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# Six-year clinical performance of lithium disilicate glass-ceramic CAD-CAM versus metal-ceramic crowns

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**PURPOSE.** To assess the clinical performance of monolithic CAD-CAM lithium disilicate glass-ceramic (LDGC) crowns and metal-ceramic (MC) crowns provided by predoctoral students. This study also assessed the effects of patient and provider-related factors on their clinical performance as well as patient preference for these types of crowns. **MATERIALS AND METHODS.** Twenty-five patients who received 50 crowns (25 LDGC CAD-CAM and 25 MC) provided by predoctoral students were retrospectively examined. LDGC CAD-CAM crowns were milled in-house using the CEREC Bluecam system and cemented with either RelyX Unicem or Calibra Esthetic resin cements. MC crowns were cemented with RelyX Unicem cement. Clinical assessment of the crowns and the supporting periodontal structures were performed following the modified California Dental Association (CDA) criteria. Patients' preference was recorded using a visual analog scale (VAS). The results were statistically analyzed using log-rank test, Pearson Chi-squared test and Kaplan-Meier survival analysis. **RESULTS.** Twelve complications were observed in the MC crown group (9-esthetic, 2-technical and 1-biological). In comparison, 2 complications in the LDGC CAD-CAM crown group were observed (1-technical and 1-esthetic). The 6-year cumulative survival rates for MC crowns and LDGC CAD-CAM were 90.8% and 96%, respectively, whereas the success rates were 83.4% and 96%, respectively. Overall, patients preferred the esthetic outcomes of LDGC CAD-CAM crowns over MC crowns. **CONCLUSION.** The high survival and success rates, low number of complications, and the high level of patients' acceptance of monolithic LDGC CAD-CAM crowns lend them well as predictable and viable alternatives to the "gold standard" MC crowns. [J Adv Prosthodont 2023;15:44-54]

**KEYWORDS**
Crowns; Computer-aided design; Metal ceramic restorations; Survival; Longevity

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## INTRODUCTION

Glass-ceramic materials with high translucency have been developed to overcome the esthetic challenges of metal-based crowns and to satisfy patients' demands. In 2006, computer-aided design-computer aided manufacturing (CAD-CAM) lithium disilicate glass-ceramic (LDGC) crowns (IPS e.max CAD; Ivoclar Vivadent, Schaan, Liechtenstein) became commercially available. Currently, it has become one of the most commonly used glass-ceramic materials for single crowns due to its excellent esthetic and mechanical properties.[1,2] The material is available in a complete range of shades and in three different levels of translucency (high translucency, medium opacity, and low translucency) for optimum color matching.[3] Low translucency LDGC material (IPS e.max CAD LT; Ivoclar Vivadent, Schaan, Liechtenstein) was found to be significantly more translucent than zirconia at thicknesses of 0.5 and 1.0 mm.[4]

Since IPS e.max CAD can be milled as thin as 1 mm, it is indicated for cases with limited space and is considered to require a minimally invasive tooth preparation. As a result, it preserves natural tooth structure and ultimately decreases the incidence of loss of vitality complications in young patients.[5-7] An additional advantage of monolithic LDGC CAD-CAM crowns is the absence of veneering porcelain, which in turn minimizes the risk of chipping which may occur with a bi-layered arrangement.[8] Furthermore, marginal adaptation of IPS e.max CAD was found to be significantly better than that of metal-ceramic (MC) crown (27 μm vs. 57 μm).[9] Clinical studies involving an observation period of 2 to10 years, evaluated the clinical performance of LDGC CAD-CAM crowns and demonstrated high survival rates between 83.5% and 100%.[10-15]

The extensive and increasing demand for LDGC crowns is supported by their numerous advantages, the patients' desire for having highly esthetic crowns, and its reasonable cost. LDGC CAD-CAM crowns have been extensively used as an alternative to MC crowns. Nevertheless, MC crowns are considered to be the gold standard for restoration of single teeth due to their long-term longevity and good mechanical and biological properties.[16-18] However, their esthetic qualities still present a challenge due to the presence of the underlying metal framework causing greying of gingival tissue and subsequent inferior optical properties. In addition, the literature reported that porcelain chipping was the most common complication in MC crowns with a rate of 2.6% after 5 years.[19]

Several clinical studies and systematic reviews have been conducted to assess the clinical performance of all-ceramic and MC crowns, but none have statistically compared the clinical performance of LDGC CAD-CAM versus MC crowns.[19-23] Therefore, the aims of this retrospective study were to assess the clinical performance of posterior LDGC CAD-CAM and MC crowns and to evaluate the effects of patient's gender, age, oral hygiene condition, location of tooth in the mouth, pulp condition (vital vs. endodontically-treated), type of cement used, nature of opposing dentition, and type of provider on their clinical performance.

