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Clinical Evaluation of CAD/CAM All-Ceramic Crowns: A Randomized Controlled Study Comparing Lithium Disilicate and Lithium Aluminosilicate

Sinem Ok Tokaç[1] | Kübra Yıldız Domaniç[2] | Yılmaz Umut Aslan[3] | Yasemin Özkan[3]

[1]Department of Prosthodontics, Faculty of Dentistry, Kent University, Istanbul, Turkey | [2]Department of Prosthodontics, Faculty of Dentistry, Atlas University, Istanbul, Turkey | [3]Department of Prosthodontics, Faculty of Dentistry, Marmara University, Istanbul, Turkey

Correspondence: Kübra Yıldız Domaniç (drkubrayildiz@gmail.com; kubra.domanic@atlas.edu.tr)

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ABSTRACT

Objective: To compare the marginal and internal adaptation and to evaluate the clinical performance and patient satisfaction of CAD/CAM-fabricated all-ceramic crowns produced from lithium disilicate (LDS) and lithium disilicate–reinforced lithium aluminosilicate (LAS) over a 24-month follow-up period.

Materials and Methods: This randomized controlled, single-blinded clinical trial included 59 posterior single crowns placed in 37 patients. Twenty-nine crowns were fabricated from LDS (IPS e.max CAD; Ivoclar Vivadent), and 30 crowns were fabricated from LAS (n!ce Blocks; Institut Straumann AG). Marginal and internal adaptation were assessed before cementation using an in vivo silicone replica technique. Clinical performance was evaluated at baseline and after 6, 12, and 24 months using the modified United States Public Health Service (USPHS) criteria together with the Gingival Index (GI), Plaque Index (PI), and patient satisfaction assessed using a visual analogue scale (VAS). Statistical analyses were performed at a significance level of $p < 0.05$.

Results: No statistically significant differences were observed between the LDS and LAS groups regarding marginal, rounded shoulder, or occlusal gap measurements ($p > 0.05$). A statistically significant difference was observed at the axial measurement site ($p = 0.014$), with the LDS group exhibiting significantly greater axial internal gap values than the LAS group. During the 24-month follow-up period, six restorations failed because of fracture or debonding, including three LDS and three LAS crowns, resulting in survival rates of 89.7% for LDS, 90.0% for LAS, and 89.8% overall. Gingival and plaque index scores remained low and stable throughout the observation period, and patient satisfaction remained high in both groups, with no statistically significant differences between materials ($p > 0.05$). All clinically surviving restorations received Alpha or Bravo scores according to the modified USPHS criteria.

Conclusions: Within the limitations of this study, CAD/CAM-fabricated LDS and LAS crowns demonstrated comparable marginal adaptation, favorable clinical performance, and high patient satisfaction after 24 months of clinical service. The fully crystallized LAS ceramic appears to be a clinically acceptable and time-efficient alternative for posterior single-crown restorations. Nevertheless, long-term randomized clinical studies with larger sample sizes are required to confirm these findings.

1 | Introduction

All-ceramic restorations have become the treatment of choice for single-tooth rehabilitation because they successfully combine excellent esthetics, favorable optical properties, biocompatibility, and satisfactory mechanical performance. Continuous improvements in ceramic microstructure, adhesive dentistry, and computer-aided design/computer-aided manufacturing (CAD/CAM) technologies have considerably expanded the indications for all-ceramic restorations in both anterior and posterior regions. Contemporary CAD/CAM systems enable standardized digital workflows with improved manufacturing precision, reduced laboratory time, and predictable clinical outcomes. Consequently, monolithic glass–ceramic restorations have become increasingly popular for the restoration of posterior teeth because they preserve esthetics while providing adequate mechanical strength for functional loading [1–6].

Despite these technological advances, the long-term success of ceramic restorations depends on considerably more than their esthetic appearance or fracture resistance. Clinical longevity is influenced by a complex interaction between restorative material properties, preparation design, adhesive cementation, occlusal loading, and the accuracy of restoration adaptation. Among these factors, marginal and internal adaptation are widely regarded as two of the most important determinants of biological and mechanical success. Excessive marginal discrepancies may promote bacterial microleakage, cement dissolution, marginal discoloration, plaque accumulation, periodontal inflammation, postoperative sensitivity, recurrent caries, and ultimately restoration failure. Likewise, inadequate internal adaptation may result in excessive cement thickness, non-uniform stress distribution, reduced fracture resistance, and compromised seating of the restoration. Therefore, achieving optimal marginal and internal adaptation is considered a fundamental prerequisite for the long-term clinical success of CAD/CAM-fabricated ceramic restorations [7–10].

