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CLINICAL AND RADIOGRAPHICAL EVALUATION OF ENDOCROWNS FABRICATED FROM DIFFERENT CAD/CAM CERAMIC MATERIALS

#MOHAMMED AL MOALEEM*, NASSER M. AL AHMARI**

*Department of Prosthetic Dental Science, College of Dentistry, Jazan University, 45142, Jazan, Saudi Arabia
**Prosthetic Department, College of Dentistry, King Khalid University, Abha 62529, Saudi Arabia

#E-mail: drmoaleem2014@gmail.com

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This study aimed to evaluate patient satisfaction via the visual analogue scale and conduct radiological assessments of the marginal adaptation of the cemented CAD/CAM endocrowns at different time intervals. Twenty-six (26) participants received endocrowns constructed from lithium disilicate ceramics and multi-layered zirconia. The construction and cementation of the endocrowns were carried out according to the manufacturer's instructions for laboratory and clinical procedures. The statistical significance was set at $p \leq 0.05$. Most of the participants recorded high numbers and percentages for the very satisfied and satisfied scales when evaluating the colour, crown morphology, and margins. The McNemar test revealed a significant difference in the colour at the 24-month follow-up ($p = 0.037$). No significant differences were detected at different time intervals in terms of the khat chewing habit, side, and arch type with cemented endocrowns. The Chi-square test revealed significant differences in the material type at baseline ($p = 0.001$); in the gender at 24 months ($p = 0.024$); and in the colour, margin, and morphology at baseline and 24 months ($p < 0.001$ and $p = 0.004$, respectively). Most patients expressed high satisfaction with the colour, morphology, and marginal adaptation of the cemented endocrowns. The use of lithium disilicate ceramics resulted in higher levels of satisfaction in terms of the colour and marginal adaptation compared with zirconia.

INTRODUCTION

Root canal treatment (RCT) is the standard management option when dental pulp is irreversibly damaged. This treatment modality involves the soft-tissue removal and then filling that gap through obturation with a synthetic material [1]. Structural failure is the most common reason for the extraction of root filled teeth [2]. As a result, there has been increasing interest in the structural and biomechanical effects of RCTs and subsequent post-RCT procedures on restoration and tooth survival [3].

The decision regarding how to restore RCTs with extensive coronal loss remains a clinical challenge [4, 5]. Crowns supported on posts and cores have been revealed to weaken the mechanical resistance of the tooth structure and increase the incidence of root fracture [6]. An endocrown restoration is a monolithic restoration that utilises the pulp chamber and remaining coronal tooth structure as a means of retention [7]. Its advantages include sealing the root canal and preventing the risk of recontamination. It provides sufficient intention stability and high fracture resistance [8–11]. For the best possible aesthetic results in modern dentistry, dental prostheses must accurately reproduce the exact tooth shade and match the neighbouring teeth, with no colour changes over time to ultimately satisfy the patient's aesthetic demands [12]. As a result of their abilities to maintain the restoration colour over time without changes, zirconia restorations and lithium disilicate ceramics (LDCs) are the most commonly used materials for the construction of endocrowns [13]. LDC is considered a highly aesthetic CAD/CAM prosthesis due to the glass matrix embedded with needle-like lithium disilicate crystals that reduce the internal scattering of light as it passes through the prosthesis. Moreover, LDC has other optical properties that allow it to closely mimic adjacent natural teeth, which include the chameleon effect [14, 15]. Both materials show clinically acceptable marginal adaptation in laboratory studies [11, 16].

The visual analogue scale (VAS) is a reliable parameter usually used for patient satisfaction measurements after intraoral cementation of a prosthesis. This scale can measure the colour, morphology, and margins of the cemented prosthesis [17]. A survey about patient satisfaction with aesthetic treatment found that

the prosthesis colour is usually the primary cause for patient dissatisfaction; 89.3 % of patients were not satisfied with their aesthetic outcome due to the colour of their restoration [18]. Bekhiet et al. recorded excellent patient satisfaction in the natural optical appearance of zirconia-strengthened lithium silicate ceramics (Celtra Press) and LDCs (e.max CAD) [19]. Both materials reached 100 % patient satisfaction in colour matching [20, 21]. A recent study by Do et al., 2024 recorded a high degree of patient satisfaction with LDGC endocrowns using the same scale and material [22].

