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The Effect of Immediate Dentin Sealing on the Marginal Adaptation of Lithium Disilicate Overlay Restorations using different types of luting agents

Efeito do selamento imediato da dentina na adaptação marginal de restaurações overlay de dissilicato de lítio utilizando diferentes tipos de agentes de cimentação: estudo in vitro

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ABSTRACT

Objective: This study evaluated the effect of immediate dentin sealing on the marginal adaptation of lithium disilicate overlays with three different types of resin-luting agents: preheated composite, dual-cure adhesive resin, and flowable composite. **Materials and Methods:** Forty-eight maxillary first premolars of similar size were prepared with a butt joint preparation design. The teeth were separated into two primary groups, each with twenty-four teeth: Group DDS: Delay dentin sealing (non-IDS) teeth were not treated. Group IDS: dentin sealing was applied immediately after teeth preparation. Each group was subsequently separated into three separate subgroups. Subgroups (DDS+Phc, IDS+Phc): cemented with preheated composite (Enamel plus HRi, Micerium, Italy), Subgroups (DDS+Dcrs, IDS+Dcrs): cemented with dual-cured resin cement (RelyX Ultimate, 3M ESPE, Germany) and Subgroups (DDS+Fc, IDS+Fc): Cemented with flowable composite (Filtek supreme flowable, 3M ESPE, USA). Using a digital microscope with a magnification of 230x, the marginal gap was measured before and after cementation at four different locations from each surface of the tooth, and the mean of measurements was calculated and analyzed statistically using the independent t-test, one-way ANOVA test, Bonferroni correction at a significance level of 0.05. **Results:** The samples that were immediately sealed with dentin bonding agent showed lower marginal gaps than delayed dentin sealing, both pre-and post-cementation for all subgroups, with a statistically significant difference ($p<0.01$). The marginal gap was significantly lower in the IDS+Fc (48.888 ±5.5 μm) followed by the IDS+Dcrs group (53.612 ±5.8 μm) and IDS+Phc (79.19 9±6.9 μm) respectively, while the largest marginal gaps were observed in the DDS+Phc group (86.505 ±5.4 μm). **Conclusion:** Generally, the teeth with IDS showed better marginal adaptation than teeth without IDS. The marginal gap was smaller with flowable composite and dual-cure resin cement than with preheated composite.

KEYWORDS

CAD-CAM; Cementation; Dental marginal adaptation; Dental Porcelain; Resin cement.

RESUMO

Objetivo: Esse estudo avaliou o efeito do selamento imediato da dentina na adaptação marginal de overlays em dissilicato de lítio com três tipos diferentes de agentes de cimentação resinosos: resina composta pré-aquecida, adesivo resinoso dual e resina fluida. **Materiais e métodos:** Quarenta e oito primeiros pré-molares maxilares com tamanho similar foram preparados com término em ombro. O dente foi separado em dois grupos primários, cada um com vinte e quatro dentes: Grupo DDS: retardado selamento da dentina (non-IDS) dente não foi tratado. Grupo IDS: selamento dentinário foi aplicado imediatamente após a preparação do dente. Cada grupo foi separado de modo subsequente em três subgrupos. Subgrupo (DDS+Phc, IDS+Phc): cimentado com resina pré-aquecida (Enamel plus HRi, Micerium, Italy), Subgrupo (DDS+Dcrs, IDS+Dcrs): cimentado com cimento resinoso dual (RelyX Ultimate, 3M ESPE, Germany) e Subgrupo (DDS+Fc, IDS+Fc): cimentado com resina fluida (Filtek supreme flowable, 3M ESPE, USA). Usando um microscópio digital com magnificação de 230x, o gap marginal foi medido antes e após a cimentação em quatro diferentes localizações de cada superfície do dente e a média das medidas foi calculada e estatisticamente analisada através do uso do teste ANOVA um-fator e teste independente de Tukey e correção Bonferroni com nível de significância de 0,05. **Resultado:** As amostras que foram imediatamente seladas com agente adesivo dentinário apresentaram menores gaps marginais do que o selamento dentinário retardado, ambos pré e pós cimentação para todos os subgrupos apresentaram diferença estatística significante ($p<0.01$). O gap marginal foi significativamente menor para IDS+Fc (48.888 ±5.5 μm) acompanhado do IDS+Dcrs group (53.612 ±5.8 μm) e IDS+Phc (79.19 9±6.9 μm) respectividamente, enquanto o maior gap marginal foi observado no grupo DDS+Phc (86.505 ±5.4 μm). **Conclusão:** Geralmente, o dente com IDS apresentou melhor adaptação marginal do que o dente sem IDS. O gap marginal foi menor com resina fluida e cimento resinoso dual do que com a resina composta pré-aquecida.

PALAVRAS-CHAVE

CAD-CAM; Cimentação; Adaptação dental marginal; Porcelana dental; Cimento resinoso.