Several methods have been proposed to evaluate marginal and internal adaptation. Conventional techniques include direct microscopic examination, cross-sectional analysis, sectioning methods, and the silicone replica technique, whereas more recent digital approaches include triple-scan protocols and micro-computed tomography (micro-CT). Three-dimensional methods provide comprehensive visualization of the restoration-tooth interface; however, their clinical application remains limited because most require laboratory conditions or are not feasible for restorations evaluated in vivo. Recent systematic reviews have concluded that, despite the development of advanced digital techniques, the silicone replica technique remains one of the most practical and reliable methods for clinical investigations because it is non-destructive, reproducible, and permits evaluation before definitive cementation [11–13].

Recent evidence further indicates that restoration adaptation depends not only on the ceramic material itself but also on the entire digital workflow. Intraoral scanner accuracy, CAD software parameters, cement-space settings, milling strategies, bur geometry, and post-processing procedures all contribute to the final restoration fit [14]. An overview of systematic reviews by Porto et al. demonstrated that restorations fabricated using digital impression workflows achieve marginal adaptation comparable with or superior to those fabricated using conventional impression techniques, reinforcing the clinical reliability of contemporary CAD/CAM systems [15]. Consequently, evaluating newly introduced CAD/CAM ceramic materials under standardized clinical conditions remains highly relevant.

Among currently available CAD/CAM ceramics, lithium disilicate glass–ceramics have been extensively investigated and are considered the reference material for monolithic esthetic restorations because of their excellent balance between esthetics, mechanical strength, and adhesive bonding potential. IPS e.max lithium disilicate restorations may be fabricated using either heat-pressing (IPS e.max Press) or CAD/CAM milling (IPS e.max CAD). Following crystallization, IPS e.max CAD exhibits a flexural strength of approximately 360 ± 60 MPa, making it suitable for single crowns and short-span fixed dental prostheses [6, 16–19]. In addition, long-term prospective clinical studies have demonstrated excellent survival rates exceeding 95% after more than a decade of clinical service, confirming lithium disilicate as one of the most predictable glass–ceramic materials currently available [20].

Recently, a fully crystallized lithium aluminosilicate glass–ceramic reinforced with lithium disilicate (LAS; n!ce Blocks, Institut Straumann AG, Basel, Switzerland) has been introduced for chairside CAD/CAM applications. According to the manufacturer, this material exhibits a flexural strength of approximately 350 ± 50 MPa and a fracture toughness of ≥ 1.5 MPa·m½ in accordance with ISO 6872. Unlike conventional lithium disilicate blocks, LAS does not require a post-milling crystallization firing cycle, thereby simplifying the clinical workflow and reducing treatment time. In addition, the material has been reported to exhibit improved machinability and reduced bur wear, allowing milling times of approximately 8–14 min. Although available laboratory studies have reported promising mechanical properties and clinically acceptable marginal adaptation, high-quality clinical evidence evaluating the in vivo performance of lithium aluminosilicate restorations remains scarce [18, 19, 21–22]. To date, most published investigations comparing CAD/CAM ceramic materials have been conducted under laboratory conditions, and relatively few randomized clinical trials have simultaneously evaluated restoration adaptation, biological performance, and patient-reported outcomes under routine clinical conditions. Furthermore, clinical evidence regarding fully crystallized lithium aluminosilicate ceramics is still limited when compared with the extensive literature available for lithium disilicate restorations. Consequently, additional prospective clinical studies are required to determine whether the simplified manufacturing protocol of lithium aluminosilicate restorations translates into comparable clinical performance.

Therefore, the present randomized controlled clinical trial was designed to compare the marginal and internal adaptation, clinical performance, periodontal response, and patient satisfaction of CAD/CAM-fabricated lithium disilicate and lithium disilicate-reinforced lithium aluminosilicate crowns over a 24-month follow-up period. The null hypothesis was that no

significant differences would exist between the two ceramic materials regarding marginal and internal adaptation, clinical performance, or patient-reported outcomes.

2 | Materials and Methods

2.1 | Study Design

This randomized controlled, single-blinded clinical trial evaluated the marginal and internal adaptation and clinical performance of CAD/CAM-fabricated all-ceramic crowns produced from lithium disilicate (LDS; IPS e.max CAD Blocks, Ivoclar Vivadent, Schaan, Liechtenstein) and lithium disilicate–reinforced lithium aluminosilicate (LAS; n!ce Blocks, Institut Straumann AG, Basel, Switzerland). The chemical composition of the ceramic materials is presented in Table 1.

A total of 37 patients (15 females and 22 males; age range: 18–65 years) requiring posterior single full-coverage crowns were recruited from the Faculty of Dentistry, Marmara University, Istanbul, Türkiye. Patients were eligible if they were at least 18 years of age, were in good general and oral health, and had no active periodontal disease. Patients with severe bruxism, pregnancy, known allergy to resin-based luting agents, or systemic conditions that could compromise oral health were

TABLE 1 | Chemical composition and characteristics of the CAD/CAM ceramic materials used in the study.