In addition, to examine the patient's preference for monolithic LDGC CAD-CAM crowns compared to MC crowns.

## MATERIALS AND METHODS

The present retrospective study was registered at ClinicalTrials.gov (Identifier: NCT03921307) on 04/19/2019. The study protocol was approved by the Research Ethics Board at the University of Toronto (No. 33291). The study included participants who had posterior monolithic LDGC CAD-CAM and MC crowns placed in opposing quadrants of their mouths at the same time at the Faculty of Dentistry for at least 6 years. A recruitment letter was mailed to 30 qualified individuals, followed by telephone calls. Of the 30 qualified patients, 25 patients agreed to participate in the study, 2 patients were not interested and 3 patients did not respond.

The crowns were prepared and cemented by final year predoctoral students who were either regular Doctor of Dental Surgery (DDS) or Internationally-trained Dentists (ITD) in the DDS program at the Faculty of Dentistry, University of Toronto. The ITDs have prior clinical experience, whereas the DDS students haven't. The inclusion criteria involved the following: indication for a posterior crown, successful

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endodontic treatment, adequate post/core seal and healthy periodontal condition.

Tooth preparation for LDGC CAD-CAM crowns were carried out according to specific criteria and according to the manufacturer's recommendations as follows: 1.0 mm axial reduction with a shoulder finish-line, rounded line angles and 1.5 mm occlusal reduction.[13,15] Tooth preparations for MC crowns were carried out as follows: 1.2 mm bucco/proximal reduction, 0.7 mm proximo/lingual reduction, rounded line angles and 1.5 mm occlusal reduction with an additional 0.5 mm in the functional cusp area.[24] Shade was selected by the operator and patient using VITA shade guide (VITA 3D Master; Vita Zahnfabrik, Bad Säckingen, Germany). The selection was confirmed by the instructor.

Impressions for both groups were taken with light-body and medium-body polyvinyl siloxane materials (Aquasil; Dentsply Sirona, Milford, DE, USA) using a custom fabricated tray. For the CAD-CAM crowns, stone dies were sprayed with CEREC Optispray (Sirona Dental Systems, Bensheim, Germany) and then scanned with an intra oral digital scanner (CEREC Bluecam; Dentsply Sirona, Charlotte, NC, USA). Crowns were milled by an experienced technician with a CEREC MC machine (CEREC software 4.0.3; Dentsply Sirona, Charlotte, NC, USA) in-house using IPS e.max CAD blocks (Ivoclar Vivadent, Schaan, Liechtenstein). The IPS e.max CAD blocks comprise 0.2-μm to 1-μm lithium metasilicate crystals ($Li_2SiO_3$) with 40% crystals by volume. After milling, the crown undergoes a two-stage firing process for 20 - 25 minutes in order to complete the crystallization process. During the course of this process, lithium disilicate crystals ($Li_2Si_2O_5$) are formed and contribute to the final shade and desired strength. The resulting ceramic is composed of fine-grains, 1.5 μm in size and a 70% crystal composition by volume.

For the MC crowns, high noble alloys (Argedent 54; The Argen Corporation, San Diego, CA, USA) were used. The alloy composed of Au 54.2%, Pd 31.0%, Ag 4.8%, In 9.0%, Ga 0.9% and Ru 0.1%. MC framework was manufactured using lost wax technique with a minimum thickness of 0.3 mm. Subsequently, metal cores were partially veneered with fine-structured feldspar ceramic (VITA VM 13; Vita Zahnfabrik, Bad Säckingen, Germany). LDGC CAD-CAM crowns were cemented with dual-cure self-adhesive universal resin cement (RelyX Unicem; 3M ESPE, St. Paul, MN, USA) and with dual-cure resin cement (Calibra Esthetic; Dentsply Sirona, Milford, DE, USA). All MC crowns were cemented with RelyX Unicem resin cement.

