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Original Article

Influence of Luting Cements on the Fracture Resistance of Hybrid Ceramic Restorations

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Abstract

For dental restorations, hybrid ceramics provide a potent blend of ceramics and resin polymers. For their lifespan and load-bearing capacity, the selection of an appropriate luting agent is essential. The purpose of this study was to investigate the effects of different luting agents on the load-bearing capability of hybrid ceramic crowns that are CAD/CAM machined. VITA CAD/CAM Fifteen identical crowns were made from ceramic hybrid blocks, divided into three groups, and cemented using glass ionomer cement (GIC), dual-cure resin, and light-cure resin. To determine the maximum loads at fracture, prefabricated polyurethane resin abutments with periodontal ligament simulation were installed on a universal testing apparatus. ANOVA was used to compare the results ($P < 0.05$). Resin luting gels showed higher loads than glass ionomer, however there was no statistically significant difference in the maximum load at fracture between the groups. Visual examination showed that GIC had more catastrophic fractures in the crowns than resin. The type of luting agent used seems to not affect the fracture stresses of CAD/CAM crowns. However, data suggest that resin might be a better choice than GIC.

Key words: Restorative dentistry, Hybrid ceramic, Luting agent, Fracture load, CAD/CAM, Composite resin

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Introduction

Dental restorations that are biocompatible, long-lasting, and natural-looking can now be produced because of recent developments in dental technology [1]. Ceramics and composites are examples of non-metallic aesthetic computer-aided design/computer-aided manufacturing (CAD/CAM) materials that have gained popularity in dentistry in recent years [2]. Because glass and feldspathic ceramics are brittle and prone to breaking, they must be handled carefully during dental treatments to avoid wearing down neighboring teeth [3]. Resin-based materials are more flexible than ceramics, but they tend to be weaker and less durable. In the world of CAD/CAM, there are now hybrid ceramics, such as resin-reinforced ceramic materials, which combine the benefits of both polymers and ceramics. All-ceramic restorations may break due to imperfections in the intaglio surface, which can cause small cracks to grow faster intraorally [4], necessitating their replacement if the ceramic veneer chips or if the entire restoration breaks [5-7]. This enables faster and more accurate restorations by doing away with the need for a final firing stage [8]. Polymer-infiltrated ceramic network (PICN) materials and materials with dispersed fillers are the two types of hybrid ceramics that are now available for CAD/CAM fabrication of definitive indirect single-tooth restorations (crowns) [9]. Both materials are particularly helpful for implant-supported restorations because they can absorb masticatory pressures and have an elastic modulus that is closer to that of dentin [9, 10]. These composite materials are very easy to characterize, repair, grind, and tint. Although PICN is similar to human enamel in its characteristics, it is incapable of recovering after being unloaded [8, 11]. Because cracks are diverted at the polymer-ceramic interface, this material is more resistant to damage than ordinary ceramics, lowering the possibility of chipping and failure [12]. Its remarkable stress-handling properties are confirmed by SEM research [13].

A variety of luting chemicals are available for use in cementing CAD/CAM milled restorations. One such compound is the glass ionomer cement-based luting agent (GIC), a mixture of zinc polycarboxylates and dental silicate cement. GIC is a multipurpose substance that forms a chemical link with the structure of teeth [14]. Additionally, it has potent anti-caries characteristics and is biocompatible and bioactive, which makes it ideal for restorative dentistry [14, 15]. Zirconia crowns are frequently attached by clinicians using GIC luting agents because studies have shown that these crowns maintain their strength even when luted with this cement up to 0.5 mm thick. If retention is adequate, GIC can also be used for the luting of high-strength all-ceramic restorations, including fixed partial dentures (FPD) and lithium disilicate glass-ceramic and oxide ceramic restorations [16]. Low-viscosity composites called resin luting agents are employed in a variety of processes, including the cementation of veneers, inlays, and orthodontic appliances. These materials are excellent for cementing cast restorations that require greater retention, as well as ceramic and composite restorations [16]. They have good working and setting times and a thin layer. There are three types of resin luting agents: dual-cured, light-cured, and self-cured. Even in non-exposed regions, dual-cured materials have excellent conversion rates and provide ease and safety. Self-adhesive cement and those that require an additional adhesive for application are the two categories of materials [14, 16].