INTRODUCTION

Indirect restorations are critical since improper marginal adaptation leads to microleakage, cement dissolution, caries, and gingivitis [1]. It has been proposed that the sealing of the recently exposed dentin with a dentin-bonding agent before impression-taking [2,3], can decrease postoperative sensitivity, microleakage, and resist mechanical loading while improving the adhesion of indirect restorations by the enhanced marginal adaptation between dentin and the restoration and reducing the cement space thickness [4,5], by making preparations with smoother surfaces and rounded angles [6,7]. This procedure is identified as immediate dentin sealing (IDS) [8]. However, Duarte et al. [9] showed that microleakage was not reduced, even with IDS. On the other hand, many studies have demonstrated that when IDS is applied, the interface showed less gap formation [10,11]. As well as one of the factors that affect the durability of restorations is the luting material. These luting agents differ by degree of conversion, linear shrinkage and color stability, wear resistance, strength, convenience, thickness, and ability to flow [12]. In recent years, preheated and flowable composite resin has been a popular luting material because of its simplicity and ease of clinical manipulation. Therefore, the selection of bonding cement has been an essential aspect for the success of the restoration with the development of restorative materials such as lithium-disilicate becoming an interesting alternative restorative material in most clinical situations [13]. The benefits of IDS with lithium-disilicate restoring material, when specific current composite resin materials are used as a luting, have not been studied much with its effects on marginal adaptation.

Therefore, the objective of the study was to estimate the effect of IDS with various luting agents (preheated composite, dual-cure adhesive resin, and flowable composite) on marginal adaptation. The null hypothesis was that the different luting agents with IDS would not affect the marginal adaptation of lithium-disilicate overlay.

MATERIALS AND METHODS

The Research Ethics Committee of the College of Dentistry, the University of Baghdad approved this in -vitro study (No. 509522/509).

Forty-eight intact maxillary 1st premolars of similar size, extracted for orthodontic reasons, were collected from patients aged 18–22 years [14]. The butt joint preparation design was used to prepare the teeth for indirect overlay restoration [7,15]. Occlusal reduction and proximal reduction were done in two stages of preparation and following the anatomy of the tooth. The teeth had their occlusal reduction by 1.5 mm by utilizing a trapezoid bur (barrel-shaped) (811 314 033, Komet, Germany). A tapered, rounded edge, depth marking diamond fissure burs with a flat end (845 KRD 314 025, Komet, Germany) was positioned parallel to the tooth long axis to create a slot of 1 mm depth for the interproximal reduction. Connecting the occlusal preparation with proximal slot boxes by using extra fine flame bur (856EF 314 012, Komet, Germany) produces a continuous smooth round shoulder finishing line with rounded angles (Figure 1).

This resulted in a round-shoulder finishing line with an interproximal box 1.5 mm wide and round internal angles (Figure 2).

The IDS protocol was associated with a three-step etch-and-rinse system [2], started with dentinal etching with 37% phosphoric acid gel (Kerr, Italy) for 15 s, rinsing for 20 s, and air drying for 3 s. A primer was applied (OptiBond FL, Kerr, Italy) twice, and air dried for 5 s. The adhesive resin was coated (OptiBond FL, Kerr, Italy) with brushing motion for 15 s, but no air thinning, and light curing for 15 s [16] (Figure 3). Then it was once more cured for 40 s, after of the glycerin gel application was performed (DeOx, oxygen barrier solution, ultradent, USA).

Two major groups of twenty-four teeth each were created from the prepared teeth: Group DDS: Not sealed immediately with dentin bonding agents but submitted to scanning followed by provisional restoration. Group IDS: Dentin sealing was applied immediately after teeth preparation, followed by scanning and provisional restoration placement.

By using CAD/CAM technology [17], the Intra-Oral Scanner (Medit I700, Korea) was then used to scan the prepared teeth as it produces the highest trueness and precision [18].

For IDS samples, to prevent adherences with a bonding agent when using temporary light-cure material (Revotek LC, GC, Tokyo, Japan), petroleum jelly (Vaseline, Unilever, Fabricado na, India) was used to isolate the IDS before the provisionalization [16].

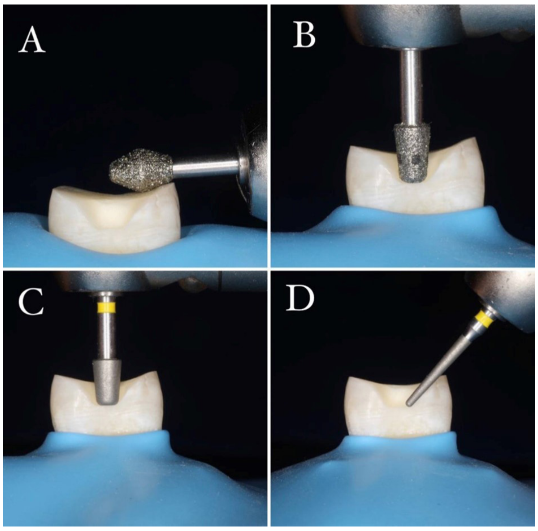

Figure 1 - Overlay preparation: (A) Planar occlusal reduction with Barrelled-shaped trapezoid bur, (B, C) slots preparation with tapered, rounded edge, depth marking diamond fissure bur (D) Connecting the occlusal preparation with proximal slot boxes by using extra fine flame bur.

