Original Article

Clinical performance of computer-aided design/computer-aided manufacture lithium disilicate ceramic endocrown restorations: A 2-year study

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Abstract

Context: Optimal restoration methods for endodontically treated teeth (ETTs) have always remained an ongoing discussion among physicians in this day and age. ETTs have a tendency to fracture when chewing, compared to initial teeth. From the perspective of biology, preserving and restoring tooth structure is critical to maintaining biomechanical, functional, and esthetic harmony. Dental bonding techniques have lessened the necessity for post-and-core restorations in ETTs with severe substance loss. A minimally invasive endodontic restoration technique called "endocrown" was initially introduced by Bindl and Mörmann in 1999.

Aims: The aim of the study was to clinically evaluate all-ceramic mandibular molar endocrowns made using computer-aided design/computer-aided manufacturing (CAD/CAM) following 2 years of follow-up.

Subjects and Methods: This unblinded study contains 56 patients with 56 mandibular molars, which had severe substance loss. After teeth preparation, lithium disilicate ceramic endocrowns were manufactured with the CEREC CAD/CAM system, and cementation was performed using a composite luting agent. The endocrowns were assessed using the modified United States Public Health Service criteria at baseline, 6 months, 1 year, and 2 years following placement. Patient satisfaction was evaluated using a questionnaire.

Statistical Analysis Used: This study used descriptive statistics, including mean, standard deviation, and 95% confidence intervals. Data were processed using STATA version 14.0 (StataCorp LLC, USA).

Results: Two endocrowns (3.6%) failed throughout the period of observation. The high clinical rating criteria (96.4%, count of 54) and the increased satisfaction percentage (94.6%, count of 53) remained practically stable during the follow-up assessments at 6 months and after 1–2 years.

Conclusions: Endocrown offers a less invasive treatment option that may be a better method for endodontically treated mandibular molars. With contemporary CAD/CAM technology and new materials, time in the chair and esthetics optimally improved, bringing satisfaction to the patient.

Keywords: Butt joint; computer-aided design/computer-aided manufacturing; endocrown; endodontically treated tooth restoration

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INTRODUCTION

Optimal restoration for endodontically treated teeth (ETTs)

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has always been of great interest to clinicians. In addition to restorative complications, weakened treated teeth have a higher fracture risk on functional performance.[1,2] Treatment options are greatly influenced by the quantity of remaining tooth structure and tooth position.[3] The posterior teeth with severe substance loss require a restoration that can adapt to their morphological and loading features.[4] A post-and-core restoration was previously thought to provide better support for the remaining tooth structure. However, according to some studies, using an intracanal post only helps preserve the prosthesis.[5,6]

Various dental bonding systems have reduced the need to use post and core for restoration of ETT with severe substance loss.[7] In 1999, Bindl and Mörmann first introduced "endocrown," a porcelain block covering the entire occlusal surface of the tooth and integrating into the pulp chamber.[8] Endocrown is a minimally invasive technique that is simple to perform, is less expensive, and has the potential to reduce endodontic postfailures.[9] For patients with occlusal consideration, endocrown was the most recommended treatment option for restoring ETT.[3,10] Literature reported many *in vitro* studies about the endocrown characteristics.[11-14] However, studies on endocrown are still limited, with *in vitro* studies accounting for the majority and few clinical studies on endocrown for posterior teeth. In addition, the satisfaction of patients with this kind of treatment is also the subject of much research.[8,15,16] We carried out this work by concentrating on the rating of endocrown criteria using the modified US Public Health Service (USPHS) criteria paralleling with the collecting of patient satisfaction toward this type of prosthesis in Vietnam.

SUBJECTS AND METHODS

Patient selection

Patients with at least one lower molar having endodontic treatment were included in this study. All patients exhibited proper oral hygiene and were included in the dental hygiene recall scheme. Listed below are the exclusion criteria:

- Endodontic-treated teeth with severe substance loss that was restored with full-crown restorations
- Teeth with partial crown restorations
- Patients with a history of bruxism.

