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ORIGINAL ARTICLE

Effect of three different preparation designs on the marginal adaptation of indirect overlay restoration fabricated from lithium disilicate ceramic material: An in-vitro comparative study☆

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KEYWORDS

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Abstract *Objectives:* Marginal adaptation is considered one of the key factors influencing the success of indirect restorations. This study aimed to estimate the marginal fit of lithium disilicate overlays with three distinct preparation designs before and after cementation.

Methods: Thirty maxillary first premolars were divided into the hollow chamfer design (HCD[1]) group, butt-joint design (BJD[2]) group, and conventional occlusal box design (COD[3]) group (n = 10 each). The samples were scanned using an intra-oral scanner, and overlays were fabricated using computer-assisted design and milled on a computer-assisted machine. The finished restorations were luted using a self-adhesive resin RelyX Ultimate. The marginal gap was assessed using a digital microscope with 230X magnification power. Statistical analysis was conducted using analysis of variance and post hoc (Bonferroni correction) tests, assuming a significance level of 5%.

Results: The HCD and BJD groups recorded significantly lower marginal gap, (11.39 ± 0.72, 16.29 ± 0.75) and (11.59 ± 0.75, 16.93 ± 0.65) respectively, than the COD group (24.57 ± 1.18, 34.45 ± 1.09) both pre- and post-cementation.

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[1] HCD: Hollow Chamfer Design.
[2] BJD: Butt-Joint Design.
[3] COD: Conventional Occlusal Design.

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Conclusion: This study demonstrated that modification of tooth preparation plays a significant role in the marginal adaptation of the lithium disilicate overlays. The gap was smaller with the HCD and BJD than with the COD, with a statistically significant difference.

1. Introduction

Dental practitioners commonly apply the principles of tooth preparation to replace lost tooth structures and enhance the occlusal force resistance using a crown with complete coverage (Tiu et al., 2015). However, these parameters require the reduction of the entire coronal surface, which may be too invasive for teeth with intact structural tissues (Yang et al., 2020). Therefore, partial coverage restorations, such as those including ceramic or composite overlays, may be considered a more conservative treatment option (Dioguardi et al., 2021).

The occlusal surface and functional cusps are dominantly affected in tooth destruction, which affects the esthetics, occlusal vertical dimension, and occlusal stability (Sirous et al., 2022). For the longevity of teeth and restorations, it is crucial to conserve the intact tooth structure (VanDijken & Hasselrot, 2010). So, new nonretentive adhesive occlusal overlay designs with novel modifications, i.e. hollow chamfer design (HCD) and butt-joint design (BJD), according to clinical needs have been proven to be useful for less invasive indirect occlusal restorations. HCD involves a hollow chamfer prep at the occlusal third, suitable for durable and aesthetic restorations. While, BJD features a margin without bevel or chamfer, recommended for minimal tooth loss or maximum healthy structure preservation (Veneziani, 2017; Ferraris, 2017). These conservative designs are a result of the advancement in adhesive substances, which have turned the emphasis away from mechanical retention toward biological, adhesive, and biomimetic practices (Flores et al., 2022). Lithium disilicate is one of the most intriguing modern materials associated with this advancement (Luciano et al., 2020). The biomechanical properties of lithium disilicate permit its use in the posterior region, with a minimum thickness of 0.7 mm that does not reduce the strength (Yan et al., 2018). This makes it the material of choice for novel occlusal overlay preparation designs, i.e., HCD and BJD), as an alternative to the conventional occlusal box design (COD) (Veneziani, 2017; Ferraris, 2017).

One of the main factors affecting the longevity of indirect posterior restorations is the quality of marginal adaptation (Abduo and Sambrook, 2018). Marginal inaccuracy can result in recurrent caries, luting cement degradation, microleakage, and restoration failure (Kim et al., 2018). There is limited evidence in the literature on overlay ceramic adhesive replacement in the posterior teeth in terms of the design of preparation performed, and whether this variable influences marginal adaption (Ferraris et al., 2021). Therefore, the present study aimed to determine how three distinct overlay preparation designs, HCD, BJD, and COD, affect the marginal fit of lithium disilicate ceramic blocks both pre- and post-cementation.