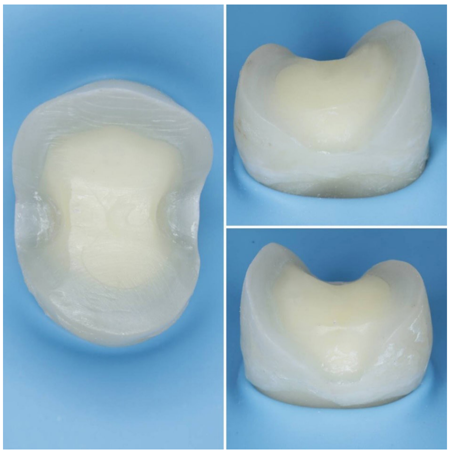

Figure 2 - Occlusal and proximal view of the finished prepared tooth.

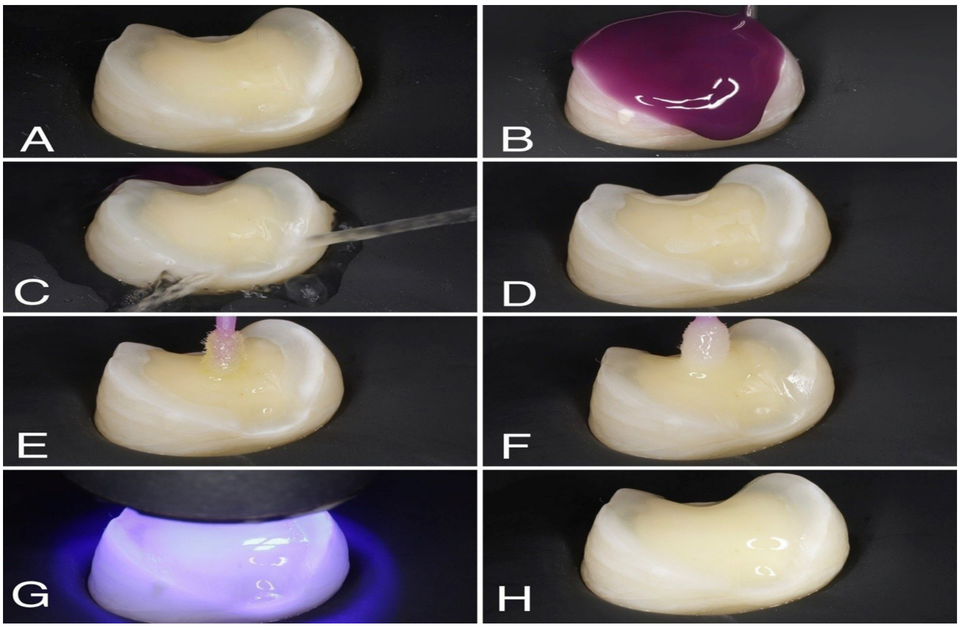

Figure 3 - Immediate dentin sealing procedure: (A) Freshly cut dentin, (B) Application of phosphoric acid etchant gel, (C) water rinsing, (D) Air drying, (E) Application of primer, (F) Application of adhesive resin, (G) Light curing, (H) resin coat (IDS).

The samples were then preserved in artificial saliva at 37°C for two weeks while waiting for the laboratory procedures to be done.

Sirona InLab CAD (20.0 software) and InLab MC XL milling unit were used to design and create the overlay restorations [19]. The overlay restorations fabricated from lithium disilicate blocks (IPS e.max CAD, Ivoclar Vivadent, Liechtenstein) were milled out using extra-fine milling mode [20]. Subsequently, the glazing paste (IPS e.max CAD paste; Ivoclar Vivadent, Liechtenstein) was fired on overlay, using the Programat P500 furnace (Ivoclar, Germany) at 840°C, for 20 min.

A specially designed specimen-holding device was then used to set each restoration on its corresponding tooth while maintaining it below a typical fixed load of 5 kg [21]. Following that, the marginal gap was measured with Image J software (Image J 1.53K, National Institutes of Health, Bethesda, USA) utilizing the digital microscope (Dino-Lite Pro; AnMo Electronics Corp., New Taipei, Taiwan) at a magnification of 230X at four locations on each surface. The pre-cementation gap was calculated using the mean of all sixteen readings obtained from each one of the samples.

Following that, each group was separated into three smaller groups, each with eight teeth, in line with the cementation procedure used: Subgroups (DDS+Phc, IDS+Phc): cemented with preheated composite (Enamel plus HRi, Dentin shade UD1, by Micerium, Italy), Subgroups (DDS+Dcrs, IDS+Dcrs): cemented with Dual-cure resin cement (RelyX Ultimate, 3M ESPE, Germany) and Subgroups (DDS+Fc, IDS+Fc): Cemented with flowable composite (Filtek supreme flowable, 3M ESPE, USA).

The internal part restorations were treated by using Hydrofluoric acid (> 5%; Ivoclar Vivadent, Liechtenstein) for 20 s., then rinsed for 15 s with water, after that cleaning off etching remnants in an ultrasonic cleaning bath with 90% alcohol for 5 minutes before silane application. Silanization was done using One bottle (prehydrolyzed porcelain primer, BISCO, USA) to the inner surface for 20 seconds followed by heat treatment. A hairdryer for 2 minutes at 100°C/212°F was used [22]. As the heat treatment will significantly enhance the effect of the silane [23-25]. The restoration looks dull/matte again after the saline is applied and dried (Figure 4).

