involved creating specific dimensions to conserve the natural tooth structure. The depth into the pulp chamber was targeted at 3 millimeters, with a tolerance of plus or minus 0.5 millimeters. The axial wall height was aimed at 2 millimeters, again allowing for a 0.5-millimeter variance either way. These dimensional parameters served two key purposes. Firstly, they preserved sufficient enamel to facilitate proper adhesion through bonding mechanisms. Secondly, they minimized variability in the tooth preparation thickness, thereby reducing the risk of compromised marginal and internal adaptation of the endo-crown restoration material. [15] Also, to provide proper accessibility for good scanning using intra oral scanner. [16]

Standard axial wall tapering of 7-degree was chosen to show less space between their walls when compared to those with a 10-degree curve in the other direction. [17] Butt joint marginal design was used for all specimens rather than chamfer finish line to reduce compressive stresses and disperse them over the pulp chamber walls and the cervical butt joint [11]. Furthermore, the enhancement of the resin cement's bonding process and the addition of bulkier ceramics at the butt joint tooth/restoration interface of endo-crowns reduced the variation in edge length. [18]

Polymer infiltrated ceramic material (Vita Enamic) was used for endo-crown restorations to preserve tooth structure as milling it to thin layers is possible without compromising its efficacy, minimally invasive to non-invasive, depending on the clinical scenario. [19] Plus, it can absorb stress better than regular ceramics since its elastic modulus is similar to dentin's. There is no need to fire Vita Enamic blocks through a crystallization cycle, unlike blocks made of lithium disilicate. Additionally, it has shown remarkable resilience after milling and an exact marginal fit for restorations. [20]

When determining whether a repair was successful, marginal integrity is crucial. Restorations with clinically acceptable margins nonetheless run the risk of having their marginal seal broken down over time owing to luting cement breakdown or material instability. As opposed to the gaps seen in ceramic restorations, Vita Enamic restorations may be more prone to marginal step formation due to their comparatively low wear resistance and stiffness. [21] Consequently, it is imperative to closely monitor the marginal adaptation of Vita Enamic restorations during subsequent follow-up appointments.

Radiopaque Breeze Self- adhesive resin cement was used due to having superior, reliable and consistent bond strength. Simple application technique with no etching, priming, bonding, hand mixing or triturating. In this study, radiopaque type of cement was very important to be easily detected by CBCT to make internal adaptation evaluation process clearer. [22]

Since both internal and marginal adaptation are critical to the restoration's therapeutic success, these metrics were used to evaluate adaptation. [23]

Because of its non-invasiveness, ability for accurate treatment planning, and high-quality images, cone beam computed tomography (CBCT) was used to evaluate the internal adaptation. [23] In order to assist a thorough review, this modality offers a wide selection of adjustable views and angles. On top of that, CBCT lets you evaluate the internal gap in three dimensions at different places and sections. [24]

Regarding the radiographic measurements for internal adaptation, it was founded that, digital scanning group has superior internal adaptation than conventional impression group (P <0.001), the elimination of possible dimensional variations caused by impression and die materials is a direct outcome of the digitization of scanning processes, which in turn reduces the likelihood of human mistake.[25]

These findings end-of-confirmed also by other studies [26-28], that reported micro-CT evaluations of end-of-crown restorations digitally outperform those made using traditional impression techniques in terms of internal and marginal adaptability. Whether direct intraoral scanning or indirect cast scanning is employed, this benefit remains constant.

On the other hand, these findings disagree with Guess et al. [29] who stated that restorations made using traditional imprints had less internal inconsistencies than those made using digital scanning. This conflict may be due to different material, design or method of measurement used in their study.

With respect to marginal adaptation in digital group using USPHS scores, the marginal fit scored (A) in 100 %of endo-crown restorations from the baseline to 6 months' period of follow up. While a detectable but clinically acceptable margin (scored b) in 10% of the restorations after one-year. while conventional group (scored b) in 30% of restorations after 6 months while after one-year (score b) reached 50% of restorations, producing a statistically significant difference between both groups after 6 months and one-year with p-value (0.008* and 0.037*) respectively. This may be due to detectable margin lead to cement dissolution that may be caused by discrepancy in impression procedure and die material. [30]

Previous studies [31, 32] highlighted that the standard impression approach yields more than 50% useless measurements for evaluating an appropriate internal fit because of mistakes caused by the impression materials. Additionally, the present study's findings are in line with previous research showing that dental tissue is incompatible with prosthesis made from ambiguous impression recordings.

Nevertheless, Oh KC et al. [33] reached the conclusion in their studies that typodont teeth with various preparations, when compared for accuracy using three digitalization methods, demonstrated that impression scanning and cast scanning yielded superior accuracy in indirect techniques. The increased deviation observed in the direct scanning method may be attributed to functional and technical challenges. The technology available at the time made it challenging to stitch images together without propagating errors.

Consistent with the present study's conclusions, Frankenberger's [34] work emphasized that clinical investigations have shown changes in marginal adaptation and marginal discoloration in partial-coverage restorations as a result of the luting cement's wear and deterioration over time, especially in areas where there are large marginal discrepancies.

The study was limited by its focus on a single restorative material fabricated using a uniform technique, as well as the relatively short-term follow-up for the endo crown restorations. Different outcomes may have resulted from the use of alternative materials or fabrication techniques. Therefore, future research is recommended to investigate the effects of various materials and fabrication methods on both marginal and internal adaptation, considering different preparation designs, and incorporating long-term follow-up evaluations of the restorations.

Conclusion

Hybrid ceramic endo-crowns fabricated by conventional impression or digital impression provided satisfactory internal and marginal adaptation following cementation from a clinical perspective. Clinically and radiographically, endo-crowns crafted from hybrid ceramic using digital impression techniques exhibited superior marginal and internal adaptation compared to those manufactured via conventional impression methods.

Funding

No funding was received for conducting this study.

Data availability

Data is available upon reasonable request from corresponding author.

Ethics approval and consent to participate

This investigation received ethical clearance from the Research Ethics Committee, Faculty of Dentistry, Tanta University, Egypt (approval no. #R-END-1-22-10). An informed consent was duly obtained from all patients.

Competing interests

The authors have no financial or proprietary interests in any material discussed in this article.

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