Cementation procedure for Calibra Esthetic resin cement are as follows:

1. Internal surface of the crown was etched with 9.6% hydrofluoric acid (Porcelain Etch Gel; Pulpdent, Watertown, MA, USA) for 15 seconds, and then rinsed and dried.
2. Silane agent (Monobond Plus; Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the etched internal surface and air dried.
3. Prepared teeth were etched with 38% phosphoric acid, rinsed with water and gently air dried.
4. Bonding agent (Prime&Bond NT; Dentsply Sirona, Milford, DE, USA) was applied to the tooth and to the internal surface of the crown and cured for 10 seconds.
5. Dual-cure resin cement (Calibra Esthetic; Dentsply Sirona, Milford, DE, USA) was applied to the internal surface of the crown and light cured with a light-emitting diode light-polymerizing unit for 10 seconds to easily remove excess cement. Then, each surface was light-cured for 20 seconds.

Cementation procedure for RelyX Unicem resin cement are as follows:

After cleaning the prepared tooth and the fitting surface of the crown, the dual-cure self-adhesive universal resin cement (RelyX Unicem; 3M ESPE, St. Paul, MN, USA) was placed inside the crown. After seating, initial polymerization was initiated with a light-emitting diode light-polymerizing unit for 2 seconds to remove excess cement. Then, each surface was light-cured for 20 seconds.

The following steps were followed in order to evaluate the crowns for each patient:

1. Informed consent was properly discussed and documented with all patients.
2. Patients were asked if they experienced any pain or sensitivity since the crown insertion.
3. Patient self-assessment using a visual analog scale (VAS) questionnaire (range 0 - 100 mm) was implemented. Patients were asked to record their

preferences for both crowns regarding the following parameters: crown color, crown shape, quality of proximal contacts (presence of food impaction next to the crown), chewing ability and overall satisfaction. In addition, the evaluators recorded their own observations for crown color, shape, and quality of proximal contacts (assessed visually as well as with dental floss).

4. A series of intraoral photographs were taken. These included frontal/buccal views of the crown and adjacent teeth, as well as occlusal views.
5. Radiographic examination (periapical and bitewing radiographs) for each crown was conducted.

The clinical evaluation was conducted by two calibrated and independent evaluators (a graduate student and a faculty member) who were not involved in the treatment procedures. The inter-rater reliability was calculated using kappa (κ) statistics. The abutment teeth and the contralateral teeth were assessed clinically and radiographically for the following parameters: presence of inflammation, pocket depth (PD) and bleeding on probing (BoP),[25,26] presence of excess cement, presence of recurrent caries at the margins, presence of periapical infection and tooth fracture.

A comprehensive assessment of the crowns was carried out following the modified California dental association (CDA) criteria.[27] The complications associated with crowns were classified into three categories: 1) biological, including recurrent caries, endodontic problems and tooth facture; 2) technical, including marginal integrity, chipping, presence of crack lines, crown fracture, open contacts, and loss of retention; and 3) esthetics, including surface texture, color match, contour quality and marginal discoloration. Marginal adaptation and presence of secondary caries were examined visually with a sharp explorer and with the aid of bitewing radiographs. Marginal discoloration was assessed visually after air-drying. The location of crown margins (supragingival, equigingival or subgingival) was also recorded in order to assess the association between periodontal health and the marginal location.

The clinical performance of crowns was assessed based on success and survival rates. Primary outcomes were the survival rate and time to event. The secondary outcome was the success rate. Success was recorded for crowns that were present without core fracture, porcelain fracture, caries, periodontal inflammation or endodontic signs and symptoms. Survival was defined as the crown having remained in-situ with or without modification over the entire observation period.[28]

Descriptive statistics were computed with SPSS 25.0 software (IBM Corp, Armonk, NY, USA). Each mechanical, biological and esthetic complication was considered as a statistical event. The level of significance for all tests was $\alpha = 0.05$. The McNemar Chi-square test for paired proportions and t-test were used in order to assess the prevalence and severity of PD and BoP. Pearson Chi-square test was used to assess the association between location of margins and periodontal condition. Kaplan-Meier survival analysis was performed to calculate the survival and success probabilities of crowns. The log-rank (Mantel-Cox) test was used to calculate the effect of several patient-based and operator-based factors on the survival rate, whereas the Pearson Chi-square test was used to calculate the effect of the same factors on the success rate. The Wilcoxon signed-rank test was used to assess patients' and operators' preferences for the two crown types. The level of agreement between patients and evaluators was assessed using intra-class correlation coefficient (ICC).