Material	Trade name	Manufacturer	Main chemical composition	Flexural strength (MPa)	Crystallization state
Lithium disilicate (LDS)	IPS e.max CAD	Ivoclar Vivadent, Schaan, Liechtenstein	SiO2–Li2O–K2O–P2O5–ZrO2 glass–ceramic with lithium metasilicate crystals	~360 ± 60*	Pre-crystallized (blue state), crystallized after milling
Lithium disilicate–reinforced lithium aluminosilicate (LAS)	Nice blocks	Institut Straumann AG, Basel, Switzerland	SiO2–Al2O3–Li2O glass–ceramic reinforced with lithium disilicate crystals	~350 ± 50*	Fully crystallized

*According to manufacturer specifications.

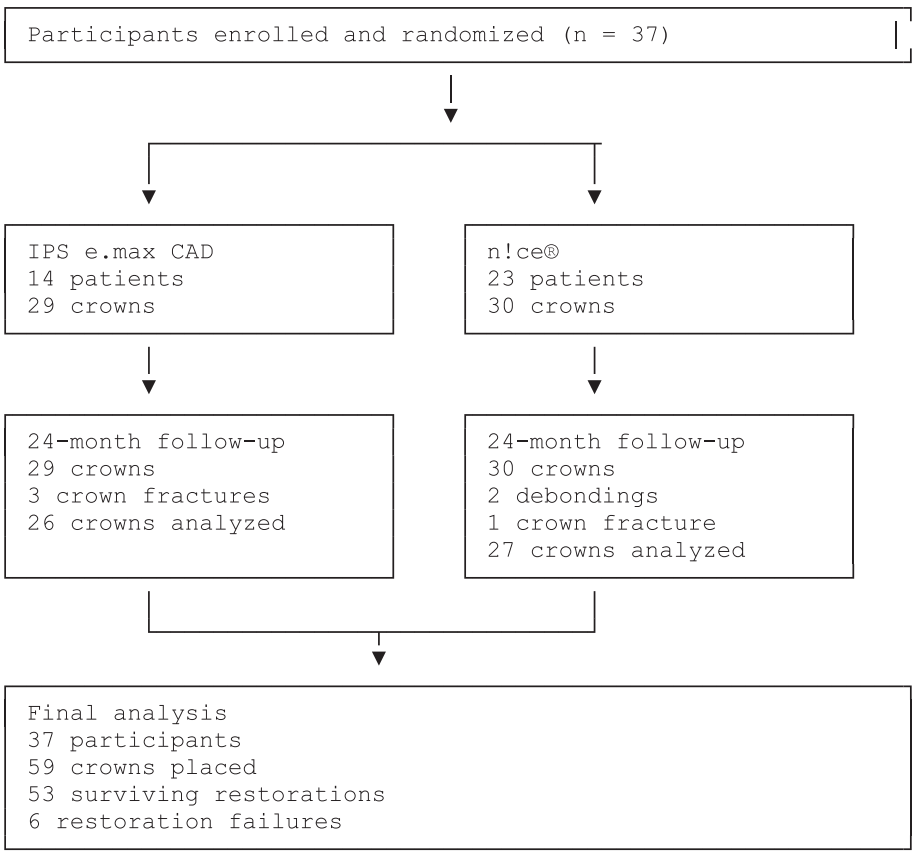

FIGURE 1 | Consort flow diagram.

excluded. The flow of participants throughout the study is presented in Figure 1.

A total of 59 posterior single crowns were placed. The LDS group consisted of 29 crowns placed in 14 patients, whereas the LAS group consisted of 30 crowns placed in 23 patients. Allocation to the ceramic material was performed using a computer-generated randomization sequence. Owing to the clinical characteristics of the recruited patients and the number of eligible teeth requiring restoration, an unequal number of restorations was allocated to each group. Each restoration was considered the experimental unit for statistical analysis.

All patients underwent standardized clinical and radiographic examinations before treatment, and baseline intraoral photographs were obtained.

The study followed a single-blinded design. Patients were blinded to the ceramic material used for their restoration, whereas the operator could not be blinded because of the different manufacturing procedures required for the two ceramic systems. Clinical outcome assessment was performed independently of the treatment procedures.

2.2 | Clinical Procedures

All clinical procedures were performed by a single experienced prosthodontist to ensure treatment standardization. Tooth preparation was identical for both ceramic systems and consisted of a circumferential 1-mm chamfer finish line located at the cemento-enamel junction.

Digital impressions were obtained using an Omnicam intraoral scanner (CEREC 3D, Sirona Dental Systems, Bensheim, Germany). Restorations were designed using CEREC SW 4.4.4 software and milled with the same CAD/CAM unit. LAS restorations were milled from fully crystallized blocks, whereas LDS restorations underwent crystallization firing after milling according to the manufacturer's instructions (Figure 2).

Before marginal fit assessment, all restorations were clinically tried in, and premature proximal and occlusal contacts were adjusted to ensure complete seating.

