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Original Article

Marginal Gap Comparison in CAD-CAM Endocrowns: Lithium Disilicate vs. Zirconia-Reinforced Lithium Silicate

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Abstract

Background: Restoration of endodontically treated teeth is critical for long-term success. Endocrowns are a conservative alternative to post-and-core restorations, with lithium disilicate and zirconia-reinforced lithium silicate commonly used materials. Marginal fit is essential for clinical performance, but material-related differences remain unclear. This in vitro study compared the marginal gap of endocrowns made from these two materials, assuming no significant difference between them.

Methods: In this in vitro experimental study, 24 extracted mandibular first molars, free of cracks, fractures, abnormal morphology, previous endodontic treatment, or restorations, underwent standardized endocrown preparation. The teeth were randomly assigned to two groups (n=12) for endocrown fabrication using lithium disilicate (IPS e.max CAD) or zirconia-reinforced lithium silicate (Suprinity). Teeth were scanned with a CAD scanner. Endocrowns were tabledesigned using inLab Software version 15 (inLab SW 15) and milled with an imes-icore 350i milling machine. The marginal gap was measured using the replica technique. Data were analyzed using one-way analysis of variance (ANOVA), t-test, and covariance analysis, with a statistical significance threshold of $P < 0.05$.

Results: Zirconia-reinforced lithium silicate (Suprinity) endocrowns exhibited a significantly higher mean marginal gap (82.95 ± 15.14 µm) compared to IPS e.max (76.22 ± 6.72 µm) across buccal, lingual, mesial, and distal surfaces ($P < 0.05$, Cohen's d = 0.58). Specifically, mean marginal gaps were: buccal (82.33 ± 11.85 µm vs. 76.21 ± 5.80 µm), lingual (83.12 ± 14.61 µm vs. 77.17 ± 6.29 µm), mesial (84.08 ± 17.33 µm vs. 76.54 ± 6.30 µm), and distal (82.27 ± 16.76 µm vs. 75.00 ± 8.48 µm) for Suprinity and IPS e.max, respectively.

Conclusion: IPS e.max endocrowns demonstrated significantly lower marginal gaps compared to zirconia-reinforced lithium silicate, suggesting that IPS e.max may enhance marginal integrity and reduce microleakage in endocrown restorations.

Key Words: Endodontically Treated Teeth; Dental Restoration; Dental Marginal Adaptation; Lithium Disilicate; Glass Ceramics; Computer-Aided Design; Computer-Aided Manufacturing

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Introduction

The method used to reconstruct teeth after root canal treatment plays a crucial role in determining the clinical success of the therapy [1]. Various methods for the reconstruction of these teeth have been proposed, including the traditional use of metal post-cores and extracoronal restorations [2]. This approach leads to a significant 11.3% loss of tooth structure, weakening the root. Moreover, it heightens the risk of accidental perforations and root breakage [3-5]. With advances in adhesive systems, endocrowns offer a viable alternative for extensively damaged posterior teeth, minimizing the need for extensive preparation and providing aesthetic and mechanical benefits while reducing time and cost [1,4]. Endocrowns can be made from ceramics or composite resins such as zirconia-reinforced lithium silicate ceramics, fiber composites, lithium disilicate ceramics, and hybrid nanoceramics [2,6].

Marginal fit plays a crucial role in the long-term success of prosthetic restorations, and this importance extends to endocrowns as well. It is influenced by factors like preparation design, impression materials, casting materials, and techniques. A larger marginal gap can lead to complications such as increased plaque accumulation, inflammation, secondary caries, and bone loss [7]. The marginal gap is measured as the perpendicular distance from the internal surface of the casting to the axial wall of the preparation at the marginal level [6].

Lithium disilicate, backed by extensive clinical evidence [8], remains the top choice for ceramic restorations due to its superior aesthetics. It is preferred for its visual appeal, mechanical strength, and ease of handling [9]. Pre-crystallization, lithium disilicate features an amorphous glassy matrix that transforms after heat treatment into a crystalline structure with approximately 70% orthorhombic $Li_2Si_2O_5$ crystals, imparting key mechanical and optical traits like high translucency [10]. Zirconia-reinforced lithium silicate primarily comprises lithium metasilicate (Li_2SiO_3) and minor lithium orthophosphate (Li_3PO_4) phases, bolstered by approximately 10% ZrO_2 in a glassy matrix. Full crystallization yields a fine-grained $Li_2O\text{-}ZrO_2\text{-}SiO_2$ microstructure [11]. Available in pre- or fully crystallized forms, the partially crystallized version facilitates CAD/CAM milling before final heat treatment to achieve optimal color and mechanical properties [11]. Crystallization drastically alters the microstructure via nucleation, with ZrO_2 finely dispersed within the glassy matrix and integrated into the crystal lattice—distinguishing zirconia-reinforced lithium silicate from lithium disilicate [12]. This thermal process is vital for its mechanical and optical performance [13]. Compared to lithium disilicate, zirconia-reinforced lithium silicate exhibits finer crystals and enhanced fracture toughness and Vickers hardness.