A durable CAD/CAM machined restoration depends on selecting the appropriate abutment tooth and luting material [14, 16, 17]. Research has shown that while the type of luting chemical employed may affect a crown's adhesion endurance, it does not affect the rate of detachment [14, 16, 18]. Due to its composition's near resemblance to hybrid ceramic crown materials, resin cement is advised for best results [17, 19]. It was discovered that multistep resin composites were more effective than traditional cementing at strengthening glass-ceramic and zirconia crowns [18, 20]. According to a study by Indergård *et al*. [19], the use of adhesive bonding rather than conventional zink phosphate luting agents significantly increased the fracture load of 3Y-zirconia crowns. In a study by Stawarczyk *et al*. [21], ceramic and composite anterior crowns showed comparable load-bearing performance using GIC or self-adhesive resin luting agents. Masuda *et al*. acknowledged that the type of luting agent did have an impact on the load-bearing capacity of premolar full-coverage restorations [22]. The strongest occlusal stresses in centric occlusion are experienced by maxillary second molars, according to a recent finite element analysis (FEA) [23]. Therefore, materials with a higher load-bearing capability than those utilized for other teeth would be required for the restoration of these teeth. To the best of the authors' knowledge, no study has yet been conducted to ascertain if the type of luting agent utilized has an impact on the load-bearing capacity and fracture pattern of PICN hybrid ceramic CAD/CAM full-coverage single-tooth restorations for second maxillary molars. The purpose of this study was to examine how the load-bearing capability of CAD/CAM milled PICN hybrid ceramic full-coverage single-tooth restorations was affected by two different types of resin-based luting agents and one non-resin-based luting agent that is often employed. The null hypothesis was that PICN hybrid ceramic crowns cemented with three distinct luting agents would not significantly differ in load at fracture.

Materials and Methods

Study design

In this in-vitro study, a universal testing machine was used to measure the maximum load at fracture (load-bearing capacity) in three different groups based on the luting agent used. A total of 15 identical CAD/CAM crowns were milled from PICN hybrid ceramic blocks. Each crown had a contour thickness of 1.0 mm and a circular outer circumference to maintain a consistent axial thickness. The crowns were randomly divided into three groups (n = 5) and placed on identical resin test blocks. Each group was cemented using one of three luting agents: GIC, self-adhesive dual-cure resin, and a dual-cure resin with a separate bonding agent. All cemented crowns were stored in distilled water at 37 °C for 24 hours, then mounted in a universal testing machine and loaded till fracture. The maximum load at fracture for all crowns was recorded and statistically compared. Fractured restorations were inspected visually and compared descriptively between groups **(Figure 1)**.