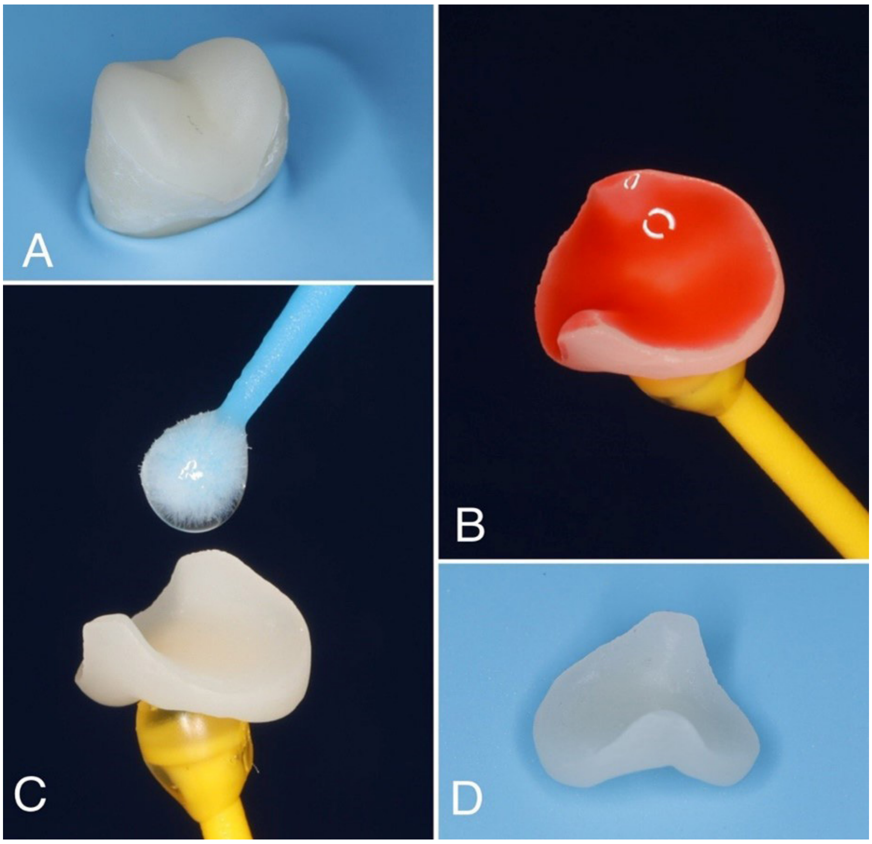

Figure 4 - Conditioning of ceramic restorations: (A) Final check of restoration, (B) Application of etching gel on the internal surface of indirect overlay restoration, (C) Application of ceramic primer using a brush applicator, (D) Air blow and hairdryer.

The filled adhesive (OptiBond FL) forms a consistent resin coating (IDS) on overlay preparation and was cleansed and reactivated after the preservation period (two weeks) by (50 μm) aluminum oxide airborne particle for 5 s at 15 mm and 2 bar using an airborne-particle abrasion device (Aqua care, UK) mounted on a dental surveyor [16,26]. All groups had their surfaces treated for 30 s with 37% phosphoric acid (Kerr, Italy), which was then thoroughly rinsed off for 20 s and dried with an air jet for 3 s. Primer was applied using a soft brush motion for 15 s, then it was air-dried for 5 s (No prime was applied to the IDS group). After that, lightly brushed with the adhesive resin for 15 s, but the adhesive resin did not polymerize (Figure 5).

For cementation: subgroups (DDS+Phc, IDS+Phc), micro-hybrid composite (Enamel plus HRi, Dentin shade UD1, by Micerium, Italy) were allowed to be preheated in a composite heater (Ena Heat Micerium, Italy) 68°C/ for 15 min [12].

For subgroups (DDS+Dcrs, IDS+Dcrs), the resin cement (RelyXTM Ultimate, 3M ESPE, USA) base and catalyst pastes were blended into a homogenous paste using a spatula in less than 20 seconds.

For subgroups (DDS+Fc, IDS+Fc), Flowable composite (Filtek supreme; 3M ESPE, USA) was introduced directly onto the fitting surface of the restoration.