After restoration placement, all patients entered an individualized maintenance program and were followed up for routine dental maintenance. The study was conducted in accordance with the ethical principles of the World Medical Association Declaration of Helsinki and approved by the Ethics Committee of our institution (72/HĐĐĐ-PCT, May 27, 2020).

Endocrown preparation and fabrication

The steps of tooth preparation are shown in Figure 1. A circular butt margin reduced by at least 2 mm in the axial direction was part of the occlusal preparation. A coronal pulp chamber and continuous endodontic access cavity were formed by the tapering of the pulp chamber; root canal preparation was not included. Walls with a thickness of <2 mm were removed automatically. After taking impression with Honigum (DMG), the CEREC system (Sirona Dental Systems GmbH) was used to carry out the computer-aided design/computer-aided manufacturing (CAD/CAM) process. e.max CAD (Ivoclar Vivadent) ceramic blocks were used. Following the manufacturer's recommendations, prosthetic intradoses were etched using hydrofluoric acid (IPS Ceramic Etching Gel, Ivoclar Vivadent), and a layer of Monobond N (Ivoclar Vivadent) was applied.

On prepared teeth, the enamel was etched using orthophosphoric acid (Eco-Etch, Ivoclar Vivadent). After rinsing, Tetric N-Bond Universal (Ivoclar Vivadent) was applied to the tooth surface. Following preparing the ceramic and finishing (checking the occlusion and contact surfaces), the crown was placed using Variolink DC (Ivoclar Vivadent). Adhesive steps on the endocrown are illustrated in Figure 2. Following endocrown placing, a periapical radiograph evaluation was taken.

After collecting the information about age and gender, the restorations were assessed by the modified USPHS criteria at the baseline, 6 months, 1 year, and 2 years.[17,18]

Assessment of patient satisfaction

Patient satisfaction was assessed using a questionnaire. Each question was answered by selecting "very satisfied," "satisfied," "neutral," "unsatisfied," or "very unsatisfied." In addition, at the follow-up examinations, participants were asked to complete a patient satisfaction questionnaire that covered three topics: esthetics, function, and general evaluation. All questions were explained to the patients so that they clearly understood their meaning.

Statistical analysis

This study used descriptive statistics, including mean, standard deviation, and 95% confidence intervals. Data were processed using STATA version 14.0 (StataCorp LLC, College Station, Texas, USA).

RESULTS

Table 1 shows the modified USPHS rating of endocrown at baseline, 6 months, 1 year, and 2 years after treatment with different quality assessments, including retention, margin adaptation, tooth integrity, margin discoloration, secondary caries, and color match. For the margin adaptation, 100% of treated teeth achieved the Alpha rate. However, the Alpha rate was 96.4% concerning the color match because 2/56 endocrowns achieved the Bravo grade.

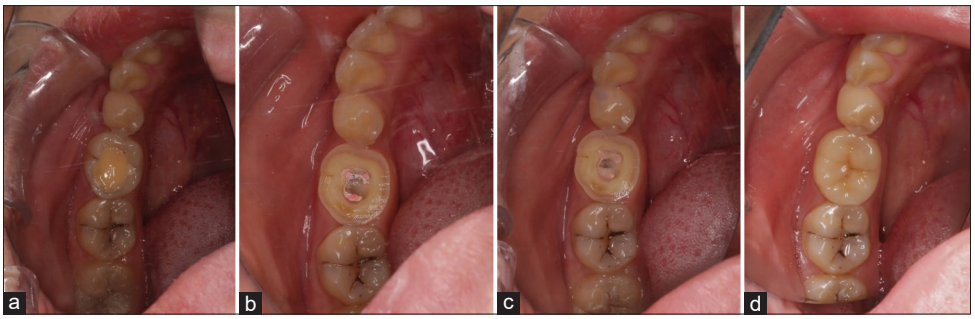

Figure 1: Clinical aspect of an endocrown from preparation to placing. (a) An endodontically treated right mandibular first molar; (b) Removing the filling, cutting the gutta-percha cones not more than 2 mm from root canal orifices using a heated tip, and performing occlusal and axial preparation; (c) Covering the cone-exposed areas using glass-ionomer cement, and polishing the cavity and cervical band; (d) Tooth after placing the endocrown