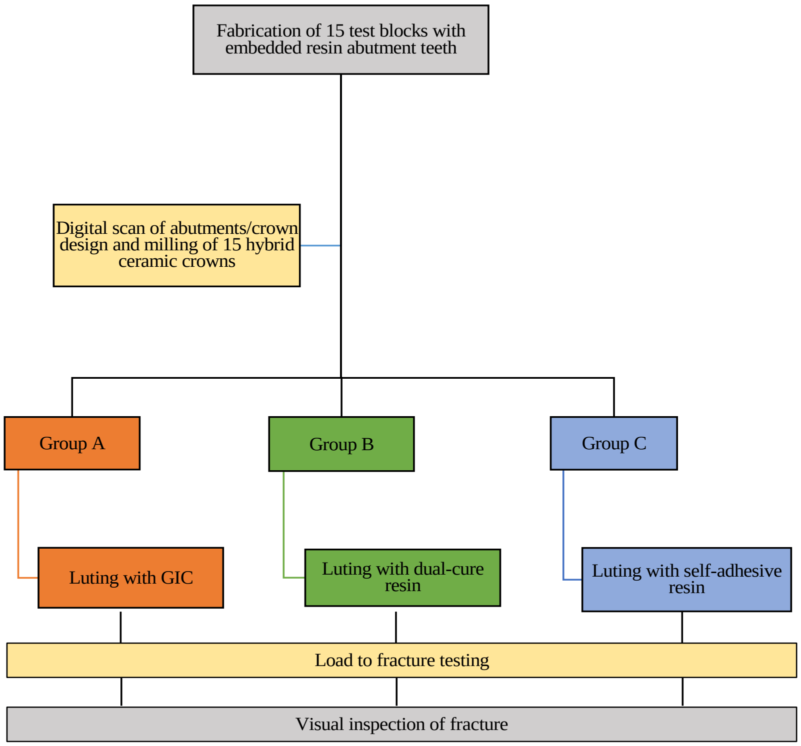


Figure 1. Study design.

Abutment teeth preparation

To create 15 abutment teeth, we duplicated a pre-prepared model acrylic maxillary second molar (UR72A, Nissin Dental Products Inc. in Kyoto, Japan). The tooth used as a master model abutment was adjusted according to specific criteria with an occlusal reduction of 1 mm. The height of the tooth crown was set at 5 mm for both buccal and lingual aspects, and 2.5–3 mm for the mesial and distal aspects. The crown width was confirmed to be 8 mm mesiodistally and 11 mm buccolingually. A uniform 1 mm circumferential heavy chamfer finish line was created, and the axial surface taper was set at 6 degrees. The occlusal form of the abutment teeth matched the natural tooth anatomy with rounded line angles.

A specially designed mold former was used to secure a duplicate of the model tooth. The silicone duplication material (Dublisil® 20 speed from Dreve Dentamid GmbH in Unna, Germany) was mixed and poured according to the manufacturer's instructions. The silicone was allowed to set for 30 minutes before carefully removing the model tooth. High-precision die resin (Mirapont, Hager, and Werken GmbH and Co. KG, Duisburg, Germany) was used to make the duplicate abutment teeth. The mixture was prepared following the instructions provided by the manufacturer. It was mixed for 15-30 seconds until a smooth and even mixture was obtained. The mixture was then poured into a silicone mold in a thin line from a height of approximately 20 cm. A vibrating device (Whip Mix vibrator, Whip Mix Corporation, Louisville, KY, USA) was used at a very low vibration to ensure the mixture was evenly distributed. After 2 hours, the duplicate abutment tooth was removed from the mold **(Figures 2a-2f)**.

The roots of the duplicated teeth were smoothed and standardized to 11.5-12 mm in length. They were then sandblasted with 110 µm Aluminum oxide particles. To simulate natural tooth mobility, the sand-blasted roots were coated with a thin layer of elastic latex material (ERKODENT Erkosin, Erich Kopp GmbH, Herrenberg, Germany), 1 mm away from the finish line

[24, 25]. This resulted in a latex thickness of approximately 0.55 ± 0.1 mm apically, mimicking the resilience of natural periodontal tissue **(Figures 2g-2i)**.

Figure 2. Duplication of the master model abutment tooth; a, b) the master model tooth secured within the mold former, c) mixing of duplication silicone, d) high-precision resin for abutment fabrication, e) silicone mold with resin poured in, f) resultant silicone mold and duplicate prepared abutment tooth, g) duplicate resin teeth with rounded sandblasted roots, h) Erkodent liquid latex material, and i) duplicate resin teeth with a latex layer covering the root portions.

Fabrication of the test blocks

The latex-covered roots of the duplicated teeth were embedded in high-precision resin (Mirapont, Hager and Werken GmbH and Co. KG, Duisburg, Germany) within cylindrical silicone molds (Dublisil® 20 speed, Dreve Dentamid GmbH, Unna, Germany) to fabricate the test blocks. The coronal portion and finish line were protected with wax beforehand till 3 mm apical to the finish line. After 2 hours, the test blocks were pulled out of the silicone molds. Statistical analysis was conducted using SPSS version 26 to get descriptive statistics as well **(Figure 3a)**.