Marginal and internal adaptation were evaluated using the in vivo silicone replica technique. The intaglio surface of each restoration was filled with a light-body silicone material (Elite HD Super Light Body, Zhermack, Badia Polesine, Italy) and seated on the prepared tooth under standardized finger pressure for 2 min. Patients were instructed to bite gently on a cotton roll to simulate clinical cementation. After polymerization, the restoration was carefully removed.

The silicone replica was reinforced using a contrasting light-body silicone material (Elite HD Light Body, Zhermack), followed by a heavy-body silicone material. Each replica was sectioned buccolingually and mesiodistally through the center of the restoration. Measurements from both sections were averaged and recorded at four predetermined locations (marginal, rounded shoulder, axial, and occlusal). A total of 20 measurement points per restoration (4 marginal, 4 rounded shoulder, 8 axial, and 4 occlusal) were evaluated under a binocular light microscope (Leica Optic, Leica Cambridge Ltd., Cambridge, UK) at ×40 magnification according to the method described by Kokubo et al. (Figure 3).

Following fit evaluation, all restorations were adhesively cemented using a dual-cure resin cement (Variolink Esthetic DC, Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's recommendations.

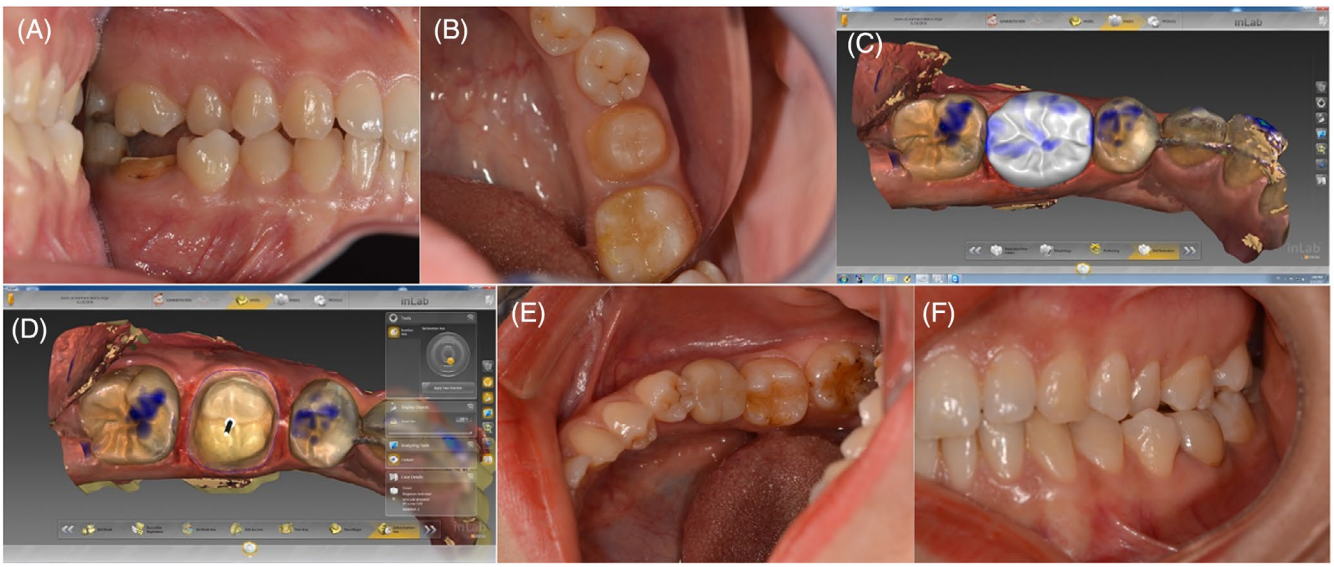

FIGURE 2 | Representative clinical workflow for the fabrication of CAD/CAM all-ceramic crowns. (A) Preoperative clinical view. (B) Tooth preparation. (C) Digital intraoral scanning. (D) CAD design of the restoration. (E) Milled all-ceramic crown. (F) Definitive restoration after adhesive cementation.