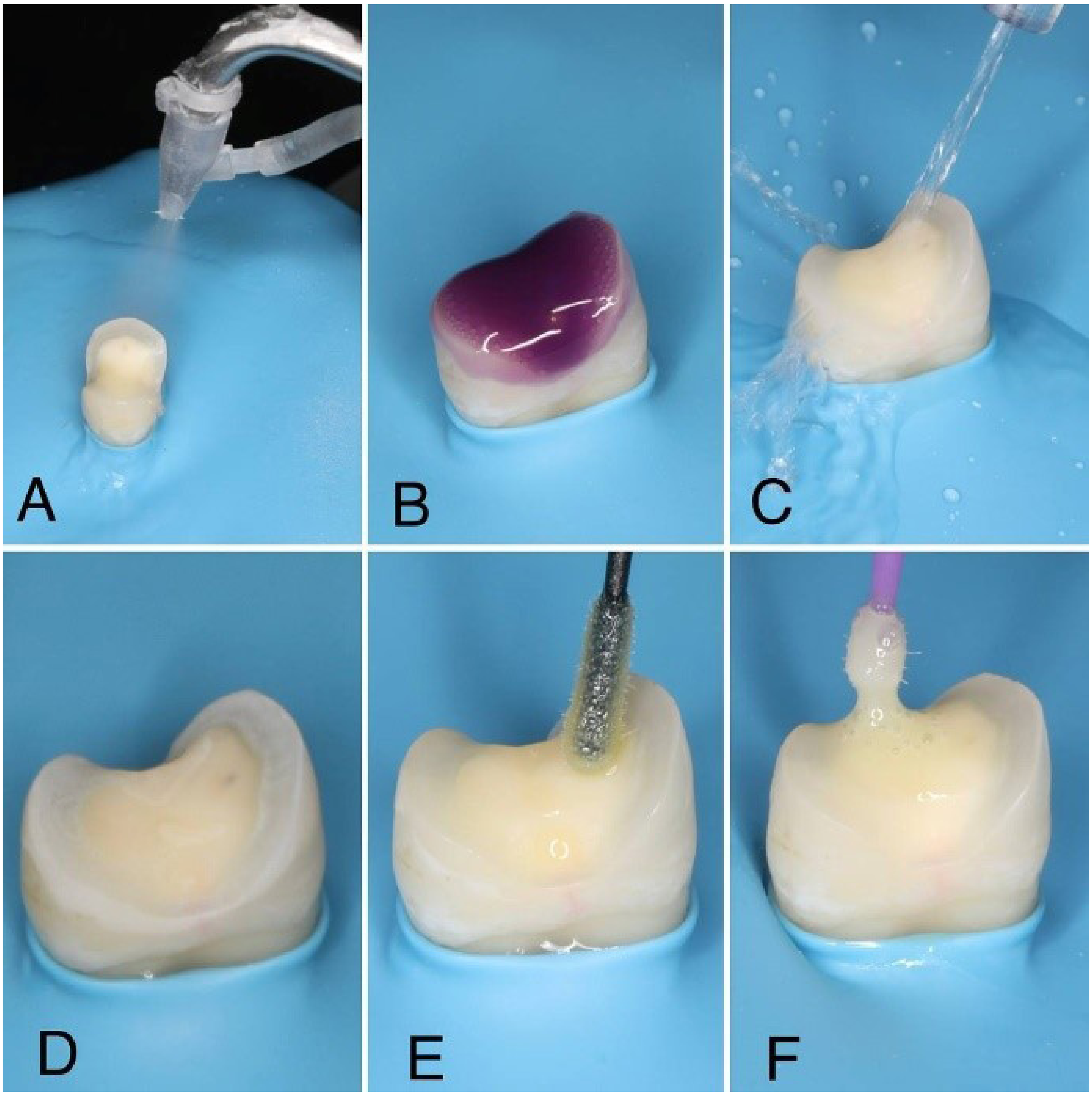

Figure 5 - Conditioning of the tooth surface: (A) Sand blasting at a distance of 1.5 cm. (B) Application of phosphoric acid etchant gel, (C) water rinsing, (D) Air drying, (E) Application of primer for DDS group, (F) Application of adhesive agent.

The restorations were slowly seated by applying finger pressure further down until complete insertion [27]. The sample was then fixed to the horizontal table of the custom-made holding device. A thin rubber material was placed at the end of the vertical arm to distribute the applied load equally within the occlusal surface of overlay restoration. The holding device was used for the final seating by applying a load of 5 kg (Approximately 50 N) on the seated restoration to simulate the biting forces created by the jaw [21,28].

The restorations were light-polymerized for 20 s, from occlusal, buccal, and lingual surfaces. Air blocking by placing glycerine gel (ultradent, USA) over the margins and polymerizing for 10 seconds per surface, then rinsed and drying (Figure 6).

The subsequent procedures were followed exactly as explained before, and the post-cementation marginal gap was determined at the same pre-cementation measurement locations (Figure 7).

The results were then analyzed statistically using an independent t-test, one-way ANOVA test, and Bonferroni correction at a significant level of 0.05.

RESULTS

As shown in Tables I and II, the IDS groups recorded a better marginal gap than the DDS groups, both pre-and post-cementation for all subgroups, with a statistically significant difference ($p<0.01$). The IDS+Fc and IDS+Dcrs groups demonstrated the best marginal adaptation (48.888 ±5.5 μm, 53.612 ±5.8 μm, respectively), and no significant difference between them ($p<0.01$), while the largest marginal gaps were observed in the DDS+Phc group (86.505 ±5.4 μm).