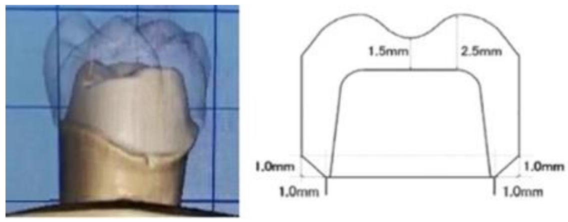
CAD/CAM fabrication of restorations

Scanning of the prepared teeth was done using Ceramill Map 400 Scanner (AmannGirrbach GmbH, Koblach, Austria). The design of the occlusal surface of the final restoration was completed using an adult molar design supplied by design software (Ceramill Mind, AmannGirrbach GmbH, Koblach, Austria). The complete crown design and dimensions were guided by the manufacturer's recommendation for Vita Enamic blocks (VITA Zahnfabrik H. Rauter GmbH and Co.KG, Bad Säckingen, Germany), with a circumferential axial thickness of 1 mm, and occlusal thickness of 1.5 mm measured in the central groove. The cement space was set at 20 µm in the region 1.0 mm above the margin and 60 µm in other regions **(Figure 3b)**.

The hybrid ceramic crowns were milled to full anatomic contour from high translucency PICN Vita Enamic hybrid ceramic blocks shade 0M1 HT (VITA Zahnfabrik H. Rauter GmbH & Co.KG, Bad Säckingen, Germany) using the Ceramill Motion

2 machine (AmannGirrbach GmbH, Koblach, Austria) Wet milling was used with four diamond burs of varying sizes: 1.8 mm, 1.4 mm, 1.0 mm, and 0.4 mm. Then, the crowns were finished and polished according to the manufacturer's instructions. All crowns were glazed with a light-cured characterization resin (GC Optigalze Color, GC Germany GmbH, Bad Homburg, Germany) **(Figure 3c)**.

a)



b)

c)

Figure 3. Resin test blocks; a) resin test blocks with embedded duplicate abutment teeth, b) digital scan and design of the tested PICN hybrid ceramic crown, and c) resin test blocks with cemented crowns.

Cementation of the crowns

For this study, the test blocks were split into three groups (each with a sample size of 5) based on the type of luting agent used: Group A used GIC, Group B used dual-cured resin, and Group C used self-adhesive dual-cure resin. To prepare for the cementation procedure, the restorations were degreased with ethanol. The inner surfaces of the crowns were treated with 5% hydrofluoric acid gel (VITA Ceramics Etch, VITA Zahnfabrik H. Rauter GmbH and Co.KG, Bad Säckingen, Germany) for 60 seconds, while the outer surfaces were protected to prevent any unintended etching. Followed by silane application (Silane, Ultradent Products Inc, South Jordan, UT, USA) for 60 seconds, according to the manufacturer's instructions. All test blocks were cleaned with ethanol to remove any debris before cementing the crowns.

Group A

A self-curing GIC luting agent (Vivaglass CEM, Ivoclar Vivadent AG, Schaan, Liechtenstein) was mixed according to the manufacturer's instructions and applied to the inner surface of the milled crowns. The crowns were cemented on the prepared duplicate abutment with finger pressure until complete setting and the excess luting agent was cleaned from the margins.

Group B

The abutments were acid etched with 37% phosphoric acid (TotalEtch, Ivoclar Vivadent AG, Schaan, Liechtenstein) for 30 seconds, then rinsed with water and dried with air for 15 seconds. A universal bonding agent (Scotchbond Universal, 3M ESPE, ST. Paul, MN, USA) was applied to the abutments and the inner surfaces of the milled crowns and then cured for 20 seconds. A dual-cure resin luting agent (RelyX™ Ultimate Clicker, 3M ESPE, ST. Paul, MN, USA) was applied to the fitting surface of each crown then the crowns were then seated with finger pressure and tack light-cured for 2 seconds. Cement excesses were removed with a #12 scalpel, and the cement was allowed to fully cure for 6 minutes while maintaining finger pressure throughout.