Recent investigations into the influence of materials on marginal gaps in endocrowns have shown contradictory results, leading to significant controversy in the field [6,14-18]. Therefore, to enhance the current knowledge regarding the durability of all-ceramic endocrowns, it is crucial to conduct new in vitro investigations with consistent material and measurement approaches [19]. This study aims to compare the marginal gap of endocrowns fabricated from lithium disilicate and zirconia-reinforced lithium silicate. The null hypothesis is that the two materials would exhibit no significant differences in marginal fit.

Methods and Materials

This experimental in vitro study was conducted at Tehran Islamic Azad University from January to March 2023.

Subject Selection, Randomization and Sample Size Estimation

The sample size was determined using power and sample size calculation software (version 3.0.43). Considering a 1% type I error, 80% statistical power, a standard deviation of 0.40, and an effect size of 0.48, a sample size of 12 per group was calculated.

A total of 24 periodontally hopeless mandibular first molars with two separate roots were selected. Teeth were included based on similar dimensions of mesiodistal and buccolingual aspects, root length, cuspal width, and pulp chamber depth. The exclusion criteria were previous root canal treatment, cracks, anomalous morphology, and existing restorations.

All teeth were scaled using handpieces and prophylactic paste, followed by ultrasonic scaling to remove debris. For disinfection, the teeth were immersed in a 0.5% chloramine solution at 4°C until further use. All procedures were performed by a single operator. The teeth were randomly assigned using a computer-assisted randomization method to two groups: one receiving lithium disilicate endocrowns and the other receiving zirconia-reinforced lithium silicate endocrowns (Table 1).

Procedure

Teeth were horizontally sectioned using a diamond bur at a distance of 2 mm above the cementoenamel junction (CEJ) and subsequently underwent endodontic treatment. The roots were shaped and

Table1. Characteristics of ceramics

Ceramic	Type	Composition (weight %)	Manufacturer
Suprinity LS	lithium disilicate endocrowns	SiO_2(56-64) Li_2O (15-21) ZrO_2(8-12) P_2O_5(3-8) K_2O (1-4) Al_2O_3(1-4)	Vita Zanhfabrik, Germany
IPS e.max CAD	Lithium Disilicate Glass Ceramic" in English	SiO_2(57-80) Li_2O (11-19) K_2O (0-13) P_2O_5(0-11) ZrO_2(0-8) ZnO(0-8)	Ivoclar Vivadent Schaan, Lichtenstein

flared, and the working length was determined using a #10 K-file, set 0.5 mm shorter than the apical foramen. Shaping and flaring of the canals were performed using a step-back technique up to a #50 file. After each file, the canals were irrigated with a 1% NaOCl solution. The canals were then dried with paper points and obturated with gutta-percha (Diadent, tapered 4%, Seoul, Korea) and sealer (AH-Plus, Dentsply, Maillefer, USA) using cold lateral condensation. Excess gutta-percha was removed 1 mm below the CEJ.

The pulp chamber undercuts were eliminated, and the internal axial walls were shaped with an 8–10-degree taper using a round-end tapered diamond bur. A circumferential butt joint with a width of 2 mm served as the finish line. The pulp chamber depth, measured with a periodontal probe after preparation, was 4 mm. Following cavity preparation for the endocrown, the canal orifices were sealed using light-cure resin-modified glass ionomer (GL Resin CEM UF, Oxford, United Kingdom).

The teeth were then mounted and scanned using an intraoral scanner (Sirona inEos Blue, Wals, Germany), and anatomical endocrowns were designed using inLab SW15 software (Figure 1).

The endocrowns were milled using an imes-icore 550i milling machine (Figure 2) and subjected to crystallization. The ceramics were fired in a furnace (100-Koushafan Pars, Auto Therm) following the manufacturer's guidelines to complete the crystallization process (Table 2). To ensure complete seating, each endocrown was placed on the corresponding tooth.