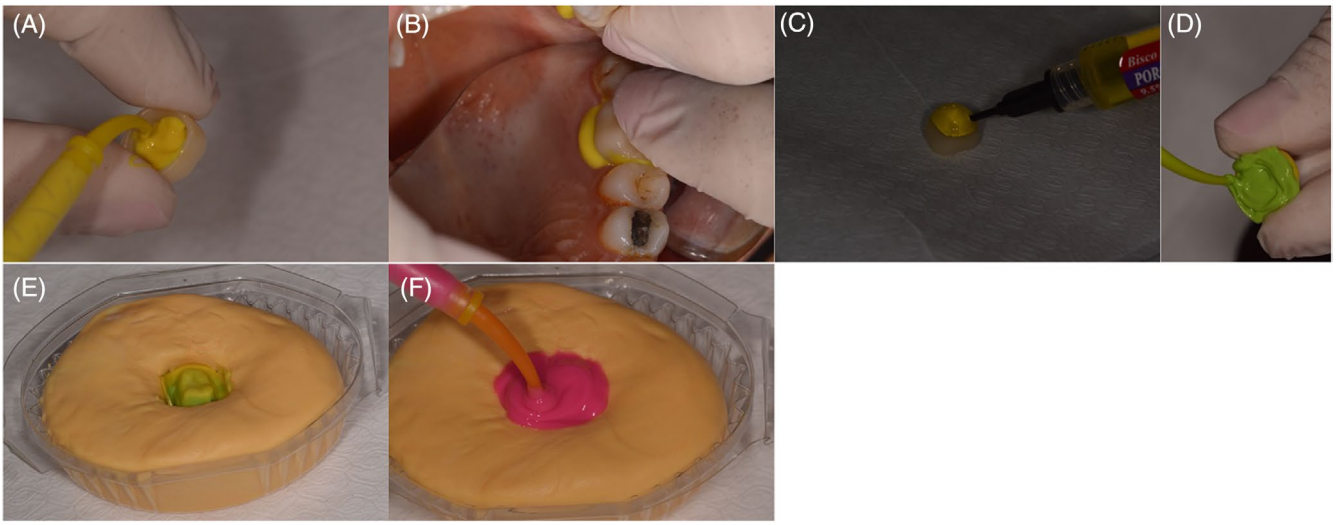

FIGURE 3 | Clinical steps of the silicone replica technique used for the evaluation of marginal and internal adaptation before definitive cementation. (A) Light-body silicone applied to the intaglio surface of the crown. (B) Crown seated on the prepared tooth under standardized pressure. (C) Polymerized light-body silicone replica after removal from the crown. (D) Reinforcement of the replica with a contrasting light-body silicone. (E) Reinforced silicone replica embedded in heavy-body silicone. (F) Final reinforced silicone replica ready for sectioning.

Clinical performance was evaluated at baseline and after 6, 12, and 24 months by two calibrated prosthodontists using the modified United States Public Health Service (USPHS) criteria. Gingival Index (GI) and Plaque Index (PI), according to Löe and Silness, were also recorded at each follow-up visit. Patient satisfaction was assessed using a 10-cm visual analogue scale (VAS).

2.3 | Statistical Analysis

Statistical analysis was performed using SPSS software (Version 26; IBM Corp., Armonk, NY, USA). Continuous variables were analyzed using independent sample *t*-tests, while categorical variables were evaluated using Chi-square tests. The level of statistical significance was set at $p < 0.05$.

No formal a priori sample size calculation was performed before patient recruitment. The sample size was determined according to the number of eligible patients requiring posterior single-crown restorations during the recruitment period.

3 | Results

3.1 | Study Population and Follow-Up

A total of 59 CAD/CAM-fabricated posterior single crowns were placed in 37 patients (15 females and 22 males; mean age: 38 ± 12 years). Twenty-nine crowns were fabricated from lithium disilicate (LDS) and 30 from lithium disilicate–reinforced lithium aluminosilicate (LAS). At baseline, no statistically significant differences were observed between the two groups regarding patient age, sex distribution, or tooth location.

All 59 restorations were evaluated for marginal and internal adaptation before definitive cementation. During the 24-month follow-up period, six restorations failed because of fracture or debonding. Three failures occurred in the LDS group (all crown fractures), whereas three failures occurred in the LAS group (one crown fracture and two debondings). Consequently, 53 restorations remained clinically functional at the 24-month evaluation, corresponding to survival rates of 89.7% for the LDS group, 90.0% for the LAS group, and 89.8% overall (Figure 1).

3.2 | Marginal and Internal Adaptation

The descriptive statistics, including median values, standard deviations, and 95% confidence intervals for marginal and internal adaptation at the marginal, rounded shoulder, axial, and occlusal measurement sites, are presented in Table 2. No statistically significant differences were observed between the LDS and LAS groups regarding marginal, rounded shoulder, or occlusal gap measurements ($p > 0.05$). However, a statistically significant difference was detected at the axial measurement site ($p = 0.014$), with the LDS group exhibiting significantly greater axial internal gap values than the LAS group.

3.3 | Clinical Evaluation

Clinical performance was assessed at baseline and after 6, 12, and 24 months using the modified United States Public Health Service (USPHS) criteria. Among the 53 restorations that remained in clinical service at the 24-month evaluation, all received Alpha or Bravo scores for color match, marginal integrity, and secondary caries throughout the observation period. No additional secondary caries, loss of retention, or endodontic complications were observed.

The Gingival Index (GI) and Plaque Index (PI) remained low and stable in both groups throughout the follow-up period, with no statistically significant differences between the ceramic materials at any evaluation interval (Tables 3 and 4).

TABLE 2 | Marginal and internal adaptation values (μm) of LDS and LAS crowns at different measurement locations.