Null hypothesis: Preparation design has no impact on marginal adaptation of overlay restorations pre- and post-cementation.

2. Materials and Methods

2.1. Teeth preparation and study design

The Research Ethics Committee of the College of Dentistry, University of Baghdad approved this in vitro study (No. 510522/510).

This study utilized 30 intact human maxillary first premolars extracted from orthodontic patients aged 18–22 years (Jlekh and Abdul-Ameer, 2018). The teeth were caries and filling-free, with no plaque, calculus, or periodontal ligament remnants. Samples were stored in 0.1% thymol solution for 1 week, followed by sterile water for 1 day at 37 °C.

The roots were mounted in a custom-made square silicone mold (Express STD, 3 M ESPE, St. Paul, USA) up to 2 mm from the cementoenamel junction (CEJ[4]) and fixed in a freshly mixed cold-cure acrylic (Premacryl Plus, Spofadental, Jicin, Czech Republic).

The 30 teeth were randomly divided into the following three groups of different preparation designs (n = 10 each): HCD group with hollow chamfer finish line, BJD group with butt-joint finish line, and COD group with conventional occlusal box and cusp reduction.

2.2. Overlay cavity preparation

The teeth were prepared using a high-speed handpiece (NSK PANA-MAX, Kanuma, Japan) with a magnification tool (6X Dental Loup-Univet, Rezzato, Italy). Parallelism standardization was confirmed using a customized dental surveyor (Paraline, Dentaurum, Leipzig, Germany) (Hmedat and Ibraheem, 2013).

For all teeth, a flat-end diamond bur (No. 8845KR 314 018, Komet, Lemgo, Germany) was used to prepare a proximal box (rounded shoulder) with rounded internal angles, 8° convergence angle, 1.5 mm width, and 1 mm depth and located 1 mm above the CEJ (Fig. 1A–C). In the HCD and BJD groups, a depth cut bur (No. DM 20.314.009, Komet) was used to prepare depth orientation grooves (DOGs)[5], followed by an anatomical occlusal reduction of 1.5 mm (butt-joint of 90° angle) using a barrel-shaped trapezoid bur (No. 811 314 037, Komet) (Fig. 2A–B). The hollow chamfer finish line in the HCD group was obtained using a cylinder chamfer bur (No. S6882L 314 014, Komet) with 0.8 mm depth (Fig. 1A, 2A). In the COD group, an occlusal box of 2.5 mm width and 1.5 mm depth was prepared using a tapered diamond bur (No. 845KRD 314 025, Komet). The DOGs were then made on the cusps, and occlusal reduction of 1.5 mm (90° angle) was performed using the barrel-shaped trapezoid diamond bur ((Fig. 1C, 2C).

[4] CEM: Cementoenamel Junction.
[5] DOG: Depth Orientation Grooves.

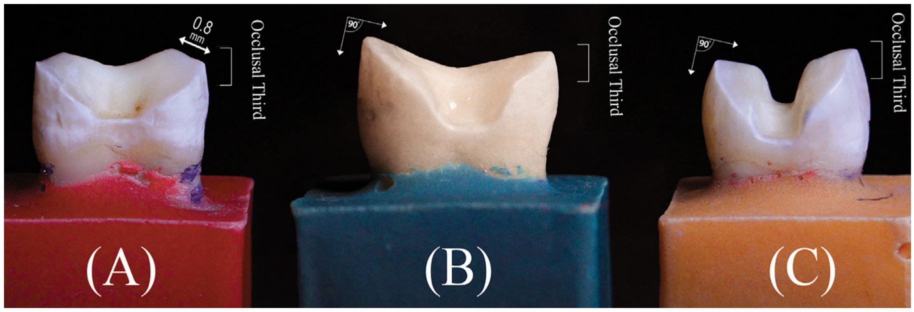

Fig. 1 Overlay preparation designs of all groups (proximal view), including the location, depth, and angles of the finish lines (A): Hollow chamfer design (HCD), (B): Butt-joint design (BJD), (C): Conventional occlusal box design with cusp reduction (COD).