## RESULTS

Twenty-five patients (7 males and 18 females) with a mean age of 57.8 years (median ± SD = 63 ± 15.36 years) were examined according to the previously described protocol, with a total number of 25 LDGC CAD-CAM and 25 MC crowns for a follow-up period of up to 6 years. The inter-rater agreement for crowns evaluation was almost perfect ($\kappa = 0.95$). According to the split-mouth design, one LDGC CAD-CAM crown and one MC crown were inserted in the same arch for each patient (Fig. 1). The distribution of examined crowns is summarized in Table 1.

The presence of recurrent caries was observed in one MC crown and was regarded as a failure. One patient in each group reported post-operative sensitivity for up to two months. No other biological complica-

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**Fig. 1.** Occlusal view of the maxillary right first molar lithium disilicate glass-ceramic crown and maxillary left first molar metal ceramic crown at the 6-year recall visit.

tions were observed. One case with an open margin was observed in each group, and one case with a marginal overhang was observed in the MC group. Open margins were considered as a failure. One MC crown debonded after 3 months. No fractures were observed for any crown in both groups throughout the observation period.

Six marginal discolorations were observed in the MC crowns group (Fig. 2). Three color mismatches were observed in the MC group while one case was reported in the LDGC CAD-CAM group. Neither group presented with deterioration in periodontal health compared to the baseline and to the contralateral teeth. Detailed information of each complication is presented in Table 2.

Of the 14 complications encountered, 3 crowns were considered as failures and were included in the survival analysis (1 open margin in the LDGC CAD-CAM group, 1 open margin and 1 recurrent caries in the MC group). The cumulative Kaplan-Meier survival rate was 96% (95% CI = 92.3% to 99.8%) for LDGC CAD-CAM crowns, and 90.8% (95% CI = 85.3% to 96.5%) for MC crowns after 6 years (Fig. 3A). Log-rank test revealed that there was no statistically significant difference in the survival of both crown groups ($P$ = .563). Patient's attributes such as age and gender had no significant influence on survival rate of all the crowns. Periodontal condition, tooth type (premolar

**Table 1.** Distribution of all the lithium disilicate glass-ceramic and metal ceramic crowns by location, type of provider, tooth vitality and type of cement used

| Group | Count | Tooth location | Premolar | Molar | DDS | ITD | Vital | Non-vital | RelyX Cement | Calibra Cement |
|---|---|---|---|---|---|---|---|---|---|---|
| LDGC CAD | 25 (50.0) | Maxilla | 9 (36.0) | 11 (44.0) | 12 (48.0) | 8 (32.0) | 9 (36.0) | 11 (44.0) | 15 (60.0) | 5 (20.0) |
| | | Mandible | 3 (12.0) | 2 (8.0) | 5 (20.0) | 0 (0.0) | 0 (0.0) | 5 (20.0) | 3 (12.0) | 2 (8.0) |
| MC | 25 (50.0) | Maxilla | 9 (36.0) | 11 (44.0) | 17 (68.0) | 3 (12.0) | 6 (24.0) | 14 (56.0) | 20 (80.0) | 0 (0.0) |
| | | Mandible | 3 (12.0) | 2 (8.0) | 5 (20.0) | 0 (0.0) | 1 (4.0) | 4 (16.0) | 5 (20.0) | 0 (0.0) |
| Total | 50 (100.0) | | 24 (48.0) | 26 (52.0) | 39 (78.0) | 11 (22.0) | 16 (32.0) | 34 (68.0) | 43 (86.0) | 7 (14.0) |

Values are presented as n (%).
RelyX Cement = dual-cure self-adhesive universal resin cement (RelyX Unicem; 3M ESPE, St. Paul, MN, USA). Calibra Cement = dual-cure resin cement (Calibra Esthetic; Dentsply Sirona, Milford, DE, USA). DDS = Doctor of Dental Surgery students. ITD = Internationally-trained dentists in the DDS program.
LDGC CAD: lithium disilicate glass-ceramic CAD-CAM, MC: Metal ceramic.


**Fig. 2.** Esthetic evaluation after 6 years for one patient with lithium disilicate glass-ceramic crown on the right side and metal ceramic crown on the left side. (A) Maxillary right second premolar lithium disilicate glass-ceramic crown with no marginal discoloration. (B) Marginal discoloration related to the maxillary left second premolar metal ceramic crown.