Measurement location	Material	Median (μm)	SD (μm)	95% CI (μm)
Marginal	LDS	53.30	11.27	47.6–59.0
Marginal	LAS	53.69	11.24	49.6–57.8
Rounded shoulder	LDS	82.61	16.79	73.8–91.4
Rounded shoulder	LAS	84.58	17.45	78.2–91.0
Axial	LDS	57.67	14.43	50.1–65.2
Axial	LAS	46.98	10.72	43.1–50.8
Occlusal	LDS	152.87	19.94	142.4–163.3
Occlusal	LAS	155.13	24.47	146.2–164.1

TABLE 3 | Gingival Index (GI) scores of LDS and LAS crowns at different follow-up periods.

Follow-up time	LDS (Mean ± SD)	LAS (Mean ± SD)	*p*
Baseline	0.42 ± 0.18	0.44 ± 0.17	0.68
6 months	0.40 ± 0.16	0.43 ± 0.15	0.55
12 months	0.39 ± 0.15	0.41 ± 0.14	0.61
24 months	0.41 ± 0.17	0.42 ± 0.16	0.73

TABLE 4 | Plaque Index (PI) scores of LDS and LAS crowns at different follow-up periods.

Follow-up time	LDS (Mean ± SD)	LAS (Mean ± SD)	*p*
Baseline	0.46 ± 0.19	0.48 ± 0.18	0.64
6 months	0.45 ± 0.17	0.47 ± 0.16	0.59
12 months	0.44 ± 0.16	0.46 ± 0.15	0.62
24 months	0.45 ± 0.18	0.47 ± 0.17	0.67

Patient-reported outcomes assessed using the visual analogue scale (VAS) demonstrated high levels of satisfaction regarding esthetics, comfort, and overall function in both groups, with mean scores exceeding 8 on a 10-point scale throughout the study period. No statistically significant differences were detected between the LDS and LAS groups for any satisfaction parameter ($p > 0.05$).

Similarly, no significant differences were observed between the two materials regarding color stability, surface roughness, or chewing efficiency at baseline, 6–, 12–, or 24-month evaluations ($p > 0.05$). Color stability (LDS: $p = 0.261$; LAS: $p = 0.194$), surface roughness (LDS: $p = 0.572$; LAS: $p = 0.392$), and chewing efficiency (LDS: $p = 0.050$; LAS: $p = 0.050$) remained clinically acceptable throughout the follow-up period.

4 | Discussion

The present randomized controlled clinical trial evaluated the marginal and internal adaptation, clinical performance, and patient-reported outcomes of CAD/CAM-fabricated lithium disilicate (LDS) and lithium disilicate-reinforced lithium aluminosilicate (LAS) crowns over a 24-month follow-up period. Overall, both ceramic systems demonstrated clinically acceptable marginal adaptation, favorable biological performance, and high patient satisfaction throughout the observation period. Statistically significant differences between the materials were limited to the axial internal gap measurements, whereas marginal, rounded shoulder, and occlusal adaptation remained comparable. Accordingly, the null hypothesis was partially rejected because a statistically significant difference was observed only at the axial measurement site.

Marginal adaptation remains one of the most important determinants of the long-term clinical success of indirect restorations because excessive marginal discrepancies may facilitate cement dissolution, bacterial microleakage, plaque accumulation, secondary caries, and periodontal inflammation. Although the clinically acceptable threshold proposed by McLean and von Fraunhofer (< 120 μm) continues to be widely accepted, recent evidence suggests that restoration accuracy is influenced by the entire digital workflow rather than by the restorative material alone. Factors such as intraoral scanning accuracy, CAD software parameters, cement-space settings, milling strategies, bur geometry, and adhesive cementation protocols all contribute to the final marginal and internal adaptation. Therefore, evaluating newly introduced CAD/CAM ceramics under clinical conditions remains highly relevant despite continuous technological improvements [7–10, 15, 22].

The marginal gap values observed in the present study were within the range generally considered clinically acceptable, and no statistically significant differences were detected between LDS and LAS restorations. These findings are consistent with recent evidence synthesizing the available literature on digital workflows. In an overview of systematic reviews, Porto et al. concluded that restorations fabricated using digital impression workflows demonstrate marginal adaptation comparable with or superior to conventional impression techniques, while no systematic review demonstrated clear superiority of conventional workflows [15]. The authors further emphasized that the clinical performance of CAD/CAM restorations depends predominantly on the integration of the complete digital workflow rather than on isolated manufacturing steps [15]. The present findings support this concept, as both ceramic systems were fabricated using identical digital

scanning, design, and milling protocols, thereby minimizing operator- and technique-related variability.

Similarly, recent systematic reviews evaluating lithium disilicate restorations have reported that CAD/CAM fabrication provides highly predictable marginal and internal adaptation with values consistently remaining within clinically acceptable limits [11, 22]. Nevertheless, these reviews also indicate substantial methodological heterogeneity among published studies regarding impression techniques, measurement protocols, cement-space settings, and evaluation methods, making direct comparison challenging. Consequently, differences reported between ceramic materials should be interpreted cautiously because methodological variables frequently exert a greater influence on restoration fit than the ceramic composition itself [11, 22].