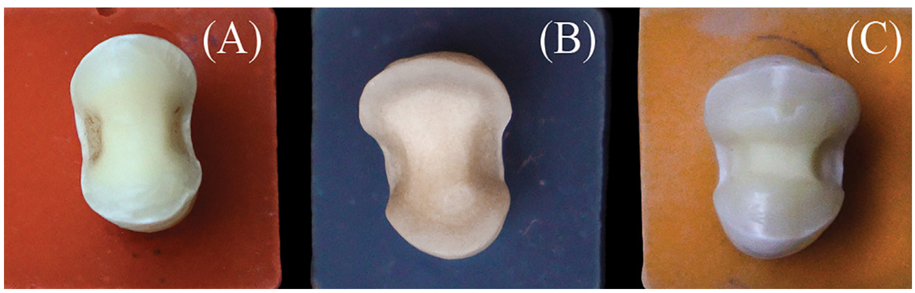

Fig. 2 Overlay preparation designs of all groups (occlusal views) (A): Hollow chamfer design finish line (HCD), (B): Butt-joint finish lines (BJD), (C): Conventional occlusal box (COD).

2.3. Immediate dentin sealing procedure

Immediate dentin sealing (IDS)[6] protocol involved dentinal etching with 37% phosphoric acid gel (Scotchbond, Universal Etchant, 3 M ESPE, St. Paul, USA) for 15 s, washed with running water, and suctioned to leave the surface visibly moist. A universal adhesive (3 M ESPE) was applied for 20 s on the etched dentin surface only and air-dried. Subsequently, light polymerization for 10 s was performed using VALO Grand (Ultradent, South Jordan, USA) at a light intensity > 800 mW/cm^2. These steps have been done following manufacturer's instructions and as described in previous studies (Deniz et al., 2021).

2.4. Digital workflow and overlay fabrication

Intraoral scanner (CEREC-Omnicam, Dentsply-Sirona, Bensheim, Germany) was used to create digital impressions. Overlays were designed by Sirona inLab software (Dentsply-Sirona) with a spacer setting of 80 µm. Restorations were milled by a five-axis In-Lab MC 5 machine (Dentsply-Sirona) using lithium disilicate for CEREC and inLab (Ivoclar Vivadent). Crystallization and glaze firing were performed at 840 °C (Programart P500, Ivoclar Vivadent).

2.5. Marginal gap assessment

The gaps were assessed by the direct view method using a digital microscope (Dino-Lite Pro, AnMo Electronics Corp., New Taipei, Taiwan).

Four dots were placed on each tooth surface (buccal, palatal, mesial, and distal), two dots at each surface mid-line and the others 1 mm away, to measure the marginal adaptation at 230X magnification power for image capture (Holden et al., 2009; Khaledi et al., 2020). DinoCapture software version 2.0 (AnMo, Electronics Corp.) was utilized to process the images, which were then opened using ImageJ 1.50i (The National Institutes of Health, Bethesda, USA) to estimate the mean pre-cementation gap value of each sample.

2.6. Cementation procedure

The intaglio surface of the overlays was etched using < 5% hydrofluoric acid (Ivoclar Vivadent) for 20 s, followed by applying a universal bond (3 M ESPE) for 20 s and light polymerizing for 10 s. The IDS was refreshed via 30 µm aluminum oxide airborne abrasion (AquaCare, Velopex, London, UK), phosphoric acid etching for 30 s, and applying adhesive agent to the prepared area for 20 s, following the manufacturer's instructions and the protocols in prior studies (Özcan et al., 2013).

Overlays were cemented with self-adhesive resin luting material (RelyX-Ultimate Clicker, 3 M ESPE) with vertical load (5 kg for 6 min) utilizing a custom-made cementation apparatus (Abdulazeez and Majeed, 2022). Finally, 20 s of light curing followed by finishing using polishing wheels (TWIST-EVE, Germany). Marginal gaps were then measured at the same pre-cementation sites.