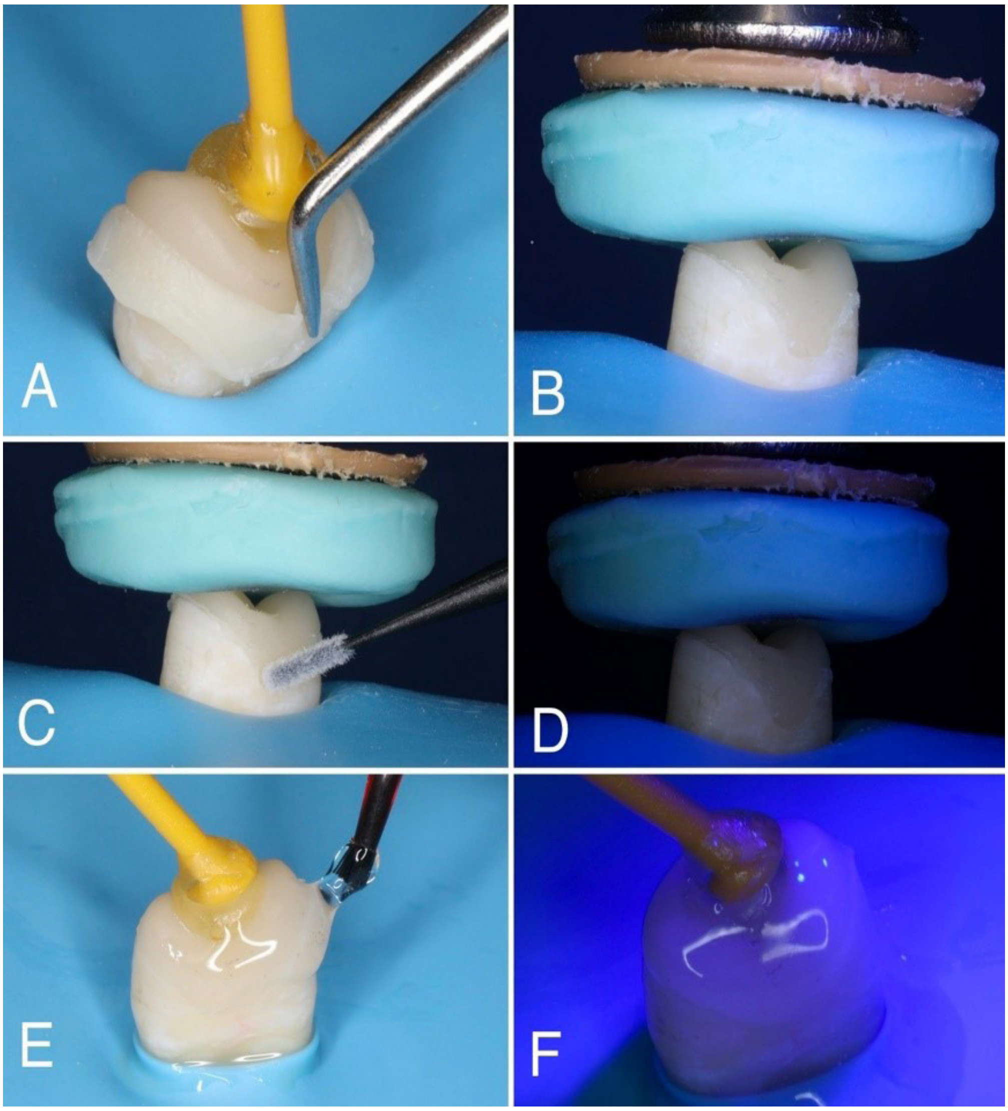

Figure 6 - Cementation of the restoration: (A) Removing the excess material with explorer, (B) Seating the restoration under the load of 5K, (C) Removing the last excess with micro brush, (D) Light curing under the load, (E, F) Application of air blocking material and last light curing.