Recently introduced ceramic systems in the form of monolithic or multi-layered zirconia with improved optical properties may lead to progress in clinical shade matching and patient satisfaction. Zirconia, introduced by VITA Zahnfabrik, is a glass ceramic material enriched with approximately 10 % zirconia by weight. This very fine homogenous dual microstructure results in a high flexural strength and provides a high percentage of glassy matrices. These structural effects provide the ceramic with good optical and polishing properties and allow the delivery of restorations with excellent aesthetics [20, 23]. The aesthetic needs of patients during prosthetic construction and cementation are crucial; otherwise, patient satisfaction will not be reached, which has a significant consequence on patient self-awareness and quality of life [24–26].

A radiological evaluation is essential in endodontics for diagnostic purposes, for the planning and execution of the treatment, and for the evaluation of the success of therapy. Periapical radiography is the main radiographic investigation used, but presents some limitations due to any 3D anatomic alteration, geometric compression, and possible anatomical structures overlapping that can obscure the area of interest [27]. Periapical radiography features greater sensitivity than panoramic radiography preoperatively and at follow-up [28]. No previous radiographical studies evaluated the clinical performances of endocrowns.

Do et al., 2024 found that an endocrown has many advantages, including a simple procedure and better biomechanical performance than conventional restorations [22]. Furthermore, with contemporary CAD/CAM technologies and new materials, the time in the chair and aesthetics are improved, bringing satisfaction to the patient [22, 29]. Endocrowns designed with a 20° bevel margin may be the favourable preparation option for endodontically treated teeth. Resin cement and bulk-fill flowable resin composite are preferred to seal the orifice of the root canal system when an endocrown restoration is planned as rehabilitation. In addition, the pulp chamber axial walls should be prepared using 6° and 12° divergences to balance the stress magnitude in the adhesive interface for restorative modality [30]. Modification in the conventional endocrown design results in an increase in the fracture strength [11].

This prospective clinical study was designed to assess and evaluate patient satisfaction of cemented CAD/CAM endocrowns via VAS at different time intervals (baseline and 6, 12, and 24 months). Radiological assessments for the marginal adaptation status of the endocrowns of endodontically treated teeth (ETT) were carried out at 12 and 24 months. The null hypothesis was that there will be no statistically significant difference in cemented endocrowns evaluated by the VAS parameters or evaluated radiographically after 24 months in relation to CAD/CAM ceramic materials.

EXPERIMENTAL

Study design

This clinical and radiographical study conformed to the standards of the World Medical Association's Declaration of Helsinki (Policy WMA). The study was approved by the institutional ethical review board at College of Dentistry, King Khalid University (SRC/GTH/2018-19/125). Clinical assessment, measurements, and follow-up data were collected from patients of private clinics from May 2022 to April 2024. In addition, an informed consent form was signed by all the participants.

Inclusive and exclusive criteria

The inclusion criteria were as follows: patient records included a phone number that made communication possible, participants had a full set of teeth, cases had been carried out by prosthodontic specialists with a similar degree and years of experiences, and patients had received CAD/CAM ceramic endocrowns for the maxillary and mandibular teeth in the right or left side. After brushing the teeth, measurements were carried out during the same time (10 AM–2 PM). A successful RCT was characterised by the absence of apical periodontitis, no internal or external root resorption, and a normal occlusion relationship. The exclusive criteria were patients with parafunctional habits, periapical pathosis, and absence of anterior teeth.

Teeth preparation, impression, construction, and cementation of endocrowns

All the cases underwent the same steps during the clinical and laboratory steps of endocrown construction (Figure 1). Figure 1A shows the isolation of the tooth during root canal treatment, 1B shows the preparation of the pulpal chamber after filling the pulpal canal with a flowable composite and modification of the intrapulpal extension. Figure 1C shows the tooth after cementation of the endocrown, while Figure 1D is the periapical X-ray after cementation.