Figure 1. Designing the endocrowns by inLab SW15 software

Figure 2. Milling machine

Table 2. Protocol of sintering for the two ceramic types

Ceramic type	Stand-by temperature (°C)	Closing time (minutes)	Heating speed (°C/min)	Sintering temperature (°C)	Cooling time (minutes)	Vacuum (°C)
Suprinity	400	4	55	840	8	First time at 410 Second time at 840
IPS e.max CAD	403	6	90	820	7:10	First time at 550 Second time at 820

The replica technique was employed for marginal gap measurement. Each endocrown was covered with vinyl polysiloxane impression material (Vonflex S, Vericom, Korea). Positioned along the axial axis of the tooth, the endocrown was pressed with a finger and held under constant pressure for 5 minutes (setting time). The excess material was then removed from the endocrown using a scaler. Subsequently, the endocrown was detached from the impression material and the tooth. To facilitate support of the light body silicone and enable sectioning for examination, the tooth and light body silicone were embedded in a circular mold (diameter: 2 mm) containing heavy body silicone (Vonflex S, Vericom, Korea). After 5 minutes, the tooth was extracted, yielding a set of light body silicone connected to the heavy body silicone.

The samples were divided into eight sections for microscopic examination using a scalpel: from the midpoint of one line in a mesiodistal direction, another in a buccolingual direction, and finally from the midpoint to each line angle. Each of the eight pieces was examined for silicone thickness at four points (Figure 3):

1. External margin angle
2. Internal margin angle
3. Midpoint of the axial wall
4. Midpoint of the occlusal surface

A stereomicroscope with ×70 magnification (SZX 12, Olympus, Japan) was used for measurements. Photomicrographs were taken using a digital camera (DP 72, Olympus, Japan) connected to the stereomicroscope. The obtained images were analyzed and measured using image processing software. For each endocrown, marginal gap measurements were recorded at 32 points. The mean of these points and the maximum horizontal gap were calculated in micrometers for statistical analysis (Figure 4).

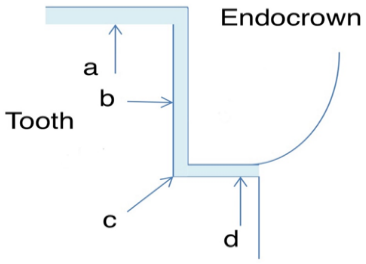

Figure 3. Schematic view of tooth and endocrown key measurement points. (a: midpoint of occlusal surface, b: midpoint of axial wall, c: internal margin angle, d: internal margin angle)

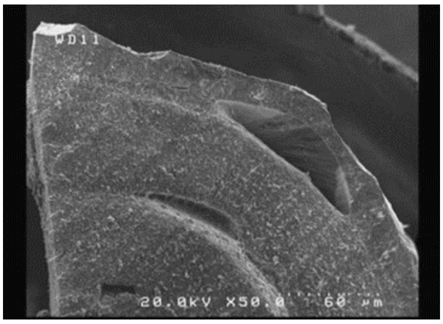

Figure 4. Image of samples using a stereomicroscope at a magnification of 70x

Statistical Analysis

The Kolmogorov-Smirnov test was used to evaluate the normal distribution of data. For inferential analyses, the independent t-test was employed to compare the mean marginal gaps (average and maximum) between the two endocrown groups (lithium disilicate vs. zirconia-reinforced lithium silicate). One-way analysis of variance (ANOVA) was used to compare marginal gaps across the different measurement points (external margin angle, internal margin angle, midpoint of axial wall, and midpoint of occlusal surface) within each group. Analysis of covariance (ANCOVA) was performed to adjust for any potential baseline covariates, such as variations in tooth dimensions across samples. All statistical procedures were conducted using SPSS software (version 26, IBM Corp., Armonk, NY, USA.

Results

Table 3 presents a comprehensive overview of the marginal gap measurements for lithium disilicate (IPS e.max) and zirconia-reinforced lithium silicate (Suprinity) CAD/CAM endocrowns across all dental surfaces.

Overall, zirconia-reinforced lithium silicate endocrowns exhibited a statistically significant higher mean marginal gap (82.95 ± 15.14 µm) compared to IPS e.max (76.22 ± 6.72 µm) across buccal, lingual, mesial, and distal surfaces. Statistical significance ($P < 0.05$) was determined using one-way analysis of variance (ANOVA), followed by a post-hoc Tukey's Honestly Significant Difference (HSD) test to identify specific group differences, with a moderate effect size (Cohen's d = 0.58).