Group C

A self-adhesive self-cure resin with tack light-cure option (Multilink Speed, Ivoclar Vivadent AG, Schaan, Liechtenstein) was applied to the fitting surface of the milled crowns then the crowns were seated with the same finger pressure, and tack cured for 2 seconds. The excess luting agent at the margins was removed with a #12 scalpel and finger pressure was maintained for 5 minutes to allow full polymerization of the luting agent.

Maximum load at fracture test and statistical analysis

The test blocks were kept in distilled water at a temperature of 37 °C for 24 hours. Next, the test blocks were mounted on a universal testing machine (UTS) (5940 Series UTS (2 kN load cell), Instron, Norwood, MA, USA). To distribute the load on the occlusal surface, a 0.3 mm thick tin foil was placed between the rounded load and the crown. The position and contact of the 3.0 mm semi-cylindrical stainless-steel indenter of the UTS were verified for all samples before the commencement of the static fracture test. The load was applied along the long axis of the tooth. The test was conducted with a crosshead speed of 0.5 mm/minute until failure, which was set at a reduction in force of 10 Newtons (N).

The maximum load at fracture for each crown in every group was recorded, and descriptive statistics were calculated. The means of the maximum load at fracture (ML) for each group was calculated and then compared using a two-way ANOVA statistical test at a significance level of $P < 0.05$. The fracture lines and cracks that resulted were inspected visually and compared between the groups.

Results and Discussion

Version 18.0 of the Statistical Program of Social Science (SPSS Inc., Chicago, USA) was used to analyze the data. The accompanying table **(Table 1)** provides descriptive statistics of the maximum stresses at fracture (in Newtons (N)) for PICN hybrid ceramic crowns that are luted with three distinct luting agents (group A = GIC, group B = dual-cure resin, and group C = self-adhesive resin).

Table 1. Descriptive statistics for the maximum loads at fracture of the test groups.

	n	Max	Min	Median	Mean	SD
Group A	5	1036.45	762.99	907.61	896.27	122.26
Group B	5	1141.26	768.88	936.04	959.13	148.39
Group C	5	1322.7	814.43	1093.25	1030.46	213.07

Note. SD = standard deviation, Max = maximum value in Newtons, Min = minimum value in Newtons.

Following group B (959.13 ± 148.39 N) and group A (896.27 ± 122.26 N), group C had the highest mean maximum load at fracture (1030.46 ± 213.07 N). When luted with self-adhesive resin cement, the hybrid ceramic crown exhibits a greater load-bearing capacity **(Figure 4)**.

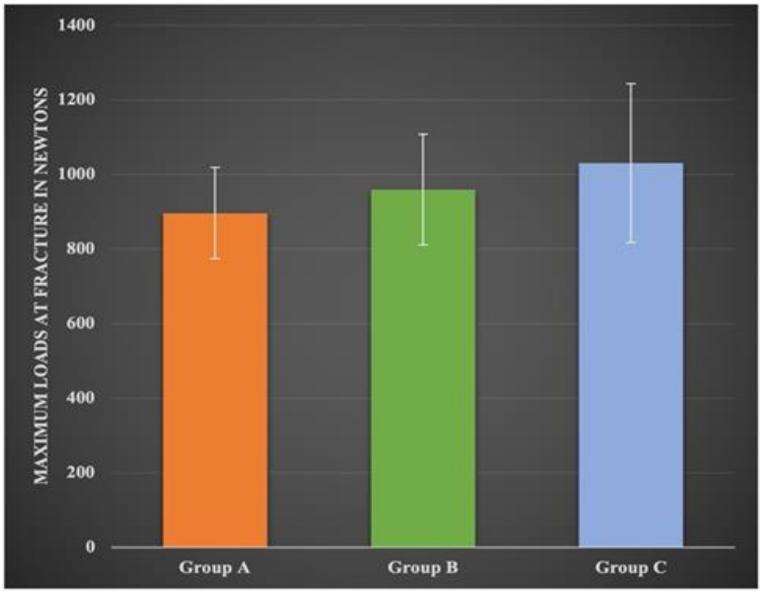


Figure 4. The maximum loads at fracture values in Newtons for the cemented crowns in the three tested groups.