2.7. Statistical data analysis

Data were analyzed using Statistical Package for the Social Sciences v26 (SPSS Inc., Chicago, USA). One-way analysis

[6] IDS: Immediate Dentin Sealing.

of variance and Bonferroni post hoc tests were used to compare group differences at 5% significance.

3. Results

Table 1 shows that the HCD and BJD groups recorded the best marginal adaptation, with no significant difference between them. However, there was a significant difference in the mean marginal gap between the HCD and BJD groups and the COD group both before and after cementation.

4. Discussion

The preparation design is crucial for evaluating the marginal adaptation of indirect restorations (Manhart et al., 2001). Marginal fit is one of the most important prerequisites influencing the long-term prognosis and clinical success of ceramic restorations (Cunali et al., 2017). This study assessed the marginal gap of lithium disilicate overlays using three distinct designs both before and after cementation. The findings suggest that modifications of the overlay design can significantly influence the marginal gap before and after cementation, hence, rejecting the null hypothesis. These results are consistent with those of prior studies that demonstrated the significant impact of indirect preparation designs on marginal adaptability (Kim et al., 2015; Sirous et al., 2022).

The overlay preparations in this study were based on the following three protocols: morphology-driven preparation design (HCD group) (Veneziani, 2017), posterior indirect adhesive restoration (BJD group) (Ferraris, 2017), and modified inlay design (COD group) (Hopp and Land, 2013). A round shoulder finishing line was used for proximal preparation in all groups, as it is a standard design after proximal caries excavation (Ferraris, 2017). A 6X magnifying tool was used to improve the accuracy of the design preparation (Atlas et al., 2022). IDS was performed as one of the basic guidelines for indirect restorations in an attempt to be clinically relevant (Magne, 2005; Gresnigt et al., 2016). The vertical marginal gap was estimated using the direct view method with a digital microscope (Holmes et al., 1989), which is a widely used and conservative method that takes less time and has less scope for errors than other indirect techniques (Ates and Yesil Duymus, 2016; Nawafleh et al., 2013).

Table 1 Comparison of the mean marginal gap between the study groups pre- and post-cementation using analysis of variance and post hoc (Bonferroni correction) test.

Group	Mean (μm) ± SD (Pre-cementation)	Mean (μm) ± SD (Post-cementation)	*p*-value*
HCD	11.39 ± 0.72^a	16.29 ± 0.75^a	< 0.001
BJD	11.59 ± 0.75^a	16.93 ± 0.65^a	
COD	24.57 ± 1.18^b	34.45 ± 1.09^b	

(HCD: hollow chamfer design, BJD: butt-joint design, COD: conventional occlusal box, SD: standard deviation).
Dissimilar letters (a, b) indicate significant differences at $p < 0.001$ post hoc Bonferroni multiple comparisons.
The significance level was set at 5%.
* Comparison among the three groups (one-way analysis of variance).

On analyzing the effects of the three different designs on the marginal gap, HCD and BJD showed significantly higher marginal adaptation than did the COD both pre- and post-cementation (Table1). This might be attributed to the simple preparation features of the HCD and BJD, including flat smooth occlusal reduction, no retentive features, and fewer internal angles. Such features have been suggested to facilitate all digital workflow procedures, such as easy scanning during digital impression taking, seamless software designing, and allowing milling burs to reproduce the details of overlays, and thus subsequently reducing the marginal gap (Contrepois et al., 2013; Goujat et al., 2019; Sirous et al., 2022). Furthermore, HCD and BJD present a good transition between the proximal boxes and occlusal finish lines, i.e., continuous boundaries with rounded corners. This reportedly produces superior adaptation of the partial ceramic restorations (Lima et al., 2018). As this study evaluated the marginal adequacy with each design, these results could also be attributed to the interaxial tooth structure reduction with the COD and formation of occlusal isthmuses. It has been shown that isthmuses can increase the risk of excessive friction during restoration insertion and negatively affect the marginal fit (Stappert et al., 2005). An analysis of the location and dimensions of the finish lines showed that HCD exhibited the best marginal fit, possibly due to its increased preparation surface area that creates more spacer, leading to reduced friction between the tooth and overlay and improved fitness. It was demonstrated that increasing the tooth surface area encompassed by a spacer enhances restoration fit (Olivera and Saito, 2006).