The mean marginal gap on buccal surfaces was 82.33 ± 11.85 µm for Suprinity and 76.21 ± 5.80 µm for IPS e.max. Lingual surfaces exhibited means of 83.12 ± 14.61 µm for Suprinity and 77.17 ± 6.29 µm for IPS e.max. The marginal gap means on mesial surfaces were 84.08 ± 17.33 µm for Suprinity and 76.54 ± 6.30 µm for IPS e.max. Distal surfaces showed means of 82.27 ± 16.76 µm for Suprinity and 75.00 ± 8.48 µm for IPS e.max.

Discussion

The present in vitro experimental study compared marginal gaps between two ceramic endocrowns: zirconia-reinforced lithium silicate (Suprinity) and lithium disilicate (IPS e.max). The results revealed a significantly lower marginal gap in IPS e.max compared to Suprinity ($P < 0.05$). Consequently, the null hypothesis—that the two materials would exhibit no significant differences in marginal fit—was rejected.

Table 3. Marginal gap measurements of cad/cam endocrowns on different surfaces

Variance	Upper Limit	Lower Limit	Standard Deviation	Mean
Zirconia - Buccal1	100	61	11.561	79.25
IPS e.max - Buccal1	91	63	8.560	77.00
Zirconia - Buccal2	100	64	9.944	83.83
IPS e.max - Buccal2	88	66	6.851	75.75
Zirconia - Buccal3	100	65	9.919	87.25
IPS e.max - Buccal3	79	65	4.134	74.00
Zirconia - Buccal4	94	43	16.006	79.00
IPS e.max - Buccal4	86	72	3.679	78.08
Zirconia - Lingual1	105	58	14.822	80.33
IPS e.max - Lingual1	83	64	5.926	75.25
Zirconia - Lingual2	125	72	15.426	89.83
IPS e.max - Lingual2	91	73	6.186	78.58
Zirconia - Lingual3	98	64		78.08
IPS e.max - Lingual3	85	67	5.248	76.92
Zirconia - Lingual4	108	58	16.864	84.25
IPS e.max – Lingual4	88	59	7.810	77.92
Zirconia - Mesial1	100	70	9.910	86.75
IPS e.max - Mesial1	89	62	8.004	77.67
Zirconia - Mesial2	104	65	11.839	81.17
IPS e.max - Mesial2	90	69	5.161	76.50
Zirconia - Mesial3	145	58	24.498	86.17
IPS e.max - Mesial3	83	71	4.108	75.83
Zirconia - Mesial4	115	47	23.081	82.25
IPS e.max –Mesial4	88	58	7.964	76.17
Zirconia - Distal1	105	55	15.567	79.83
IPS e.max - Distal1	90	64	8.345	78.00
Zirconia - Distal2	106	71	11.889	89.58
IPS e.max - Distal2	87	59	6.995	76.75
Zirconia - Distal3	114	40	21.410	81.75
IPS e.max - Distal3	87	57	9.013	73.83
Zirconia - Distal4	107	56	18.178	77.92
IPS e.max - Distal4	91	58	9.577	71.42

Several studies on CAD/CAM-fabricated all-ceramic endocrowns have identified an acceptable marginal fit range of 64–83 µm [20]. After examining 111 crowns, Fraunhofer and McLean concluded that the maximum acceptable gap for a technically satisfactory crown is 121 µm [21]. Considering the mean marginal gaps of 82.95 µm in the Suprinity group and 76.22 µm in the IPS e.max group, it can be inferred that both endocrowns meet the technical criteria for satisfactory restorations [21]. Consistent with the present findings, Gaye Saglam et al. [15] aimed to compare the impact of material type on marginal gap and concluded that the marginal gap in Suprinity was significantly greater than in IPS e.max. Attar et al. [6] conducted a study comparing the marginal gap of endocrowns fabricated from lithium disilicate ceramic (IPS e.max CAD), zirconia-reinforced lithium silicate ceramic (VITA Suprinity), and polymer-infiltrated ceramic (VITA Enamic). Their results showed that VITA Suprinity exhibited significantly higher gap width values than VITA Enamic ($P = 0.005$). However, no significant differences in gap width values were observed between VITA Enamic and IPS e.max CAD or between VITA Suprinity and IPS e.max CAD ($P > 0.05$). The contrasting findings may be attributed to differences in measurement points, instrumentation, and materials. The current study measured four points for the horizontal gap, while Attar et al. [6] assessed eight points around the marginal area. Additionally, the present study employed the replica technique with silicone material for gap measurement, whereas Attar et al. used a digital camera and stereomicroscope. Elsayed et al. [22] evaluated fabrication techniques for glass ceramics and noted higher marginal gaps in machinable zirconia-reinforced lithium silicate (Celtra Duo, 60 µm) compared to IPS e.max CAD, although the difference was not statistically significant. Hasanzadeh et al. [23] and Taha et al. [1] similarly observed non-significant trends toward higher gaps in Suprinity-like materials following cementation and aging, highlighting the influence of measurement methods, material subtypes, and post-processing on outcomes. Nagi et al. [24] reported better marginal adaptation in PEEK compared to lithium disilicate, underscoring material-specific differences in fit.