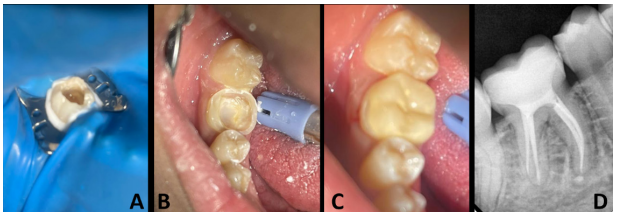

Figure 1. A: during root canal treatment, B: modification of the tooth for the endocrown preparation, C: after endocrown cementation, D: preapical X-ray of the cemented restoration.

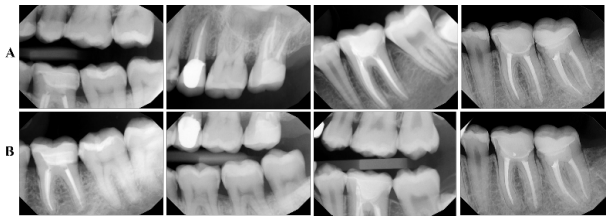

Figure 2. Radiographic image showing the follow up of the LDC endocrown.

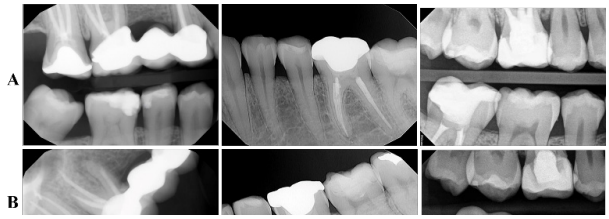

Figure 3. Radiographic image showing the follow up of the multi-layered zirconia endocrown.

Patient grouping, assessment and data collection

Patients were reached via their mobile number to arrange a clinical and radiographical examination. All the data were collected and stored using the CS-R4 program (CSR4 plus Practice Management Software version 4, Carestream Dental LLC, Atlanta, GA, USA). Charts were prepared by two evaluators to assess the reliability and accuracy of the obtained results. The examination and assessments were performed using the clinical examination sheet [19, 21]. The following information was obtained: phone number and personal information such as the age of the patient, their gender, khat chewing (yes or no), arch type (maxillary or mandibular), arch side (right or left), type of CAD/CAM ceramic material used (lithium disilicate glass ceramic or multi-layered zirconia), and presence of proximal teeth preparation variation (yes or no).

Patient satisfaction measurements

Overall patient satisfaction using VAS was assessed and scored as very satisfied, satisfied, fairly satisfied, and not satisfied at baseline (week of cementation) and during the follow-up periods of 6, 12, and 24 months [19–21, 22].

Radiographical evaluation after different periods

Radiographical X-rays were obtained at the recall appointment after the time of the clinical evaluation. The radiographical parameters for the used materials were classified according to Geduk et al., with some modifications. For different types of restorative materials, the evaluation criteria were as follows: continuous with the contour of the endocrown; good adaptation; slight overhang or under-contour of the endocrown; presence of < 1 mm ledging; and obvious endocrown ledging ≥ 1 mm [31]. Sample X-rays used in evaluating the marginal adaptation status according to the material used are presented in Figure 2 for the LDC and Figure 3 for the multi-layered zirconia, where A and B represent the follow-up after 12 and 24 months, respectively.

Data analysis

Data from the collected participants were categorised and summarised in an EXCEL sheet on a computer. The results of the descriptive statistical analysis for patient characteristics were categorised. Patient satisfaction using VAS was presented as the frequency, percentages, and standard deviation (SD) using the Statistical Package for Social Science software program platform version 28.0 (Chicago, Illinois, USA). The comparisons and associations between the endocrown material types for VAS at different time intervals and other parameters (gender, khat chewer, arch, side, material used, and presence of preparation modifications) were assessed using Chi-square and McNemar tests, with significance set at $p \leq 0.05$. The radiographic outcome was represented as a number and percentage in relation to the different materials used.

RESULTS

The mean and SD of the patients' age was 24.43 ± 5.78 years. Of the 26 participants, four (15.4 %) were male and four were khat chewers. Most of the endocrowns were cemented in the mandibular arch (19, 73.1 %), constructed from the LDC (21, 80.7 %), and with the presence of the proximal area modification of the prepared teeth (19, 73.1 %). The follow-up endocrowns were almost equal in both arch sides, with 12 (48.3 %) and 14 (51.7 %) for the right and left sides, respectively (Figure 4).