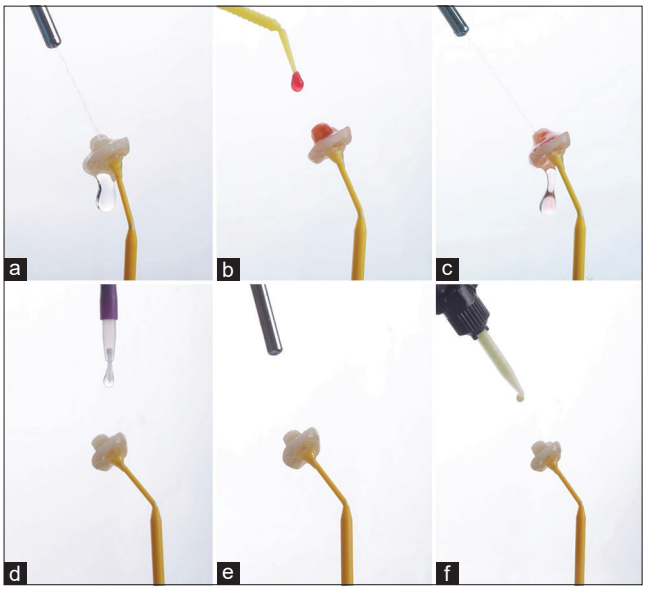

Figure 2: Endocrown preparation. (a) Cleaning with water; (b) Etching with hydrofluoric acid; (c) Rinsing off the etching gel; (d) Applying a layer of bonding agent; (e) Dispersing; (f) Applying adhesive cement

After two years, 100% of endocrowns maintained the Alpha rate in terms of retention, margin adaption, and secondary caries criteria. For tooth integrity, 100% endocrown achieved the Alpha rate 6 months and 1 year after placement. Two years after treatment, one endocrown was rated Bravo because of the recovery batch. The margin discoloration decreased the Alpha rate's endocrown by 100% in 6 months, 96.4% in 1 year, and 94.6% in 2 years after treatment. For the color match, the Alpha:Bravo ratio was 96.4%:3.6% maintained in 6 months, 1 year, and 2 years after endocrown placement.

The patient satisfaction is presented in Table 2. One hundred percent of patients were very satisfied with the function of the prosthesis. Esthetic and comfort percentages were 96.4% and 94.6%, respectively. No one expressed a neutral and unsatisfied attitude toward the treatment. In general, 94.6% were delighted with the endocrown.

Table 1: Modified United States Public Health Service rating of endocrowns at baseline, 6 months, 1 year, and 2 years after treatment, *n* (%)

Quality assessment	Alpha	Bravo	Charlie	Delta
Retention				
6 months	56 (100)	0	0	0
1 year	56 (100)	0	0	0
2 years	55 (98.2)	0	1 (1.8)	0
Margin adaptation				
Baseline	56 (100)	0	0	0
6 months	56 (100)	0	0	0
1 year	56 (100)	0	0	0
2 years	56 (100)	0	0	0
Tooth integrity				
6 months	56 (100)	0	0	0
1 year	56 (100)	0	0	0
2 years	55 (98.2)	1 (1.8)	0	0
Margin discoloration				
6 months	56 (100)	0	0	0
1 year	54 (96.4)	2 (3.6)	0	0
2 years	53 (94.6)	3 (5.4)	0	0
Secondary caries				
6 months	56 (100)	0	0	0
1 year	56 (100)	0	0	0
2 years	56 (100)	0	0	0
Color match				
Baseline	54 (96.4)	2 (3.6)	0	0
6 months	54 (96.4)	2 (3.6)	0	0
1 year	54 (96.4)	2 (3.6)	0	0
2 years	54 (96.4)	2 (3.6)	0	0

DISCUSSION

Fifty-six mandibular molars of 56 patients were treated by endocrown in our study. Sixty-eight percent of study subjects were between 18 and 30 years old. Men made up the majority of our research (60.7%). 71.4% of teeth were endodontically treated but not restored, whereas 10.7% had not been restored well and needed to be treated; only 16.1% were due to tooth caries and pain, and 1.8% were periodically examined and discovered that the tooth needed treatment.