Clinically, the observed smaller marginal gaps in IPS e.max may translate to enhanced marginal integrity, potentially reducing microleakage—a key factor in restoration longevity. In vitro evidence indicates that narrower gaps correlate with decreased dye penetration, a surrogate marker for microleakage. For instance, one study on full-coverage crowns demonstrated that zirconia crowns with 82.7 ± 7 µm gaps achieved 83% no-leakage rates with self-adhesive resin cement, outperforming lithium disilicate (92.6 ± 4 µm) and cobalt-chromium (96.5 ± 7 µm) variants ($P = 0.042$ between zirconia and cobalt-chromium; $P = 0.029$ between cement types) [25]. Another study on endodontically treated premolars demonstrated that endocrowns with butt margins (44.66 ± 10.71 µm gaps) exhibited lower dye penetration (55.46 ± 4.1 µm) than shoulder margin designs (46.72 ± 13.1 µm gaps, penetration 109.76 ± 4.4 µm; $P < 0.05$) [26]. Additional in vitro studies have reinforced the association between smaller gaps and reduced microleakage through techniques such as deep margin elevation and the use of bonding agents [27].

Although no direct evidence definitively links gap size to secondary caries development, minimized microleakage may lower the risks of bacterial infiltration, pulpal irritation, and subsequent restoration failure. These findings favor the selection of IPS e.max for endocrowns in high-load posterior regions. Clinicians may prioritize IPS e.max to optimize marginal seal quality, potentially improving patient outcomes such as reduced postoperative sensitivity and extended restoration durability, particularly in endodontically treated teeth which are inherently more susceptible to fracture [25-27].

Despite providing valuable insights, the present study has several limitations. The sample size was relatively small, and obtaining decay-free, structurally sound teeth posed challenges.

Methodologically, variable finger pressure during endocrown placement and limited CAD/CAM scanning accuracy for sharp angles (90 degrees) represent additional constraints. Furthermore, the use of a single measurement technique may not capture the full spectrum of marginal adaptation.

Future studies should address these limitations to provide more comprehensive insights. Expanding the sample size, ensuring the inclusion of robust, pristine teeth, and exploring alternative measurement techniques for marginal gap assessment—such as micro-CT imaging or the novel digital replica technique—could enhance the comprehensiveness and generalizability of future research.

Conclusion

Based on the study findings, IPS e.max endocrowns demonstrated a significantly smaller mean marginal gap compared to zirconia-reinforced lithium silicate (Suprinity) across all dental surfaces. This indicates that IPS e.max offers superior marginal fit and integrity, potentially reducing microleakage and enhancing restoration longevity compared to Suprinity.

Declarations

Ethical Approval and Consent to Participate

This article does not include any studies involving human participants or animals performed by any of the authors. Accordingly, ethical approval from an institutional review board and informed consent from participants were not required for this work.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are not publicly available due to institutional privacy regulations but are available from the corresponding author on reasonable request.

Conflict of Interest Statement

The authors declare no conflicts of interest related to this study. No funding was received for this research, and the authors have no financial or personal relationships with any individuals or organizations that could inappropriately influence or bias the content of this paper.

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Authors’ Contributions

ME (Mahyar Ezzati) contributed to the conception and design of the study, data acquisition, interpretation of findings, and drafting of the manuscript. EJ (Ezzatollah Jalalian) contributed to the supervision of the study, study design, critical revision of the manuscript, and provided overall academic guidance. APH (Amirahmad Pahlavan Hoseini) contributed to data collection, experimental procedures, and drafting of sections of the manuscript. DL (Deniz Lesan) contributed to data acquisition, literature review, and manuscript preparation. All authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Declaration of Generative Artificial Intelligence (AI) Utilization

The authors acknowledge the use of artificial intelligence (AI) tools, specifically ChatGPT (OpenAI) and Grammarly, during the preparation of this manuscript. These tools were employed exclusively for language editing, grammar correction, and formatting assistance to improve readability. No AI tools were used to generate, analyze, or interpret data, nor to formulate scientific conclusions. Following the use of these AI-assisted technologies, the authors thoroughly reviewed, revised, and verified all content. The authors assume full responsibility for the final version of this manuscript and the integrity of the work presented.

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