In terms of the patient attitude toward the VAS parameters, the overall colour of the VAS was between very satisfied and satisfied at the different recall intervals.

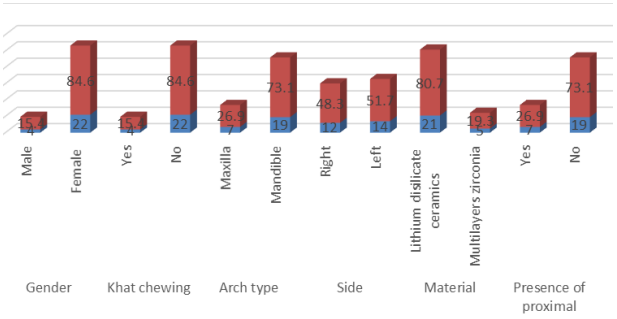

Figure 4. Participants' characteristics.

The results showed that 20 (76.9 %) and 6 (23.1 %) participants were very satisfied and satisfied, respectively, at baseline and after 6 months. However, these values decreased to 17 (65.4 %) for very satisfied and increased to 9 (34.6 %) at the 24-month follow-up, with significant differences ($p = 0.037$ using the McNemar test). For the morphology, the cemented endocrowns were similar at baseline and 6 months in the very satisfied (23, 88.5 %) and satisfied (3, 11.5 %) scales, but increased at 12 (20, 76.9 %) and 24 months (6, 23.1 %). For the margin, almost all of the cemented endocrowns were high in the very satisfied scale at baseline (26, 100 %) and 6 months (22, 48.6 %), and it reached the highest satisfied scale at 24 months (4, 15.4 %). No significant differences were found for the morphology and margin ($p \geq 0.050$; Table 1).

No significant differences were detected at the different time intervals in VAS with relation to the khat chewing habit, side, and arch type with cemented crowns. The Chi-square test showed a significant difference between the material type at baseline ($p = 0.001$), for the colour at the 24-month recall between gender (p 0.024), and for the morphology at baseline and 24 months (p value < 0.001 and $p = 0.004$, respectively). No patient reported fairly or unsatisfied scale in all the VAS parameters toward the cemented endocrown at all the follow-up times (Table 2).

Table 3 shows the percentage of the marginal adaptation of endocrowns in relation to the restorative material type and evaluation period. The LDC endocrown demonstrated much higher success rates of 95.2 % and 85.6 % compared with the multi-layered zirconia (60.0 % and 40.0 %, respectively) after 12 and 24 months, respectively. The occurrence of endocrown with < 1 mm ledging and ≥ 1 mm was 20.0 % for the multi-layered zirconia after 12 and 24 months, but these values were 4.8 % and 0.00 % for the LDC endocrown after the same time period.

DISCUSSION

The renewed interest in endocrowns is driven by the apparent advantages of the adhesive bonding, which can be achieved with appropriate isolation, restoration and dentine substrate preparation well-executed adhesive cementation, and preserved maximum tooth tissue, reduced need for auxiliary retentive geometry, and low treatment time and expense. In endocrowns, few operation steps are involved, root tissues are preserved, and the internal preparation of the pulp chamber is limited to its anatomic shape. Ceramics are used throughout the entire extension of the cavity. Moreover, the development of dental CAD/CAM systems provides a novel means of chair-side design and automatic fabrication of all the ceramic restorations, especially the ceramic endocrown that constructs the crown and the core as a single unit [3, 32, 33]. In cases of endocrowns, lithium disilicate can be considered one of the best restorative materials in the field [3, 8].

This prospective clinical study was designed to assess and evaluate the patient satisfaction of different cemented CAD/CAM endocrown materials via VAS at different time intervals. The radiological assessments

Table 1. Distribution of the colour, morphology, and margin in different time points via the McNemar test according to VAS.