The proportions of teeth 36 and 46 were nearly equal at 32.1% and 33.9%, respectively. The remaining teeth 37 accounted for 14.3%, and tooth 47 accounted for 19.6%.

Table 2: Patient satisfaction after treatment, *n* (%)

Topic	Very satisfied	Satisfied	Neutral	Unsatisfied	Very unsatisfied
Esthetic	54 (96.4)	2 (3.6)	0	0	0
Function	56 (100)	0	0	0	0
Uncomfortable feelings	53 (94.6)	3 (5.4)	0	0	0
General evaluation	53 (94.6)	3 (5.4)	0	0	0

According to Zou *et al*., endocrown is mainly indicated for molars.[19] The molars were selected to reveal that there is a greater surface accessible for bonding on molars compared to premolars. The crown base-to-crown height ratio may cause larger leverage for premolars compared to molars, increasing the risk of restorative fracture. The failure rate of endocrown in premolars is higher than in molars.[14] The smaller tooth structure in the pulp chamber of premolars reduces the bonding surface, limiting the bonding strength of the adhesive system and the resin.[14] Hence, only molars were selected for the study.

Several clinical studies have concluded that residual crown tissue is critical to the clinical efficacy of ETT. Hence, a conservative approach is required for endocrown preparation. In our study, restoration preparation followed a butt joint design and no ferrule, similar to Dogui *et al*., to obtain a large and stable surface that resists the compressive forces encountered in molars.[20] The surface was prepared parallel to the occlusal plane to withstand pressures along the central axis of the tooth.[20] Numerous studies were carried out to compare the use of different abutment preparation designs for endocrown and the effect on the fit of restorations. The amount of contour deformation recovered during firing is influenced by the width and design of the finish line, with a more significant effect in the transverse plane.[4] Hence, the design of the butt joint shows a higher clearance at the restoration margin than at the finish line. The results regarding the fit inside the restoration show no considerable difference between a butt joint design and another finish line design.[4]

Immediately after cementation, the color matching of the endocrown and natural teeth achieved an Alpha score of 96.4% and a Bravo score of 3.6%. This figure did not change after evaluation at 6 months, 1 year, and 2 years after mounting, similar to the study of Zou *et al*. with the color matching rate up to 99.1%.[19] It was higher than that of Bindl and Mörmann, with 67% point B, and the analysis of Chrepa *et al*., with 83.1% score A.[8,21] This difference comes from fabrication materials, ceramic endocrowns, especially lithium disilicate with CAD/CAM technology, for a more realistic color range than plastic and composite restorations. The color-matching rate will decrease over time, partly due to the change in color and clarity of natural teeth in the oral environment.[19]

Margin adaptation is a factor in indirect restoration maintenance and clinical advantage.[22] In our study, 100% of endocrown repairs achieved a closeness of A score immediately after mounting and maintained this result at 6 months, 1 year, and 2 years later. There was no gap between the tooth tissue and the restoration using the sharp probe. This rate was similar to the 6-month assessment in Zou *et al*.'s study.[19] However, after 3 years, this author's rate of A dropped to 98.8%. Chrepa *et al*.'s study also recorded a high concordance rate of 97.4%.[21] In contrast, the results from Bindle and Mörmann studies conducted in 1999 and 2005 showed the majority of the B score.[8,14] For example, the endocrown fitted that score A at the time of crown cementation in Otto and Mörmann study was 64%. However, after 12 years, this figure was only 36%.[23] The noticeable difference came from the duration of the study. Clinical studies showed that the CAD/CAM technique was proven to be an essential factor that affected the internal fit of the endocrown to reduce human error and control for all variables. The fit achieved depends mainly on the endocrown design.[24-27]

