Marginal Seating of Zirconium Monolithic Crown Restorations Utilising Different Types of Luting Agents - A Comparative Study

Abstract

Background: Marginal adaptation plays a critical role in the clinical success of ceramic inlays, and several factors, including the type and composition of luting cement, can influence the marginal fit and overall integrity of restorations. **Aim of the Study:** This study aimed to investigate the effects of varying composite luting cement compositions on the marginal adaptation of Cerec inlays. **Materials and Methods:** A total of 40 healthy maxillary first premolars were used, divided into three groups according to the type of cement: Group A (3M U200), Group B (BISCEM), and Group C (Riva GIC), with eight teeth in each group. The null hypothesis stated that the type of cement would not affect the marginal adaptation of the ceramic systems. **Results:** One-way ANOVA analysis (F = 104.577; *P* = 0.000) revealed that the vertical marginal discrepancy (VMD) was significantly influenced by the type of cement and the phases of manufacturing and cementation. Group B (BISCEM) showed the lowest mean marginal discrepancy at 81.69875 µm. All tested groups exhibited VMD values within clinically acceptable ranges. Two-way ANOVA and Bonferroni tests were used to analyse the influence of cement space thickness on crown retention and to determine statistically significant differences between the groups. **Conclusion:** The type of luting cement significantly affects vertical marginal adaptation due to differences in viscosity, film thickness, and interaction with water, highlighting the importance of selecting appropriate cement materials to ensure optimal marginal fit of ceramic restorations.

Keywords: *Luting agent, resin composite bonding, restoration, zirconium monolithic crown*

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Introduction

The success of indirect restorations depends not only on the restorative material itself but also critically on the choice of luting cement and the cementation technique, as both serve to prevent fluid intrusion at the tooth–restoration interface. Currently, five main types of luting cements are available, namely zinc phosphate, zinc polycarboxylate, glass ionomer cement (GIC), resin-modified GIC, and resin composite cement, none of which are universally suitable for all indirect restoration cases.[1,2] Resin composite cements are especially valued in all-ceramic restorations due to their strong adhesion to various substrates, resistance to salivary degradation, high mechanical strength, and superior shade-matching capabilities.

Unlike metal-ceramic restorations, all-ceramic restorations lack a metal substructure and thus rely heavily on the cement-tooth complex for support, especially given their inherent brittleness. Marquis reported that when cracks occur in all-ceramic restorations, resin cement infiltration significantly reduces crack propagation and increases fracture resistance, contributing to long-term clinical success.[2] A notable component of resin cements is methacryloyloxydecyl dihydrogen phosphate (MDP), which chemically bonds to zirconia. Therefore, cements and primers designed for zirconia restorations should include 10-MDP to ensure effective adhesion.[1] As described by Paul (2015), resin cements vary in their curing mechanisms: light-cure, self-cure, and dual-cure types.[3] Light-cure resin cements rely entirely on light activation, commonly using camphorquinone as the photo-initiator.

Inadequate polymerisation leads to the presence of free monomers and unpolymerised resin, increasing marginal solubility and contributing to complications such as pulp necrosis, secondary caries, marginal discoloration, fluid absorption,

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and ultimately mechanical degradation.[4] Consequently, light-cure cements are best reserved for translucent restorations such as porcelain laminate veneers and glass ceramics that permit sufficient light penetration.[3,5] Self-cure resin cements are suitable for areas with limited light accessibility, such as metal restorations, thick ceramics, or porcelain-fused-to-metal (PFM) restorations. These rely on benzoyl peroxide and tertiary amine as initiators. However, their color stability and shade options are limited due to discoloration over time caused by peroxide degradation.[6] Dual-cure cements have been developed to combine the benefits of light-cure and self-cure mechanisms.

While chemical curing ensures setting in deep or light-inaccessible areas, light activation enables rapid surface finishing. However, polymerisation in dual-cure cements still significantly depends on adequate light exposure, which is influenced by the ceramic's translucency and crystalline content.[7] Studies have shown that self-cure mechanisms in dual-cure systems are often inadequate without sufficient light.[8] The degree of light transmission is further affected by the ceramic type and crystal content—more crystalline and opaque ceramics attenuate light more significantly. Manufacturers rarely specify the exact exposure times required for effective curing through various materials. Strydom emphasised that dentists often provide insufficient light-curing time, and extended exposure is necessary to overcome attenuation effects and to ensure full polymerisation through the ceramic.[9] The aim of this study is to evaluate the degree of adaptability of all-ceramic crowns within the cervical area, particularly in relation to the type and curing mechanism of resin-based luting cements.