Variable	Time	Very Satisfied	Satisfied	Fairly Satisfied	Not Satisfied	P value*
Colour	Baseline	20 (76.9)	6 (23.1)	0 (0.00)	0 (0.00)	
	6 Months	20 (76.9)	6 (23.1)	0 (0.00)	0 (0.00)	1
	12 Months	18 (69.2)	8 (30.8)	0 (0.00)	0 (0.00)	0.063
	24 Months	17 (65.4)	9 (34.6)	0 (0.00)	0 (0.00)	0.037*
Morphology	Baseline	23 (88.5)	3 (11.5)	0 (0.00)	0 (0.00)	
	6 Months	23 (88.5)	3 (11.5)	0 (0.00)	0 (0.00)	1
	12 Months	20 (76.9)	6 (23.1)	0 (0.00)	0 (0.00)	0.125
	24 Months	20 (76.9)	6 (23.1)	0 (0.00)	0 (0.00)	0.125
Margin	Baseline	26 (100.0)	0 (0)	0 (0.00)	0 (0.00)	
	6 Months	24 (92.3)	2 (7.7)	0 (0.00)	0 (0.00)	NC
	12 Months	23 (88.5)	3 (11.5)	0 (0.00)	0 (0.00)	NC
	24 Months	22 (84.6)	4 (15.4)	0 (0.00)	0 (0.00)	NC

*: McNemar test; NC: Not calculated.

Table 2. Distribution of the colour, morphology, and margin at baseline and after 24 months of follow-up by the smoking, arch, side, material, remaining height, and modification.

Parameters		Baseline					24 Months				
		Colour									
		Very Satisfied	Satisfied	Fairly Satisfied	Not Satisfied	P value	Very Satisfied	Satisfied	Fairly Satisfied	Not Satisfied	P value¶
Gender	Male	4 (19.0)	0 (0)	0 (0)	0 (0)	0.224	3 (12.5)	1 (15.4)	0 (0)	0 (0)	0.823
	Female	17 (81.0)	5 (100)	0 (0)	0 (0)		16 (87.5)	6 (84.6)	0 (0)	0 (0)	
Khat chewing	Yes	4 (19.0)	0 (0)	0 (0)	0 (0)	0.223	3 (12.5)	1 (15.4)	0 (0)	0 (0)	0.781
	No	17 (81.0)	5 (100)	0 (0)	0 (0)		16 (87.5)	6 (84.6)	0 (0)	0 (0)	
Arch Type	Maxilla	5 (27.8)	2 (40.0)	0 (0)	0 (0)	0.947	5 (27.8)	2 (40.0)	0 (0)	0 (0)	0.624
	Mandible	16 (72.2)	3 (60.0)	0 (0)	0 (0)		16 (72.2)	3 (60.0)	0 (0)	0 (0)	
Side	Right	10 (50.0)	2 (33.3)	0 (0)	0 (0)	0.231	8 (50)	4 (50.0)	0 (0)	0 (0)	0.837
	Left	10 (50.0)	4 (66.4)	0 (0)	0 (0)		8 (50)	6 (50.0)	0 (0)	0 (0)	
Material used	LDC	20 (95.2)	1 (33.3)	0 (0)	0 (0)	0.001	20 (95.2)	1 (33.3)	0 (0)	0 (0)	0.082
	Zirconia	3 (4.8)	2 (66.4)	0 (0)	0 (0)		3 (4.8)	2 (66.4)	0 (0)	0 (0)	
Presence of proximal variation	Yes	5 (25.0)	2 (33.3)	0 (0)	0 (0)	0.872	5 (25.0)	2 (33.3)	0 (0)	0 (0)	0.436
	No	15 (75.0)	4 (66.4)	0 (0)	0 (0)		15 (75.0)	4 (66.4)	0 (0)	0 (0)	
		Morphology									
Gender	Male	4 (20)	0 (0)	0 (0)	0 (0)	0.389	3 (14.3)	1 (12.5)	0 (0)	0 (0)	0.901
	Female	20 (80)	2 (100)	0 (0)	0 (0)		18 (85.7)	7 (87.5)	0 (0)	0 (0)	
Khat chewing	Yes	4 (20)	0 (0)	0 (0)	0 (0)	0.220	4 (20)	0 (0)	0 (0)	0 (0)	0.695
	No	18 (80)	4 (100)	0 (0)	0 (0)		18 (80)	4 (100)	0 (0)	0 (0)	
Arch Type	Maxilla	6 (28)	1 (25)	0 (0)	0 (0)	0.901	6 (28.6)	1 (25)	0 (0)	0 (0)	0.847
	Mandible	17 (72)	2 (75)	0 (0)	0 (0)		15 (71.4)	4 (75)	0 (0)	0 (0)	
Side	Right	10 (43.4)	2 (75)	0 (0)	0 (0)	0.941	10 (47.6)	2 (40)	0 (0)	0 (0)	0.122
	Left	13 (56.6)	1 (25)	0 (0)	0 (0)		11 (52.4)	3 (60)	0 (0)	0 (0)	
Material used	LDC	21 (95.5)	0 (0)	0 (0)	0 (0)	< 0.001	20 (95.2)	1 (20)	0 (0)	0 (0)	0.004
	Zirconia	1 (4.5)	4 (100)	0 (0)	0 (0)		1 (4.8)	4 (80)	0 (0)	0 (0)	
Presence of proximal variation	Yes	6 (27.3)	1 (25)	0 (0)	0 (0)	0.779	6 (28.6)	1 (20)	0 (0)	0 (0)	0.642
	No	16 (72.7)	3 (75)	0 (0)	0 (0)		15 (71.4)	4 (80)	0 (0)	0 (0)	
		Margin									
Gender	Male	4 (25)	0 (0)	1 (50)	0 (0)	0.124	2 (8)	2 (50)	0 (0)	0 (0)	0.024
	Female	20 (75)	2 (100)	1 (50)	0 (0)		20 (92)	2 (50)	0 (0)	0 (0)	
Khat chewing	Yes	4 (20)	0 (0)	0 (0)	0 (0)	0.219	4 (20)	0 (0)	0 (0)	0 (0)	0.689
	No	18 (80)	4 (100)	0 (0)	0 (0)		18 (80)	4 (100)	0 (0)	0 (0)	
Arch Type	Maxilla	7 (29.6)	0 (0)	0 (0)	0 (0)	0.366	7 (28)	0 (0)	0 (0)	0 (0)	0.901
	Mandible	17 (70.4)	0 (0)	2 (100)	0 (0)		16 (72)	0 (0)	3 (100)	0 (0)	
Side	Right	11 (45.8)	0 (0)	1 (50)	0 (0)	0.960	10 (45.5)	2 (50)	0 (0)	0 (0)	0.941
	Left	13 (54.2)	0 (0)	1 (50)	0 (0)		12 (54.5)	2 (50)	0 (0)	0 (0)	
Material used	LDC	20 (80)	0 (0)	1 (100)	0 (0)	0.504	19 (79.2)	0 (0)	2 (100)	0 (0)	0.326
	Zirconia	5 (20)	0 (0)	0 (0)	0 (0)		5 (20.8)	0 (0)	0 (0)	0 (0)	
Presence of proximal variation	Yes	6 (25)	0 (0)	1 (50)	0 (0)	0.548	5 (22.7)	0 (0)	2 (50)	0 (0)	0.377
	No	18 (75)	0 (0)	1 (50)	0 (0)		17 (77.3)	0 (0)	2 (50)	0 (0)	