**Table 2.** Biological, technical, and esthetic complications observed in the lithium disilicate glass-ceramic and metal ceramic groups

| Type of Complication | N (%) | Tooth* | Vitality Status | Time (months) | Outcome |
|---|---|---|---|---|---|
| Biological | | | | | |
| Recurrent caries | | | | | |
| LDGC CAD-CAM | 0 | --- | --- | --- | ----- |
| MC | 1 (4.0) | 36 | Non-vital | 51.0 | Failed |
| Technical | | | | | |
| Open margin | | | | | |
| LDGC CAD-CAM | 1 (4.0) | 25 | Vital | 36.0 | Failed |
| MC | 1 (4.0) | 14 | Non-vital | 48.0 | Failed |
| Debonding | | | | | |
| LDGC CAD-CAM | 0 | --- | --- | --- | ----- |
| MC | 1 (4.0) | 16 | Vital | 3.0 | Survived |
| Esthetic | | | | | |
| Color mismatch | | | | | |
| LDGC CAD-CAM | 1 (4.0) | 25 | Vital | 36.0 | Survived |
| MC | 3 (12.0) | 14<br>26<br>46 | Non-vital<br>Non-vital<br>Non-vital | 75.0<br>77.0<br>45.0 | Survived<br>Survived<br>Survived |
| Marginal discoloration | | | | | |
| LDGC CAD-CAM | 0 | --- | --- | --- | ----- |
| MC | 6 (24.0) | 15<br>15<br>16<br>25<br>25<br>26 | Vital<br>Vital<br>Non-vital<br>Non-vital<br>Non-vital<br>Non-vital | 70.0<br>69.0<br>72.0<br>73.0<br>49.0<br>77.0 | Survived<br>Survived<br>Survived<br>Survived<br>Survived<br>Survived |
| Total | | | | | |
| LDGC CAD-CAM | Technical = 1 (4.0)<br>Esthetic = 1 (4.0) | | 2-Vital<br>0-Non-vital | | 1-Failed<br>1-Survived |
| MC | Biological = 1 (4.0)<br>Technical = 2 (8.0)<br>Esthetic = 9 (36.0) | | 3-Vital<br>9-Non-vital | | 2-Failed<br>10-Survived |

*Tooth number according to the Federation Dentaire Internationale (FDI) numbering system.

or molar), tooth location (maxilla vs. mandible), vitality status, type of cement, nature of opposing teeth and provider's clinical experience (DDS vs. ITD) had no effect on the survival rate.

All fourteen complications (Table 2) were considered in order to estimate the success rate. After 6 years, overall success rate was 96% (95% CI = 92.3% to 99.8%) for LDGC CAD-CAM crowns and 83.4% (95 CI = 77.2% to 89.8%) for MC crowns (Fig. 3B). Chi-square test showed that all patient and operator attributes had no significant effect on the success rates of both crown groups.

Mean values of patient's response (VAS questionnaire) for both crown groups were analyzed (Table 3). Statistically, the results showed that LDGC CAD-CAM crowns were rated significantly higher than MC crowns in the following domains: color (90.0% vs. 80.7%, $P$ = .016), chewing ability (96.2% vs. 93.6%, $P$ = .021), and overall rating (91.0% vs. 85.7%, $P$ = .035) (Fig. 4A). Evaluators rated the color and shape higher in the LDGC CAD-CAM group. No significant difference was found between the two crown groups regarding the quality of proximal contacts ($P$ = .337) (Fig. 4B). The intra-class coefficient correlation analysis be-