Only the axial internal measurements demonstrated a statistically significant difference between the investigated materials. Although statistically significant, the magnitude of this difference was relatively small and is unlikely to be clinically relevant considering that both groups remained within clinically acceptable internal gap ranges. Internal adaptation is affected by numerous factors including convergence angle, preparation geometry, cement-space parameters, scanner resolution, software algorithms, milling bur diameter, and restoration geometry. Because all restorations in the present investigation were produced using the same CAD/CAM workflow, differences observed at the axial walls are more likely related to subtle variations in preparation geometry and restoration morphology than to intrinsic differences between the ceramic materials themselves. This interpretation is supported by contemporary systematic reviews demonstrating that restoration design and manufacturing variables frequently have a greater influence on internal adaptation than the restorative material alone [11, 22–24].

An additional finding was that the highest internal discrepancies were consistently observed at the occlusal surfaces in both groups. Similar observations have been reported in numerous laboratory and clinical investigations evaluating CAD/CAM restorations [11, 25–27]. Complex occlusal anatomy, limitations in milling bur diameter, restricted accessibility during machining, and software smoothing algorithms may contribute to larger occlusal discrepancies compared with axial or marginal regions. These findings reinforce the concept that internal adaptation should be interpreted according to the specific measurement location rather than as a single overall value.

One of the strengths of the present investigation is the use of the in vivo silicone replica technique for evaluating marginal and internal adaptation before definitive cementation. Among currently available assessment methods, the silicone replica technique remains one of the few non-destructive approaches applicable under clinical conditions. Unlike destructive sectioning techniques, it allows restorations to remain clinically usable after evaluation while providing reproducible measurements at predetermined anatomical locations. Recent systematic reviews have highlighted that the silicone replica technique continues to represent the most practical method for clinical investigations because it combines acceptable accuracy with minimal patient risk and does not interfere with subsequent cementation procedures [12].

Nevertheless, the silicone replica technique also presents recognized limitations. Because measurements are obtained from sectioned silicone replicas, the method provides only two-dimensional information and may be influenced by material deformation, tearing during sectioning, operator-dependent specimen preparation, and measurement variability. Alternative approaches, particularly micro-computed tomography (micro-CT), allow three-dimensional visualization of the entire internal space without sectioning and eliminate several methodological limitations associated with silicone replicas. However, despite its superior spatial analysis, micro-CT remains primarily a laboratory-based technique because scanning definitively cemented restorations in vivo is not clinically feasible. Consequently, recent methodological reviews continue to recommend the silicone replica technique as the preferred approach for clinical studies evaluating marginal and internal adaptation, whereas micro-CT is considered the reference method for in vitro investigations [12, 13].

Furthermore, an important methodological consideration concerns the number and distribution of measurement points. Rather than relying on a limited number of linear measurements, the present study evaluated 20 predefined locations for each restoration, including marginal, rounded shoulder, axial, and occlusal regions. This comprehensive measurement protocol reduced the influence of localized irregularities and provided a more representative assessment of restoration adaptation than protocols using only a few measurement sites. Such an approach is consistent with current recommendations advocating standardized measurement locations to improve comparability among future clinical investigations [12].

Beyond restoration adaptation, the present study demonstrated that both ceramic systems exhibited favorable clinical behavior throughout the 24-month observation period. Although seven restorations failed because of fracture or debonding during follow-up, the overall clinical performance remained satisfactory, and no significant differences were observed between the LDS and LAS groups regarding periodontal parameters, color stability, surface roughness, chewing efficiency, or patient satisfaction. These findings suggest that the fully crystallized lithium aluminosilicate ceramic performs clinically in a manner comparable to the well-established lithium disilicate system during short-term clinical service.

Lithium disilicate has become one of the most extensively investigated CAD/CAM ceramic materials because of its favorable combination of mechanical properties, esthetics, adhesive bonding potential, and long-term clinical reliability. Recently, Margvelashvili-Malament et al. reported a 14-year prospective clinical evaluation of 662 pressed lithium disilicate restorations placed in patients with severe tooth wear, demonstrating an overall survival rate of 98.6%, with failures occurring predominantly during the early years of service and very few biological complications [20]. Although the present study had a substantially shorter follow-up period and evaluated a different clinical population, the favorable short-term outcomes observed in

the LDS group are consistent with these long-term findings and further support the clinical predictability of lithium disilicate restorations [20, 28–30]. The lower survival rates observed in the present investigation are likely related to differences in study design, sample size, restoration characteristics, follow-up duration, and the definition of clinical failure rather than to the restorative material itself.