¶: Chi-square test; NC: Not calculated.

Table 3. Percentage of the marginal adaptation evaluation by radiograph.

Endocrown Material Type	Radiographical Variable	12 months (%)	24 months (%)
Lithium disilicate ceramics	Good adaptation	95.2	85.6
	Presence of < 1 mm ledging	4.8	9.6
	Presence of crown ledging ≥ 1 mm	0.0	4.8
Multi-layered zirconia	Good adaptation	60.0	40.0
	Presence of < 1 mm ledging	20.0	20.0
	Presence of crown ledging ≥ 1 mm	20.0	40.0

for the marginal adaptation of the endocrowns were conducted at 12 and 24 months. The results revealed that the LDC endocrown after follow-up at 6, 12, and 24 months showed a high percentage of patient satisfaction (colour, morphology, and marginal adaption). However, the radiographical marginal adaptation of the multi-layered zirconia showed slight differences in comparison with the LDC endocrowns after follow-up at 12 and 24 months. The null hypotheses of the study (there will neither be no statistically significant differences in the cemented endocrowns evaluated by the VAS parameters after 24 months in relation to the CAD/CAM ceramic materials nor a significant difference in the radiographical outcome) was accepted in VAS parameters and partially rejected in relation to the radiographical assessments. The overall result after 24 months was considered clinically and radiographically acceptable.