Materials and Methods

In this research, a selection of 40 healthy maxillary first premolars with similar dimensions and form was made. These teeth were extracted for orthodontic reasons from patients aged between 18 and 24 years. Only teeth without cracks, cavities, or enamel imperfections were included. Ethical approval was received from the ethical and research committee at College of Dentistry, University of Basrah, Basrah, Iraq (No. BDC-7-05-24-3 dated 4/5/2025). To maintain hydration, the teeth were preserved in deionised distilled water throughout the study. Each tooth was embedded in cold-cured acrylic resin, positioned 2 mm below the cemento-enamel junction, simulating the level of the supporting alveolar bone. To ensure consistency, a single operator prepared all the teeth for monolithic zirconia crowns. The preparation utilised a modified dental surveyor equipped with a high-speed handpiece attached to a coolant system (air/water) on the horizontal arm. This configuration maintained the alignment of the bur with the long axis of the tooth during axial wall preparation.

To preserve consistent angulation, the acrylic block was fixed to a movable horizontal table, ensuring the bur remained parallel to the long axis of the tooth. Standardised protocols for InCoris TZI C (Pre-Shaded Translucent Zirconium Oxide Sinter Ceramic) were followed, using a rugby ball bur (NO) to prepare for full ceramic restorations. The preparation features included: planar occlusal reduction, 1–1.5 mm axial reduction, 0.8 mm deep chamfer finish line, a 60° convergence angle, and 4 mm occluso-gingival height. A tapered fissure bur with a round end (No. 903319) was used for preparation, and (No. 931749) for finishing [Figure 1]. After preparation, the teeth were divided into three groups of eight teeth each, according to the cement type: Group A (3M U200), Group B (BISCEM), and Group C (Riva GIC). A CAD-CAM milling system was used to fabricate crowns in line with manufacturer protocols for InCoris TZI C. All fabrication steps, model scanning, software design, milling, and sintering were standardised, enhancing procedural consistency and accuracy.

A consistent scanning technique was applied to all scanners, producing 3D digital models exported in STL format. Crowns for all groups were fabricated using the same milling machine, the MCX5 (Sirona, Germany). Designs were imported into CAM software (InLab SW16.1) and, after milling, sintered in an in-Fire HTC speed furnace (Sirona, Germany). For cementation, a custom-designed holding device was used to apply a standardised seating force. A 5-kg vertical load was chosen, simulating clinical conditions for accurate and consistent seating. A modification in the device enabled precise seating of each zirconia crown onto the natural tooth sample. Marginal gap evaluation involved measuring perpendicularly from the crown margin to the preparation's finishing line [Figure 2]. A Dino-Lite digital microscope (280× magnification) connected via USB was used. DinoCapture software captured two images per sample, which were analysed using ImageJ 1.50i software (NIH, Bethesda, MA, USA). Calibration was achieved by imaging a 1-mm ruler at 280× magnification. In ImageJ, a line corresponding to 1 mm was drawn using the straight-line tool. Under the 'Analyze' menu, the 'Set Scale' function converted pixel values to micrometers. The

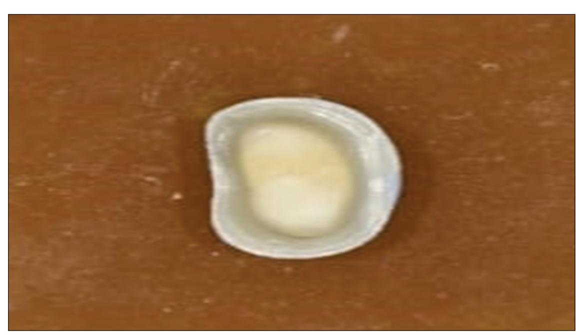

Figure 1: Planar occlusal reduction, axial reduction measuring 1–1.5 mm, a deep chamfer finishing line with a depth of 0.8 mm, a convergence angle of 60 degrees, and an occluso-gingival height of 4 mm

unit (μm) and known distance (1000) were entered, with the software automatically calculating pixel equivalency. This calibration ensured high accuracy and reliability in all digital measurements.