Currently, there is no consensus on the minimum clinically acceptable marginal gap value (Kim et al., 2018; Goujat et al., 2019). It was suggested to be < 100 μm by some authors, whereas others assumed < 120 μm as the clinically permissible value (Alajaji et al., 2017; Ferraris et al., 2021). The results of marginal gap in the present study were within these limits for all treatment groups, regardless of the significant difference between them.

In this study, the general mean value was estimated for each sample by calculating the mean marginal gap in the buccal, palatal, mesial, and distal regions, as described in previous studies (Holden et al., 2009; Khaledi et al., 2020; Ibraheem and Abdulkareem, 2016). This was done to appreciate the design as one bulk, rather than splitting the results depending on the preparation location. The latter method could be affected by other factors, such as the type of teeth or anatomical variations, which might be difficult to cover in one study.

The results of the current research corroborated the findings of Falahchai et al. (2020), which showed that when comparing the marginal gap of the conservative overlay with traditional preparation, the conservative preparation recorded the significantly highest marginal fit both pre- and post-cementation. There was also an agreement with a recent study on the influence of preparation designs (butt joint, full bevel, shoulder overlays, and crown) on the margin quality. They found that all overlay designs have a continuous margin with a mean value of 98.7%, as good continuity between the restoration and tooth can only be achieved with a well-adapted restoration (Ferraris et al., 2021). While these two previous studies used molar teeth as the study model, this could open up the possibility of future comparative in vitro research or clinical trials on HCD and BJD using different study models with other anatomical variations.

In this study, the marginal gap increased significantly in all the groups after cementation (Table 1). These results reflect the assumption that the prostheses might not be completely seated after adhesive cementation, which could be attributed to the hydraulic pressure produced during restoration seating (Mounajjed et al., 2018; Habib et al., 2019). This post-cementation increase is in agreement with previous studies on the marginal adaptation of indirect restorations (Guess et al., 2014; Falahchai et al., 2020). However, HCD and BJD groups recorded significantly lower marginal gap than COD group after cementation. This may be because the HCD and BJD allow for a better flow of cement during cementation than the COD. This lacking property in the latter might cause more hydraulic pressure and problematic discharge of excess cement, resulting in an increased marginal gap (Contrepois et al., 2013; Veneziani 2017). The reported gap increases after adhesive cementation, ranging from 13 µm to 50 µm (Stappert et al., 2005; Guess et al., 2014; Mounajjed et al., 2018). While the marginal inaccuracy in this study increased approximately by 5 µm in the HCD and BJD groups and 10 µm in the COD group. This could be because of the utilization of more accurate custom-made electrical- and air-pressure-controlled cementation devices. This is in contrast to previous studies that employed a manual holding tool or finger pressure, which may affect the uniformity between the two surfaces of the cement layer and subsequently affect the marginal fit (Falahchai et al., 2020).

Nevertheless, one of the limitations of this study is the assessment of the marginal gap without simulation of the oral environment. Therefore, future studies could consider the impact of the oral environment on marginal fit of different overlay designs to reflect the challenges of the clinical situation of such restorations.

5. Conclusions

Within its limitations, the present study demonstrated that the modification of tooth preparation had a statistically significant effect on the magnitude of the marginal gap present around lithium disilicate overlays. Based on the findings of this in vitro research, it might be suggested that the HCD and BJD are more suitable clinically than the COD for overlay restoration of posterior teeth.

Ethical statement

This study was approved by the Medical Ethics Committee from the College of Dentistry, University of Baghdad (Reg. NO. 510522**,** Ref. NO. 510 in 10/3/2022).

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CRediT authorship contribution statement

Sajad Athab Hasan: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Investigation, Validation. **Zainab Mohammed-Hussain Abdul-Ameer:** Conceptualization, Methodology, Data curation, Visualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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