In dentistry, accurate and predictable shade matching between natural teeth and restorative materials represents a challenge for clinicians and laboratory technicians. For decades, visual shade matching was most commonly used for shade selection in dental clinics because it is easy and does not require expensive equipment [34, 35]. VAS has been used to evaluate the aesthetics, complete denture satisfaction, dental anxiety, and postsurgical assessment; it is also extensively used to support and validate clinical research findings in prosthodontics [17, 22].

In this study, the assessment of patient satisfaction was based on three criteria: colour, morphology, and margin adaptation. The results of endocrown restoration showed that patients were very satisfied with the function and aesthetics. LDC endocrowns showed clinically acceptable colour changes after staining with coffee for 2 weeks [11]. The participants were very satisfied about their LDC endocrown (93.8 %) after 24 months, and no one expressed an unsatisfied attitude toward the colour of the cemented partial crowns. Similarly, a previous study [36] found no colour change for CAD/CAM LDC crowns after 2 years of service. In a survey by Do et al., they concluded that 100 % of patients were very satisfied with the function of the prosthesis [22]. The aesthetic and comfort percentages in the present study were 96.4 % and 94.6 %, respectively, and no one expressed a neutral and unsatisfied attitude toward the treatment. Zou et al. found that the high satisfaction percentage (98.0 %) for the colour remained unchanged ($P > 0.05$) throughout the follow-up assessments at 6 months and after 1, 2, and 3 years [37]. Monolithic zirconia endocrown restorations represent an effective method of restoring posterior teeth after RCT and under a short-term observation period. Thus, this type of endocrowns can be considered a reliable restoration for RCT molars with extensive coronal loss of substance.

Samorodnitzky et al. found that the restoration colour is the primary cause for patient dissatisfaction, as 89.3 % of patients were not satisfied with their aesthetic treatment [18]. However, 96.4 % of patients were satisfied about their endocrown colour, and no one expressed a neutral and unsatisfied attitude toward the treatment [20]. According to the VAS, 100 % of the patients were satisfied with their colour, whereas 0 % were dissatisfied by the restoration in both endocrown material groups. This result was contradictory to the findings of Chaiyabutr et al., who reported colour variations in CAD/CAM LDCs [14]. They explained that this phenomenon may be due to the optical characteristics of the material, which allows the underlying tooth shade stump to affect the final colour of the crown.

The marginal adaption of endocrowns in relation to LDCs showed good adaptation by 95.2 % and 85.6 % and less than 1 mm ledging by 4.8 % and 9.6 % after 12 and 24 months, respectively; these results disagreed with the marginal discrepancies detected among clinically acceptable crowns by Badar et al. [38]. Moreover, these values were much higher than the 49.1 % reported by Fattahi et al. [39], who showed marginal discrepancies in 85 % of the cases when examined radiographically. These discrepancies could be due to inaccuracies in the impression-taking by the clinician or improper handling of the dental casts by the dental technician. Recently, a systematic review showed that LDC and zirconia all-ceramic CAD/CAM crowns offer parallel marginal gap values [40], but the LDC material shows an excellent internal endocrown fit compared with zirconia [16].

Concerning patient satisfaction in the morphology of endocrown, a high percentage was very satisfied after 6, 12, and 24 months with 88.5 %, 76.9 %, and 76.9 %, respectively; patients who were satisfied represented 11.5 %, 23.1 %, and 23.1 % after the same recall periods, respectively; and no patient showed dissatisfaction. Similar findings were recorded previously for the same parameters and at similar follow-up periods [22]. The patients' satisfaction increased when the restorations were received in an academic institution, denoting that patients' confidence in the school or good relationship with the dental student may have elevated their opinions of the care received [41].

In contrast to our finding, CAD/CAM LDGC endocrowns had higher marginal adaptation values than zirconia endocrowns and other partial veneers constructed by the same systems as reported in previous studies [42, 43]. LDC and/or zirconia endocrowns fabricated for posterior teeth in both arches using CAD/CAM or heat press had marginal adaptation values within an acceptable range [16]. A recent systematic review showed that LDC and zirconia CAD/CAM crowns offer parallel marginal gap values, but LDGC material presents an excellent internal fit compared with zirconia [40].