Statistical analysis

All data are presented as frequencies and percentages. We used SPSS (version 26) with the dependent t-test (two-tailed) and independent t-test (two-tailed) for variables with normally distributed distributions. We employed the Mann-Whitney U test, Wilcoxon test, and Chi-square test on variables with non-normal distributions. M < 0.05 was considered statistically significant.

Results

The success of an indirect restorative treatment is partially dependent on the cementation method utilised to establish a bond in the space between the restoration and the tooth. Although the adhesion of cement to different surfaces is crucial, adequate bonding can still occur even when the junction between the tooth and the restoration is not entirely sealed, which may lead to possible clinical issues.[10] Traditionally, definitive cementation has been viewed as a critical phase in restorative procedures. Selecting the right type of cement and properly implementing the cementation process are essential for achieving effective marginal sealing and ensuring the long-term stability of the restoration.[11] In other research, conventional and modified GICs and self-adhesive cements were used for the cementation of zirconia-based restorations. The initial hypothesis of the study was that there would be no statistically significant differences in vertical marginal discrepancy (VMD) values among the tested cement types.[12] However, the findings of the current study contradicted this hypothesis, demonstrating substantial differences in VMD values among all groups tested. The results of a one-way ANOVA (F = 104.577; P = 0.000) indicated that VMD was significantly influenced by both the manufacturing and cementation phases[13] [Table 1].

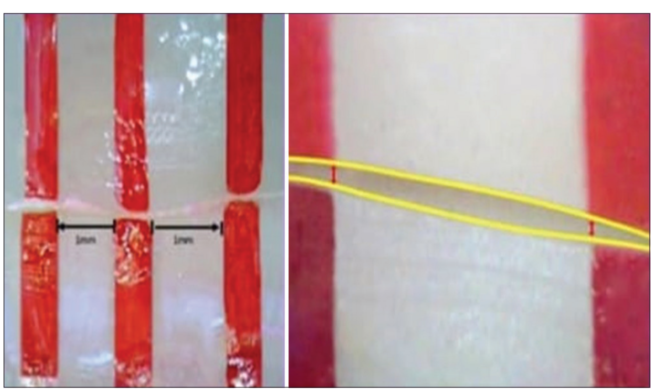

Figure 2: Measuring the vertical marginal gap, measured perpendicularly the distance from the edge of the crown restoration to the edge of the finishing line preparation

Notably, Group B exhibited the lowest mean marginal discrepancy of 81.69875 μm for monolithic zirconia crowns produced through CAD/CAM technology, as analysed in this research [Table 2]. The CAD-CAM monolithic zirconia crowns' VMD was greatly impacted by the cementation procedure. For every tested group, the average VMD values fell within the ranges that are considered clinically acceptable, generally less than 120 μm, based on standards reported in previous studies.[5] This threshold is commonly cited in the literature as the upper limit for acceptable marginal fit in fixed prosthodontics, beyond which increased plaque accumulation, microleakage, and cement dissolution may occur.[14] The one-way ANOVA test revealed a statistically significant difference in mean VMD values among the three cement groups (F = 104.577, P < 0.001), indicating that the type of cement used had a significant effect on marginal adaptation.

Discussion

Because of the film thickness, viscosity, rheological characteristics, or the influence of water, the significant changes observed in VMD after cementation may be attributed to the inherent differences among the luting cements used [Table 3]. The type of cement used[15] and the

Table 1: Two-way ANOVA summary of variance between and within groups

ANOVA	Sum of Squares	df	Mean Square	*F*	Sig.
Between Groups	6542.945	2	3271.472	104.577	<0.001
Within Groups	656.939	21	31.283		
Total	7199.884	23			

df: Difference

Table 2: Descriptive statistics of measurement values across experimental groups

	n	Minimum	Maximum	Mean
Group A (3M U200)	8	97.138	114.938	105.61±5.75
Group B (BISCEM)	8	73.910	95.650	81.69±7.42
Group C (RIVA GIC)	8	119.45	125.14	121.90±2.36