After conducting the Kolmogorov-Smirnov Test of Normality, it was determined that the load at fracture values in all three groups had a normal distribution ($P > 0.05$). One-way analysis of variance (ANOVA) was used to compare the groups at a significance level of 0.05 after the Levene test revealed homogeneity of variances ($P = 0.647$). The groups' maximum loads at fracture did not differ statistically significantly **(Table 2)**.

Table 2. One-way analysis of variance (ANOVA) for the maximum loads at fracture of the test groups.

	SS	df	MS	F-ratio	P
Between groups	45075.97	2	22537.99	0.8209	0.4633
Within groups	329466.29	12	27455.52		
Total	374542.27	14			

Note. SS = sum of squares, df = degrees of freedom, MS = mean of squares, P = significance value (P > 0.05, not significant).

Upon visual examination of the fractured crowns, it was discovered that the applied occlusal load had caused dislodged fracture fragments. Following group A's fracture tests, the crown pieces separated from the abutments. One test block in group C and two in group B had the major fracture line pass through the mesial fossa, but in all other groups, it passed through the central fossa in the occlusal surface in a buccolingual direction. The test blocks in groups B and C split in two, with the smaller piece flaking away and the larger portion of the crown remaining attached to the resin abutment underneath. It was observed that the resin luting agents persisted on the inner surface of the crown as well as the tooth surface of the abutment. As reference points, the primary fracture line's location, the number of broken pieces, and the crown's separation from the underlying abutment were used to evaluate the fracture pattern **(Table 3)**.

Table 3. Visual inspection results of fracture pattern in the test groups.

	Group A	Group B	Group C
The mean number of fragments	2.8	2	
Main fracture line position	Central fossa	Central fossa, some mesial fossa (2 in each group)	
Fragments detachment	All fragments	Only smaller fragment	

Note. * = standard deviation, ** = fracture through central fossa, *** = fracture through mesial fossa.

More people are looking for more aesthetically pleasing dental restorations, including ones for their back teeth [22]. Full-coverage restorations made from aesthetic hybrid ceramic blocks that were manufactured using CAD/CAM technology were examined in this study. The study found that the groups' maximum loads at fracture varied. However, there were no statistically significant differences between them. Therefore, it was necessary to accept the null hypothesis ($P > 0.05$) that the maximal load at fracture for PICN hybrid ceramic crowns cemented with three distinct luting agents did not differ significantly. The stress-strain curves of every tested crown in this study were normal, indicating that the experimental design was sound and excluding any occlusal loading that might have been caused by the test block material or testing equipment.

The same design software (Ceramill Mind, AmannGirrbach GmbH, Koblach, Austria) and milling equipment (Ceramill Map 400 Scanner, AmannGirrbach GmbH, Koblach, Austria) were used to mill full-coverage crowns using PICN hybrid ceramic prefabricated CAD/CAM blocks (Vita Enamic, VITA Zahnfabrik H. Rauter GmbH & Co.KG, Bad Säckingen, Germany) to reduce variability among the milled crowns. For CAD/CAM milled crowns made of ceramic and hybrid ceramic materials, a minimum occlusal thickness of 1.5 mm is advised to withstand biting pressures [22]. The CAD/CAM PICN hybrid ceramic crowns that were milled for this investigation were 1.5 mm thick at the cusp apex and 2.5 mm thick at the central groove. These measurements are similar to those proposed in the study by Zimmerman *et al*. where it was found that, in comparison to 0.8 and 0.5 mm, a thickness of 1.5 mm had the largest load at fracture values [26]. The milled crowns were fitted precisely by scanning each test block separately. This lessens the possibility that any crown misfit will have an impact on the ultimate load values. Since cuspal inclination was discovered by Kuroishi *et al*. to considerably affect the load-bearing capability of milling crowns, crowns must match the other teeth and have the proper cuspal inclination for bearing loads [27]. All of the crowns in this study had the same cuspal inclinations and occlusal anatomical design, which was an adult, anatomic maxillary molar as provided by the CAD software. This was done to replicate a clinical setting while guaranteeing that there were no variations among the evaluated restorations that would have an impact on the load results.