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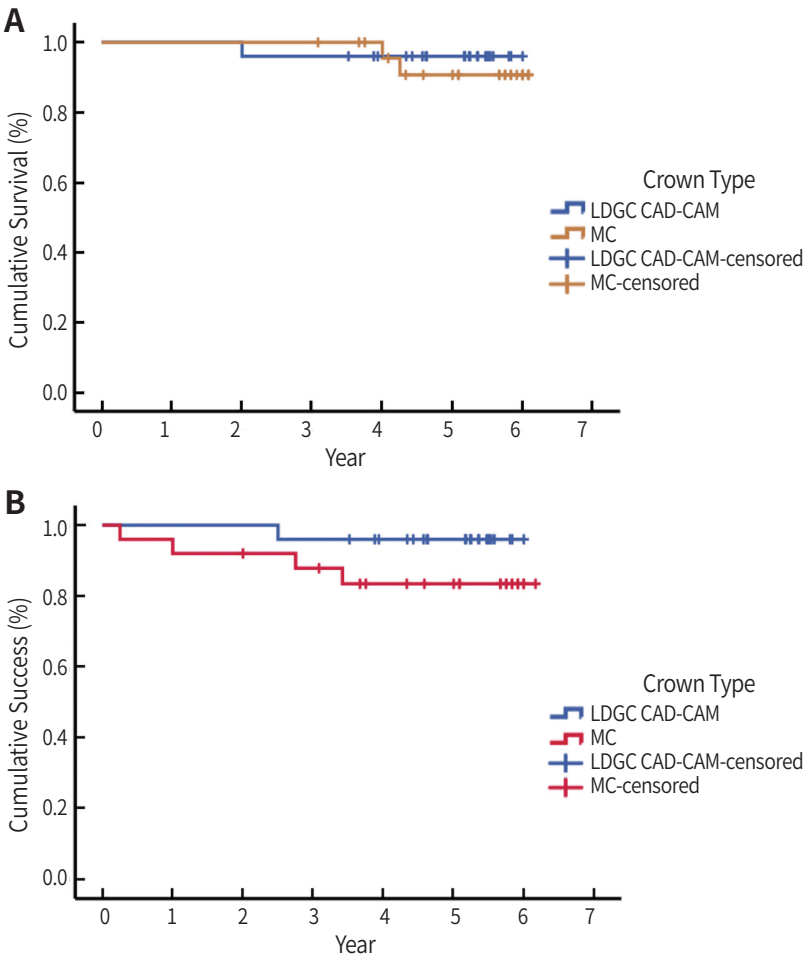


**Fig. 3.** (A) Kaplan-Meier survival analysis of lithium disilicate glass-ceramic and metal ceramic crowns at 6 years. (B) Kaplan-Meier success probabilities of ithium disilicate glass-ceramic and metal ceramic crowns at 6 years.

tween patients and evaluators showed fair agreement for the crowns' color (0.43), shape (0.48) and quality of proximal contacts (0.40).

## DISCUSSION

The split-mouth study design was introduced by Ramfjord *et al*.,[29] in an effort to decrease much of the inter-subject variability present in the whole-mouth design, while increasing the power of the study.[30] In addition, this design considerably reduces the differences between subjects from different treatment groups by establishing 'within-patient' comparisons, rather than 'between-patients' comparisons.[31]

After a follow-up period of 6 years, the cumulative survival rate of LDGC CAD-CAM crowns (96.0%) was higher than MC crowns (90.8%). Findings of the present study are in agreement with those of two previous studies that lasted 24 and 42-months and reported a 100% survival rate of LDGC CAD-CAM crowns.[12,14] For MC crowns, a survival rate of 90.8%, which is similar to what was found in the present study, was reported by Reitemeier *et al*.[17] However, it is lower than a 5-year survival rate of 95.7% reported by Sailer *et al*.[19] in a systematic review. Nevertheless, the sample size in the latter study was much larger and this may have affected the overall survival rate. In the present study, the sample size was fairly small, and therefore, findings of the present study must be interpreted with caution.

In the present study, there was one recurrent caries case in the MC group. This represented 4% of the sample and was higher than rates reported in other studies on MC crowns.[19,32,33] No loss of vitality for teeth with MC crowns was observed. This differed from other studies reporting rates between 1.8 to 16%.[19,34,35] No loss of vitality for LDGC CAD-CAM groups was observed in the present study. This also

**Table 3.** Patients' and evaluators' preference for lithium disilicate glass-ceramic and metal ceramic crowns recorded with visual analogue scale; mean differences calculated with Wilcoxon Signed Rank test