The marginal adaptation is mostly evaluated by assessing the marginal gap, which is described as the distance between the internal surface of the restoration and the finish line of the preparation [44]. Inadequate

marginal adaptation can cause plaque accumulation, microleakage, cavities, and soft and hard tissue inflammation, resulting in restoration failure [45]. The marginal and internal discrepancies increase depending on the cavity depth, and both chairside CAD-CAM systems show similar discrepancies in the endocrowns [46].

Crown margins should be blended and confluent with the tooth structure without having any positive or negative ledges or gaps [47]. In clinical practice, crowns with faulty and imprecise margins are common. Multiple studies proposed the use of radiographic aids and clinical examinations for the detection of the proximal marginal fit of fixed dental restorations [38, 39, 48]. Radiographs were captured in the present study to evaluate the proximal marginal fit because they provide near-parallel images of the abutment tooth [31, 49]. Such images help in obtaining practical information regarding the adaptation of the crown margins, its location, and its relation to the crestal bone, resulting in an improved assessment of the treatment prognosis [39]. Similar findings have stated that ceramic types have a 100 % radiographical survival rate at 2 years [50–52].

Schaefer et al. described a 0.05–0.15 mm gap as acceptable marginal discrepancies [53], whereas Fattahi et al. considered the marginal gap > 0.05mm to be an open margin [39]. In the present study, the marginal adaptation of endocrowns in relation to the LDC was 95.2 % and 85.6 % with less than 1 mm of ledging after 12 and 24 months, respectively; these percentages were considered good and acceptable marginal adaptations, respectively. These values disagreed with the marginal discrepancies detected among clinically acceptable crowns by Schaefer et al. [53], who reported 49.1 % of the cases, but were near the percentage reported by Fattahi et al., who found marginal discrepancies in 85 % of the cases when examined radiographically [39]. These discrepancies could be due to inaccuracies in the impression-taking by the clinician or improper handling of the dental casts by the dental technician. Durre and Ahmad evaluated patients with cemented crowns and bridges on periapical radiographs and found marginal discrepancies in 13 % – 18 % of the cases [54]. They attributed these discrepancies to improper tooth preparation and impression errors or casting defects.

In the present study, multi-layered zirconia endocrowns showed good adaptation rates of 60 % and 40 % after 12 and 24 months, respectively. In multi-layered zirconia, the percentages of < 1 mm and > 1 mm crown ledging after 12 months were the same (20 %); after 24 months, the crown ledging rates were 20 % and 40 % for < 1 mm and > 1 mm, respectively. These findings agreed with the results of Geduk et al., who showed that preformed permanent molar zirconia crowns exhibit significantly lower plaque accumulation and gingival inflammation than permanent molar crowns in permanent first molars [31].

Endocrowns present a viable treatment option for RCT posterior teeth. They permit the preservation of the residual tooth structure, as post space preparation and placement, as well as preparation of a ferrule design, are avoided. Recent systematic reviews and meta-analyses demonstrated a high success rate for endocrowns in molars (72 % – 99 %) with a follow-up range of 3–19 years, revealing no significant difference between tooth types [55].

One of the limitations of the current study was that the sample size was calculated from a single population, and the follow-up period was short. Therefore, this study does not accurately reflect the population size, and its results should be evaluated with caution. Moreover, some problems associated with patients were encountered during the follow-up period, as the patients may not be present during follow-up appointments due to travel or changes in the place of work. Comprehensive studies that include additional areas, large sample sizes, and long follow-up periods are necessary to perform the clinical and radiographic evaluation of endocrowns made of different CAD/CAM ceramic materials. This paper may be considered a reference for future studies with large sample sizes to confirm the findings of this study.

CONCLUSION

On the basis of the findings of this prospective clinical study, the following conclusions were drawn:
Most of the participants expressed high satisfaction with the colour, morphology, and marginal adaptation of their endocrown at the 24-month follow-up.

The clinical results showed high patient satisfaction with LDC in comparison with the multi-layered zirconia endocrown, with significant differences in the colour and gender.

The radiographical marginal adaptation of multi-layered zirconia showed slight discrepancies in comparison with the LDC endocrown after follow up at 6 and 12 months.

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