In earlier research, a variety of methods were employed to guarantee that indirect restorations were positioned correctly during cementation. These methods included not stating a specific method, exerting pressure with the finger, or controlling static loading with universal testing equipment [25, 28]. In the current investigation, all milled crowns were seated by a single investigator to reduce the potential for pressure fluctuation. This was done because it has been noted in the literature that individual differences in finger pressure exist [25]. This method has been used in earlier research that has been referenced in the literature [25, 29]. When compared to other research that uses various techniques, the cement film thicknesses may change because the current study used finger pressure for seating. Consequently, there can be differences between the results of this study and other research.

During rest and mastication, the teeth in the oral cavity are subjected to a variety of intense forces. The periodontal ligament (PDL), which permits some degree of tooth movement in the alveolar bone, absorbs these [30]. The tooth embedment material must mimic bone and supporting PDL during an in-vitro load at fracture test to resist compression and other applied pressures as well as masticatory forces [31]. The results of the fracture load test were shown to be more affected by PDL simulation than by the type of embedment material [32]. The PDL was simulated in the present investigation by directly painting the root sections of abutments embedded in the test blocks with liquid latex rubber (ERKODENT Erkosin, Erich Kopp GmbH, Herrenberg, Germany). This method was used in several earlier research and was found to be effective [24, 33, 34]. Alveolar bone simulation in test blocks has been achieved using several types of resins in various in-vitro load-bearing capacity tests [24, 25]. Metal alloys have a significantly higher elastic modulus than resins, which have a much lower elastic modulus (around 2000 MPa) that is closer to the alveolar bone [35, 36]. The abutment roots were placed in isocyanate model resin test blocks (Mirapont, Hager and Werken GmbH and Co. KG, Duisburg, Germany) with a flexural modulus greater than that of stainless steel metal used in other load-bearing capacity studies (around 100,000 MPa [37]), to replicate the natural bone support of teeth and guarantee correct crown placement in this study [21, 22, 27]. To prevent the test block resin from interfering with the abutment's finish line, abutment scan, and/or crown seating, a 3 mm gap was left below the finish line. The biological breadth [38] that ought to be preserved in clinical situations was modeled by this gap.

According to earlier research, the maximum load at fracture values may vary depending on the abutment's material for the load-bearing capacity test [22, 27, 31, 39, 40]. When compared to crowns tested on teeth with resin abutments, Sakaguchi *et al*. claim that the use of metal abutments results in noticeably lower fracture loads [31]. In contrast to softer abutment materials like resins, Lan *et al*. found that employing zirconia abutments caused higher stresses at fracture for the tested crowns [40].

A model resin material (Mirapont, Hager and Werken GmbH and Co. KG, Duisburg, Germany) with extremely low polymerization shrinkage (0.02%), similar to the model resin used in earlier load-bearing investigations [24, 41], was utilized to create the test blocks and abutment teeth for this investigation. This would guarantee the creation of precise replicas of abutment teeth with minimal variance between them. Additionally, flexural characteristics of resin materials were shown to be more similar to those of natural tooth structure than those of metallic materials [39, 41]. Thus, the model abutment tooth would be easily, accurately, and consistently duplicated while emulating the structure of the natural teeth if the high-precision, low-shrinkage resin were used for the abutment tooth fabrication. With a sintered-glass ceramic network that is 86% by weight and 75% by volume, PICN hybrid ceramic CAD/CAM has an elastic modulus of 30,000 MPa, which is comparable to that of natural dentin [42].