| Criteria | Crown system | Patient Mean (SE) | Patient 95% CI Lower | Patient 95% CI Upper | Patient Median | Patient Wilcoxon Signed Ranks | Evaluator Mean (SE) | Evaluator 95% CI Lower | Evaluator 95% CI Upper | Evaluator Median | Evaluator Wilcoxon Signed Ranks | ICC (95% CI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Color | LDGC CAD | 90.00 (2.28) | 85.09 | 94.51 | 91.00 | $P = .016$ | 82.24 (2.36) | 77.35 | 87.13 | 84.00 | $P = .002$ | 0.43 (0.01 – 0.67) |
| | MC | 80.72 (3.37) | 73.75 | 87.69 | 84.00 | | 70.52 (2.11) | 66.16 | 74.88 | 71.00 | | |
| Shape | LDGC CAD | 93.08 (2.09) | 88.76 | 97.40 | 97.00 | $P = .118$ | 94.72 (1.04) | 92.56 | 96.88 | 96.00 | $P < .001$ | 0.48 (-0.71 – 0.49) |
| | MC | 89.96 (2.13) | 85.56 | 94.36 | 93.00 | | 79.92 (2.52) | 74.70 | 85.14 | 82.00 | | |
| Proximal contact | LDGC CAD | 90.48 (2.69) | 84.91 | 96.05 | 95.00 | $P = .337$ | 90.44 (2.63) | 85.01 | 95.87 | 96.00 | $P = .581$ | 0.40 (-1.13 – 0.61) |
| | MC | 90.28 (1.86) | 86.43 | 94.13 | 92.00 | | 90.32 (2.25) | 85.66 | 94.98 | 94.00 | | |
| Chewing ability | LDGC CAD | 96.28 (0.90) | 94.41 | 98.15 | 97.00 | $P = .021$ | NA | NA | NA | NA | NA | NA |
| | MC | 93.60 (1.23) | 91.06 | 96.14 | 96.00 | | | | | | | |
| Overall | LDGC CAD | 91.00 (1.90) | 87.08 | 94.92 | 94.00 | $P = .035$ | 82.60 (2.35) | 77.74 | 87.46 | 85.00 | $P < .001$ | 0.29 (-0.13 – 0.58) |
| | MC | 85.72 (2.28) | 81.00 | 90.44 | 89.00 | | 71.56 (1.75) | 67.94 | 75.18 | 72.00 | | |

SE = Standard error. 95%CI = 95% Confidence interval. ICC = Intra-class correlation coefficient. NA = not available.

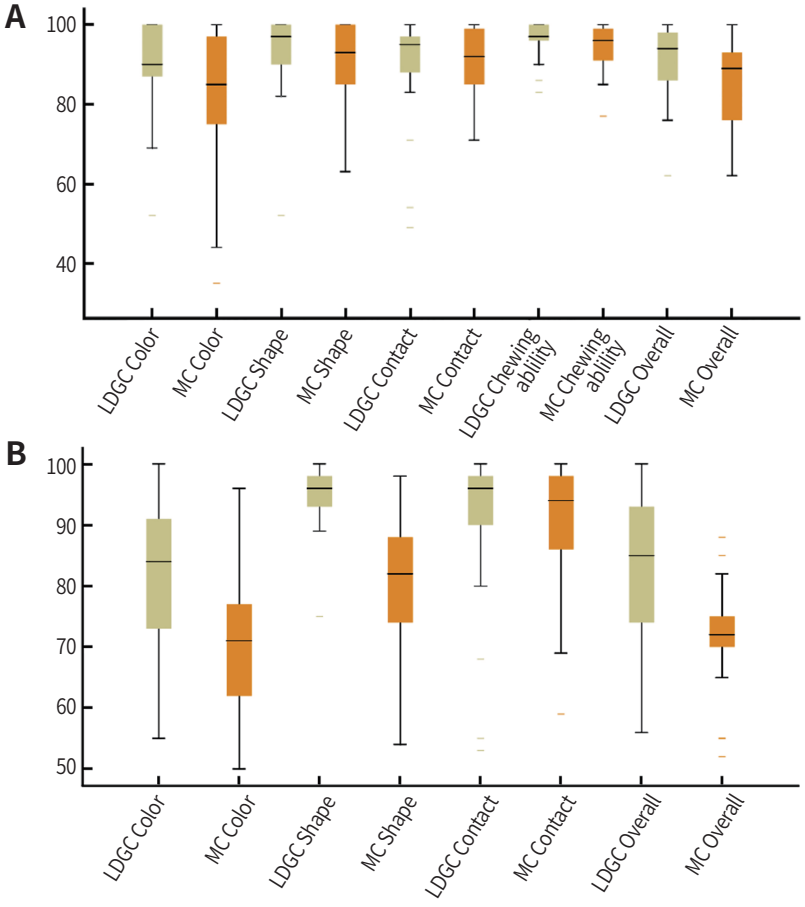


**Fig. 4.** Patients' and evaluators' satisfaction with both crown groups recorded with visual analog scale (VAS). (A) Patient outcomes: lithium disilicate glass-ceramic and metal ceramic crowns recorded with VAS. Box plots represent median, 25th and 75th percentiles, minimum and maximum values. (B) Evaluator outcomes: lithium disilicate glass-ceramic and metal ceramic crowns recorded with VAS. Box plots represent mean, 25th and 75th percentiles, and minimum and maximum values.