Table 3: Bonferroni *post-hoc* test for pairwise comparison between cement types

Cement type	Mean Difference	Std. Error	Sig.
3M U200 self-adhesive resin			
Bicsem self-adhesive resin	23.91950*	2.79655	<0.001
RIVA Luting GIC capsules	−16.28375*	2.79655	<0.001
Bicsem self-adhesive resin			
3M U200 self-adhesive resin	−23.91950*	2.79655	<0.001
RIVA Luting GIC capsules	−40.20325*	2.79655	<0.001
RIVA Luting GIC capsules			
3M U200 self-adhesive resin	16.28375*	2.79655	<0.001
Bicsem self-adhesive resin	40.20325*	2.79655	<0.001

luting technique[16,17] are two primary factors that can affect a crown's marginal fit after cementation. For example, a study[17] reported that resin-based cements typically offer better marginal adaptation compared to glass ionomer-based materials due to their superior mechanical properties and lower solubility. Similarly, a study emphasised that proper cementation techniques, such as application pressure and seating dynamics, greatly influence final marginal integrity.[18]

The filler loading and particle size of the luting composites used in this study vary. The viscosity of a luting composite is thought to be its most important clinical characteristic. Additionally, it is essential to consider that the type of luting media utilised may possess unique rheological properties when subjected to pressure, resulting in a significantly different film thickness.[19] This is particularly relevant when considering self-adhesive resin cements, which are known to exhibit shear-thinning behavior, allowing better flow under pressure but rapid setting when static. This occurrence could be attributed to the varying flow characteristics demonstrated by these cements. Such differences may clarify the variations in marginal discrepancy values noted with the aforementioned luting media.[20,21] Furthermore, the relationship between marginal fit and cement type remains an area of ongoing research.

While some studies suggest that the luting agent may not significantly affect marginal adaptation, others indicate otherwise.[22] A review of the relationship between marginal openings and marginal leakage in all-ceramic crowns, considering the type of cement used, reveals limited evidence supporting the claim that luting agents have no effect on marginal adaptation.[23] The viscosity of a luting agent may influence the minimum film thickness that can be attained when seating a restoration. The viscosity of resin cement increases too rapidly, preventing it from flowing sufficiently towards the cervical area, resulting in its extrusion from the edges of the crown.[24] This rapid viscosity increase creates hydraulic pressure beneath the crown, possibly preventing complete seating. This occurrence is likely to cause the unwanted discharge of excess cement and hydraulic pressure, which in turn raises the cement, resulting in a considerable accumulation of luting cement on the occlusal surface of the prepared tooth.[25] This excess may hinder the correct seating of the crown restoration, contributing to marginal discrepancy issues following the cementation procedure.[26]

Conclusion

The type of cement used had an impact on marginal adaptation due to the differences in thickness and viscosity. The VMD of the crowns evaluated was significantly influenced by the various phases of manufacturing and cementing. By choosing BISCEM self-adhesive resin cement, sticking to the standard cementing protocols, and assuring proper curing, clinicians can enhance the marginal adaptation and longevity of zirconia monolithic crowns. This information provides a reliable guide to achieve optimal clinical outcomes in the context of zirconia restorations. Our recommendations are that improving the marginal adaptation and clinical success of zirconia restorations is imperative, based on the three recommendations from a study called 'Marginal Seating of Zirconium Monolithic Crown Restorations Utilizing Different Types of Luting Agents'. To ensure superior marginal adaptation and optimal clinical outcomes in zirconia-based restorations, it is recommended to utilise BISCEM self-adhesive resin cement, which has demonstrated favorable flow characteristics and adaptability under pressure. Additionally, it is crucial to maintain standardised cementation protocols, including proper seating force and timing, to establish an optimal fit between the crown and the prepared tooth. Removing excess cement as soon as possible is essential to reduce the risk of crown misalignment and marginal gaps that may compromise the restoration's longevity. Finally, clinicians should optimise curing protocols when using dual-cure resin cements, ensuring adequate polymerisation both at the surface and in deeper areas to maximise mechanical performance and marginal seal integrity.

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Conflicts of interest

There are no conflicts of interest.

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