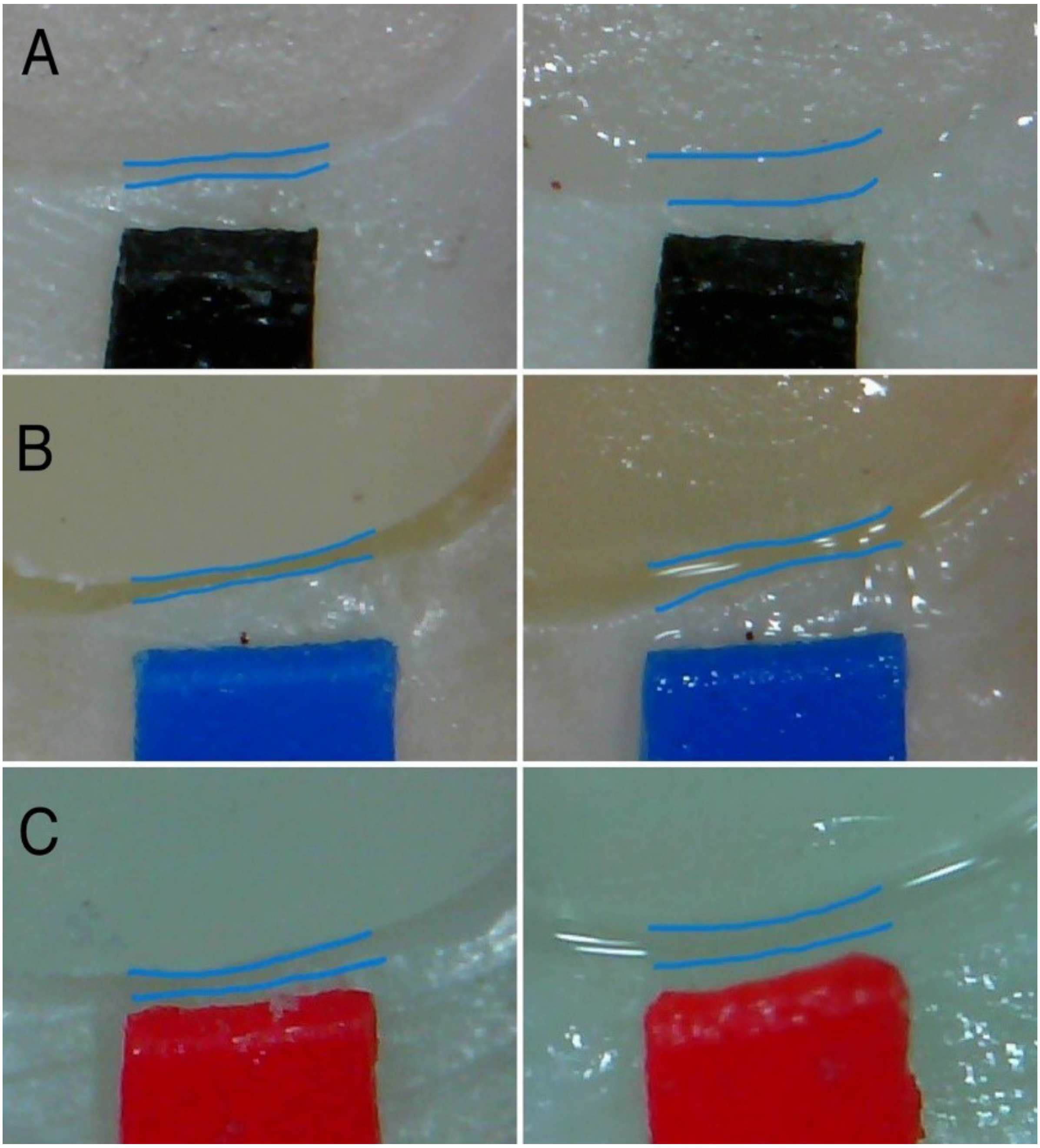

Figure 7 - Digital microscopic image of the pre-and post-cementation marginal gap: (A) cemented with preheated composite, (B) cemented with dual-cure resin, (C) cemented with flowable composite.

Table I - The mean marginal gap pre- and post-cementation using analysis of variance, independent t-test, and one-way ANOVA test at a significance level of 0.05

	Mean (µm) ± SD Pre-cementation				Independent t-test/p-value
	DDS+Pc	49.762 ±4.5	IDS+Pc	35.740 ±4.7	0.000
	DDS+Dcrs	48.335 ±5	IDS+Dcrs	35.917 ±5.2	0.000
	DDS+Fc	49.179 ±3.5	IDS+Fc	34.758 ±5.7	0.000
One-way ANOVA		0.813		0.894	
	Mean (µm) ± SD Post-cementation				
	DDS+Pc	86.505 ±5.4	IDS+Pc	79.19 9±6.9	0.034
	DDS+Dcrs	60.297 ±6.2	IDS+Dcrs	53.612 ±5.8	0.043
	DDS+Fc	58.982 ±4.7	IDS+Fc	48.888 ±5.5	0.000
One-way ANOVA		0.000		0.000	

Table II - Multiple inter-group comparisons of the marginal adaptation using post hoc (Bonferroni correction) test

groups	Subgroups	Subgroups	Mean Difference	*P*
DDS	DDS+Pc	DDS+Dcrs	26.207	0.000
		DDS+Fc	27.522	0.000
	DDS+Dcrs	DDS+Pc	-26.207	0.000
		DDS+Fc	1.315	1.000
	DDS+Fc	DDS+Pc	-27.522	0.000
		DDS+Dcrs	-1.315	1.000
IDS	IDS+Pc	IDS+Dcrs	25.587	0.000
		IDS+Fc	30.311	0.000
	IDS+Dcrs	IDS+Pc	-25.587	0.000
		IDS+Fc	4.723	0.413
	IDS+Fc	IDS+Pc	-30.311	0.000
		IDS+Dcrs	-4.723	0.413

DISCUSSION

The physicomechanical characteristics of the restoration and its luting cement have an impact on how long indirect restorations last [29], as well as, one of the most essential aspects is marginal adaptation, since it affects their durability [30,31]. Marginal errors can produce recurrent caries, deterioration of the luting cement, microleakage, and restoration failure [32]. The majority of studies showed a marginal gap clinically accepted when it fell within a range of less than 120 μm [1]. Other studies suggest that CAD/CAM all-ceramic onlays may be situated between 80-85 μm [33,34]

The design of the cavity, the type of adhesive employed, the thickness of cement, the methods used to treat the dentin surface before the cementation of the final restoration, and forces acting on the tooth-restorative interfaces all have a significant impact on the adaptation of indirect restorations [35].

The results presented that the gaps between all subgroups were less than the clinically accepted value. This might be attributed to the simple preparation design used in this study (butt joint), including flat smooth occlusal reduction, no retentive features, and fewer internal angles [36]. Such features allow for a better flow of cement during cementation and do not cause hydraulic pressure or problematic discharge of excess cement [1,36,37]. As a result, the best mechanical behavior and adaptation compared to other preparation designs [13].