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differed from previous studies on chairside LDGC CAD-CAM crowns, where the reported loss of vitality was the most frequent biological complication occurring in the first two years with rates ranging from 4.9% to 6.7%.[11,13,15] These results are in line with previous studies confirming that CAD-CAM crown preparations are more conservative and, as a result, may cause less pulpal trauma.[6,7] In the present study, the LDGC CAD-CAM group performed biologically better than the MC group with no recurrent caries. These findings are in accordance with the findings of a systematic review that evaluated all-ceramic and MC crowns for a period of 5 years.[19]

While assessing the technical complications, one open margin was found in each group. This counted as a failure as it may lead to crown replacement. One MC crown was debonded after 3 months which was in agreement with previous studies reporting a loss of retention rate between 2.0% to 2.9%.[32,34] The crown and tooth were intact and the crown was re-cemented with RelyX Unicem resin cement. No debonding was observed in the LDGC CAD-CAM group with either cements. No porcelain chipping was observed in either group in spite of the fact that reports in the literature indicated that porcelain chipping was the most frequent technical complication for MC crowns with a rate of 1.8 to 3%.[19,32,33] In contrast, monolithic LDGC CAD-CAM crowns were not associated with porcelain chipping potentially due to the absence of veneering porcelain.[12,14,15] Overall, findings in the present study suggests that monolithic LDGC CAD-CAM crowns are strong and reliable even when they are provided by novice predoctoral students. This finding was confirmed in previous studies.[36-38]

With regards to the esthetic assessment of both groups, the MC crowns presented with more esthetic complications than LDGC CAD-CAM crowns (36% vs. 4%). Crown marginal discoloration and gingival discoloration of subgingival margins were reported only with the MC group. This finding may be related to the type of cement as all MC crowns were cemented with RelyX Unicem resin cement. Self-adhesive resin cement was associated with marginal discoloration and deterioration in marginal adaptation after 3 years [39] and 4 years [40] due to resin cement wear as well as patient-related factors (e.g. level of oral hygiene, diet, and smoking). In addition, some elemental content of MC crown alloys were related to marginal discoloration.[41] However, no crown was replaced due to poor esthetics. In contrast, esthetic properties of LDGC crowns remained excellent and patients were very satisfied with the esthetic appearance as described in this study and other reports.[15,42] No marginal discoloration was observed in this study for either cements (RelyX Unicem and Calibra Esthetic resin cements) when used with LDGC CAD-CAM crowns. Currently, the new materials and fabrication techniques dramatically improve marginal accuracy. It has been reported that the average marginal discrepancies of CAD-CAM restorations range from 35 to 71 microns, which is well within the acceptable marginal gap of less than 120 microns.[9,43,44] Minimal marginal gap will reduce the incidence of recurrent caries and marginal discoloration of all crowns. However, the results of this study suggest that RelyX Unicem and Calibra Esthetic resin cements can be safely used with LDGC CAD-CAM restorations.

The limitations of our study include the limited number of participants and a relatively short observational period. More clinical studies with larger sample sizes and longer observational periods are needed to examine the long-term success of LDGC CAD-CAM crowns and the effect of different factors on their longevity.

## CONCLUSION

Based on the findings of this retrospective clinical study, LDGC CAD-CAM crowns performed better than MC crowns over a period of 6 years with higher survival rates (96.0% for LDGC CAD-CAM vs. 90.8% for MC crowns) and success rates (96.0% for LDGC CAD-CAM vs. 83.4% for MC crowns). No porcelain chipping or fractures were observed for either crown types.

Esthetic outcomes of monolithic LDGC CAD-CAM crowns were significantly superior to MC crowns. Patients preferred monolithic LDGC CAD-CAM crowns over MC crowns.

Crowns fabricated with LDGC material using CAD-CAM technology could be considered as a viable and effective alternative to MC crowns.

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