Unlike lithium disilicate, published clinical evidence regarding lithium aluminosilicate ceramics remains relatively limited. Consequently, one of the strengths of the present randomized clinical trial is that it provides prospective clinical data regarding a fully crystallized CAD/CAM lithium aluminosilicate material under routine clinical conditions. Although four failures were observed in the LAS group, survival rates were comparable with those of LDS restorations, and no statistically significant differences were detected in the evaluated clinical parameters. These findings suggest that fully crystallized lithium aluminosilicate ceramics may represent a clinically acceptable alternative for posterior single crowns while offering the practical advantage of eliminating the post-milling crystallization firing procedure, thereby reducing chairside and laboratory time [31].

Another important observation was the stability of periodontal conditions throughout the follow-up period. Gingival Index and Plaque Index scores remained consistently low in both groups, and no statistically significant differences were detected between the ceramic materials. Periodontal health around indirect restorations depends on multiple factors, including restoration contour, emergence profile, surface smoothness, marginal adaptation, cement removal, and oral hygiene. Because both ceramic systems demonstrated satisfactory marginal integrity and polished surfaces, comparable periodontal outcomes were expected. The absence of secondary caries and endodontic complications further supports the biological compatibility of both CAD/CAM ceramic systems during the observation period [28, 29].

Patient-reported outcome measures have become increasingly important in restorative dentistry because successful treatment should not be evaluated exclusively by clinician-based criteria. In the present study, patient satisfaction remained consistently high throughout the 24-month follow-up with respect to esthetics, comfort, chewing efficiency, and overall treatment acceptance. No statistically significant differences were observed between the two ceramic systems. These findings indicate that patients were unable to perceive clinically meaningful differences between the restorations despite the minor differences detected in axial internal adaptation. This observation emphasizes that statistically significant laboratory or clinical measurements do not necessarily translate into differences that are relevant from the patient's perspective. Consequently, incorporating patient-reported outcome measures alongside conventional clinical criteria provides a more comprehensive assessment of restorative success [18, 31, 32].

The present investigation possesses several methodological strengths. First, the study was designed as a randomized controlled clinical trial, thereby reducing selection bias and improving the level of clinical evidence. Second, all clinical procedures, including tooth preparation, digital impression making, restoration fabrication, and adhesive cementation, were performed using standardized protocols, minimizing operator-related variability. Third, marginal and internal adaptation were evaluated before definitive cementation under true clinical conditions using a standardized silicone replica protocol. Finally, objective clinical assessments were complemented by patient-reported outcomes, allowing simultaneous evaluation of biological, mechanical, esthetic, and patient-centered parameters.

Nevertheless, several limitations should be considered when interpreting the findings. Although the silicone replica technique represents one of the most practical methods for in vivo assessment of restoration fit, it remains an indirect two-dimensional technique that may be influenced by silicone deformation, sectioning procedures, and measurement variability [12, 13]. Furthermore, only posterior single crowns fabricated from two CAD/CAM ceramic systems were investigated; therefore, the findings cannot be directly extrapolated to anterior restorations, multi-unit fixed dental prostheses, or other ceramic materials. In addition, no a priori sample size calculation was performed, and the study population consisted of a convenience sample of eligible patients recruited during the study period. Therefore, the study may have been underpowered to detect small differences between the ceramic materials, particularly for secondary outcomes and relatively infrequent biological or mechanical complications. Furthermore, although the 24-month observation period allowed assessment of short-term clinical performance, it may not have been sufficient to detect late biological or mechanical complications.

Within these limitations, the present findings contribute to the growing body of evidence supporting the clinical application of CAD/CAM-fabricated glass–ceramic restorations. The results indicate that restoration success depends not only on the ceramic material itself but also on meticulous clinical execution, accurate digital workflow, appropriate adhesive cementation, and regular maintenance. Continued technological advances in intraoral scanning, CAD software algorithms, milling accuracy, and ceramic manufacturing are expected to further improve restoration adaptation and long-term clinical performance. Well-designed multicenter randomized clinical trials with extended follow-up periods remain necessary to establish the long-term durability of fully crystallized lithium aluminosilicate restorations and to determine whether their simplified manufacturing protocol translates into clinically meaningful advantages over conventional lithium disilicate systems [15, 20, 31].

5 | Conclusion

Within the limitations of this study, CAD/CAM-fabricated lithium disilicate (LDS) and lithium disilicate–reinforced lithium aluminosilicate (LAS) crowns demonstrated comparable marginal adaptation, favorable clinical outcomes, and high patient satisfaction after 24 months of clinical service. Both materials appear suitable for posterior single-crown restorations.

The findings of this 2-year clinical investigation suggest that the experimental LAS ceramic material provides clinically acceptable performance and represents a time-efficient alternative to conventional all-ceramic systems due to its fully

crystallized state, which eliminates the need for post-milling firing. Nevertheless, further long-term clinical studies with larger sample sizes are required to confirm the durability and long-term behavior of LAS restorations.

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The authors have nothing to report.

Ethics Statement

The study protocol was reviewed and approved by the Human Ethical Research Committee of the Faculty of Dentistry, Marmara University (Approval No: 2016/47), and all procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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