The IDS procedure was established in the direction to overcome the problems affecting the adaptation of restoration as shown in this study, before and after cementation (regardless of cement type), for both group types (IDS or DDS), there was a statistically significant difference between them. The samples that were sealed immediately with dentin bonding agent showed lower marginal gaps than delayed dentin sealing. Before cementation, IDS may smoothen the cavity surfaces and round angles, creating better geometry [38], These are essential for achieving effective adaption of ceramic restoration due to the designs of the burs used to mill the wax molding disc or ceramic block [39]. IDS with round angles and smoother surfaces are preferred for optical scanning and laboratory work and affects the thickness of the resin cement layer by improving restoration adaption compared to a cavity without IDS application [6,40]. After cementation, it was possible that covering the dentin with a hydrophobic monomer or a low-viscosity composite may have aided in the improvement of marginal adaptation by absorbing the developing polymerization shrinkage of the cement [41,42]. This result supports that the IDS produces less discrepancy in the vertical marginal gap.

Ashy et al. [43] found that Luted ceramic inlays had a better marginal adaptation immediately after cementation using IDS compared with using DDS. Medina et al. [30] assessed the effect of various materials used with the resin coating technique and found an efficient alternative method to maintain the marginal adaptation and improve the bond strength of indirect composite resin restorations by first sealing the dentin with the adhesive system, then applying it again right before cementation.

Following cementation, the marginal gap increased in both group types that were cemented with three different types of cement. This result is consistent with the earlier studies, which showed that the cementation procedure increased the marginal gap [1,44].

Regarding the type of luting material, the samples were sealed immediately with a dentin bonding agent and cemented with three types of luting agents showed less marginal gap than delayed dentin sealing as in pre-cementation, with a statistically significant difference between them. This might be due to the IDS group getting less pre-cementation marginal gap compared to the DDS group. Furthermore, composite resin usually shrinks toward the surfaces to which they are bonded [45]. Unlike inlay, shrinkage pulls the overlay restoration along the axis of the tooth to the preparation [12]. The developing polymerization shrinkage of the cement was absorbed by the layer of hydrophobic monomer (IDS) that covers the dentin which improves marginal adaptation [41].

Regarding to the three luting agents, the restoration cemented with preheated composite displayed a higher marginal gap with statistical differences than resin cement and flowable composite material. This might be associated with the change in film thickness of luting materials since the preheated composite showed a higher marginal gap after cementation as compared with resin cement and flowable composite, which could be correlated to a high film thickness of the preheated composite that produced an increase in marginal discrepancies in the final restoration seating.

The thickness of the dental cement layer along the preparation walls determines the gap size, and this layer also affects how the restoration will be seated [46], As film thickness decreases, the fitness of restoration increases [47]. Sampaio et al. [48] investigated the luting agents with varying film thickness. They found, no matter whether they were preheated or not, that the restorative composite resin film thickness was higher than that of the flowable composite resins and the veneer cement.

Blalock et al. [49] stated that regardless of heating temperature, the conventional composite had a film thickness superior to that of flowable composite resins that could be used at room temperature (at 54°C, 140 μm, and 35 μm respectively). A study estimated the effect of the filler shape and viscosity of luting resin on a marginal gap and showed that the higher composites viscosity used for cementation of ceramic partial restoration would increases displacement and marginal inaccuracy [50]

Furthermore, by evaluating and comparing the film thickness of resin cement and two composite resins (preheated and/or ultrasonically vibrated). The study found resin cement had the lowest film thickness, and preheating and ultrasonic vibration reduced the film thickness of composites, but vary between composites type, and not all could be reduced below 50 μm [51].

The dual-cure (relyX ultimate) resin cement showed a slight increase in the marginal gap over (Filtek supreme) flowable composite with no significant differences found between them. Mounajjed et al. [44] considered the marginal adaptation of lithium disilicate pressed crowns with a different cement: preheated composite resin, Resin cement, and Flowable composite resin. They found that heated composite showed the maximum marginal gap with a significant difference between resin cement and flowable composite, and no significant difference between the latter two types of cement. Alajrash and Kassim [52] identify the outcome of various resin cement on the marginal gap using Emax, CAD/CAM crowns. They found that the preheated composite had a higher degree of marginal gap than the flowable composite and resin cement.

Nevertheless, the limitation of this study is the evaluation of the marginal gap without reproduction of the oral situation. Therefore, coming research should focus on the thermocycling technique. Different restorative materials and novel reinforcing materials (Fiber reinforced composite, and ribbons) have been used as a bio-base to improve the fracture strength may affect the seating of restoration and produce marginal inaccuracy.

CONCLUSION

Within the limitations of the study, teeth treated with Immediate Dentin Sealing exhibited better marginal adaptation compared to teeth without IDS. When flowable composite and dual cure cement were used as luting materials, they demonstrated the most substantial improvement in overall marginal adaptation, followed by preheated composite, respectively.

However, it is important to note that the results of the study showed that the marginal gaps of all luting agents were within the clinically acceptable limit.

Author's Contributions

YHY: Conception, design, data acquisition, and interpretation, drafted and critically revised the manuscript, and performed all statistical analyses. AJK: Conception, design, data acquisition, and interpretation, drafted and critically revised the manuscript. All authors gave their final approval and agree to be accountable for all aspects of the work.

Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of: The College of Dentistry, the University of Baghdad. The approval code for this study is: 509522/509.

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