After 6 months and 1 year of placement, restoration retention was assessed at a score of A of 100%. However, at the 2-year follow-up, one case was recorded with a score of C when the crown was lost (1.8%) [Table 1]. The retention rate in Chrepa *et al*.'s study was 97.7% for the same reason as crown loss, which was remedied by re-adhesion. In this study, we used dual polymeric cement (Variolink II, Ivoclar Vivadent) and LD porcelain to perform endocrown on molars.[21] A study by Gresnigt *et al*. showed that the adhesive qualities of lithium disilicate ceramics make them one of the best materials for restoration.[28,29] In the clinical situation, the operator cannot assess the structure and suitability for bonding the available dentin surface in each case. According to Bindl *et al*., it is impossible to determine whether the dentin is hardening or not.[14] Sclerosing dentin is characterized by peritubular dentin absorption, deposition of minerals in the tubules, and a hybrid layer that is less porous, thus thinner, and less homogeneous over the nonsclerosing dentin, thus reducing adhesion compared to nonsclerosing dentin. The effect of the preparation is also a factor to consider to ensure the retention of the restoration. High bond strength is achieved when combined with cement paste with a thickness of 50–100 um. If the preparation creates a margin gap of 150 um or more, the cement washout is significantly higher and reduces retention of recovery.[26] For the case of crown loss in our study, it may be due to insufficient stability of the endocrown retention in the pulp chamber.

The structure restored after 6 months of endocrown attachment achieved integrity with a 100% A grade. However, after 2 years, this rate was only 98.2% due to one case being evaluated with a B grade (1.8%) because of the recovery batch. After grinding and polishing, the

endocrown retains its esthetic and functional results, under the patient's wishes, so we do not replace them. All cases of fractures and recovery blocks were male. The cause may come from the eating habits of male patients. Studies by Otto and Mörmann also recorded one case of crown fracture and one case of cusp fracture when assessing the integrity of the restorations.[23] New porcelain crowns and endocrowns soon replaced these cases. Bruxism was considered to be the highest risk factor for restorative fracture in ETT teeth.[15] In our study, patients with a history of bruxism were excluded, which was why the rate of reversible fractures was relatively positive.

Six months after prosthesis placement, 100% of the cases had no discoloration. However, at 1-year follow-up, 96.4% got grade A and 3.6% B because of the bruise at the restoration margin. We had overcome this by cleaning and polishing the edge of the endocrown to return to point A. However, after 2 years, we had one more case that bore this situation, making the percentage of A score only 94.6%. The cause may be difficulty cleaning the lateral teeth while performing the restoration, causing the cementitious part to become discolored at the restoration margin. Cleaning and polishing were conducted to remedy this situation. Border discoloration was also noted in the study of Zou *et al*., however, at 2 and 3 years after crown placement.[19]

During the 2-year follow-up, 100% of the endocrown cases in the study had no recurrent caries. It was similar to the studies of Chrepa *et al*., Borgia Botto *et al*., and Otto and Mörmann.[15,21,23] In contrast, Bindl and Mörmann recorded one failure due to recurrent caries under restoration after 2 years of follow-up.[8] Similar to the study of Zou *et al*., there was one case recurrence after 2 and 3 years of follow-up.[19]

In our study, most patients were "very satisfied" with the esthetics (96.4%). All patients were delighted with the function of the restoration. After two years of placement, 94.6% of the participants were very satisfied and 5.4% were satisfied overall. These rates are consistent with a small number of studies that have evaluated patient satisfaction with endocrown treatment. According to Zou *et al*.'s study, the assessment of patient satisfaction was based on three criteria: color, appearance, and comfort.[19] Similar to Belleflamme *et al*. study, where the "very satisfied" and "satisfied" rates were 92.9% and 2%, respectively, Otto and Mörmann only reported that all patients were "very satisfied" and "satisfied" with the treatment results, regardless of criteria.[7,23] In general, with endocrown restoration, patients are very satisfied with function and esthetics. In this study, all samples were molars. Hence, the patient's esthetic requirements, including color and shape, were not too high compared to the anterior teeth.

CONCLUSIONS

Endocrown has many advantages, including simple procedure and better biomechanical performance than conventional restorations. Furthermore, with contemporary CAD/CAM technology and new materials, time in the chair and esthetics optimally improved, bringing satisfaction to the patient. The study outcome demonstrated the short-term success of the latest minimally invasive restoration method, endocrown, in terms of esthetics and function. However, extensive clinical trials assessing the efficacy of these restorations are of paramount importance to making endocrown a practical choice.

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Conflicts of interest

There are no conflicts of interest.

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