Clinical failure of CAD/CAM crowns can occur from fracture as well as detachment [43]. In the current investigation, the load was applied axially perpendicular to the occlusal surface and distributed throughout the occlusal surface using a 0.3 mm mesh to measure the load-bearing capacity. According to earlier reports, the maximum load at fracture value is influenced by the direction of the force applied to the restoration [44]. Previous research investigating the load-bearing capacity of indirect restorations used silicone rubber or tin foil to disperse the stress [24, 41]. Cracks can appear on the occlusal surface of teeth in the grooves and fissures. The most force is placed on the maxillary second molar during lateral excursive movements and centric closing [22, 23]. Furthermore, a prior investigation by Masuda *et al*. [22] found that premolar crowns cracked along the central groove. Only a small percentage of cases in the current study had the major fracture line pass through the mesial fossa; most of the fractures occurred in the central fossa in a bucco-lingual orientation, breaking the crown into two pieces. In a prior investigation of ceramic and hybrid ceramic crowns, Güleç and Sarıkaya [42] noted that the crowns in the current study fractured up without chipping. Compared to crowns cemented using resin luting agents, the GIC cemented crown group had a higher mean number of fragmented fragments (2.8). Some of the group A samples showed a smaller piece that broke away from the underlying abutment closer to the cervical third of the tooth. The cervical thirds of the crowns in this group might have been affected by a greater concentration of stress on the occlusal surface. This might be a result of the non-adherent luting media's diminished capacity to disperse stress. A prior study found that GIC luting agents had a lower elastic modulus, flexural and compressive strength, and compared to dual-cure resin cement [45]. According to earlier research, PICN hybrid ceramic CAD/CAM crowns might be more resilient to compressive stresses than more brittle ceramic and zirconia materials [22, 27]. Additionally, the appearance of multiple fracture lines seems to indicate the highest point of a CAD/CAM crown's fracture load [22]. Crowns from groups B and C in this investigation displayed occlusal compressive deformation, suggesting that stresses were probably absorbed and distributed more uniformly by the underlying resin abutment and stronger resin luting agents (all having equal elastic moduli). These crowns might have been more load-resistant than if they had been luted with a weaker agent like GIC since they were additionally linked to the abutment and luting agent. Because the bigger portion of the broken crowns in groups B and C stayed linked to the underlying abutment, there was less chance of the patient aspirating a large fragment, which could be useful in clinical settings. Additionally, the unsightly effect of a cracked crown can be lessened by keeping the part of the crown that is still connected to the tooth underneath.

There was no statistically significant difference in the maximum load-at-fracture between the various luting agent groups in the current investigation, which examined the impact of the luting agent on the load-bearing ability of PICN hybrid ceramic crowns. This outcome partially supports a similar study conducted by Masuda *et al*. in the past, which found no discernible difference in the load-bearing capability of hybrid ceramic CAD/CAM crowns attached on premolars (about 2800 N) using self-bonding or conventional resins. However, the load was larger than those cemented using polycarboxylate luting agents [22]. However, hybrid ceramic crowns cemented with resin or polycarboxylate did not significantly differ in their load-bearing ability, according to Kuroishi *et al*. [27], which may be related to the current study's lack of significant differences. Because premolars have a simpler occlusal morphology than maxillary molars, earlier studies may have used stronger hybrid ceramic material, had different cement spaces and axial inclinations, and had higher loads (maximum 1322.7 N) than the current study. Both research findings, however, point to the possibility that resin bonding to the abutment teeth may increase the fracture strength of CAD/CAM crowns. This is consistent with the findings of a prior study on high-strength ceramic CAD/CAM crowns conducted by Blatz *et al*. [18]. The highest maximal load at fracture in the current investigation was recorded by crowns fastened with self-bonded luting resin (1030.46 ± 213.07 N), dual-cure resin with a separate bonding agent (959.13 ± 148.39 N), and GIC (896.27 ± 122.26 N). Self-bonding luting resins generated the highest loads at fracture but were statistically insignificant, according to a study by Kuroishi *et al*. [27]. In comparison to resin luting agents, Sagsoz *et al*. showed that GIC luting cement resulted in reduced loads at fracture in CAD/CAM premolar crowns [46]. The load-bearing ability of resin anterior crowns cemented with either resin or GIC, however, did not differ significantly, according to Stawarczyk *et al*. [21]. Due to their low elastic moduli, self-bonding luting resins can be flexible and have a high load resistance [27]. The current study's mean maximum load at fracture for PICN hybrid ceramic crowns luted with self-bonding resin is comparable to that of earlier investigations by Zimmermann *et al*. [26] (about 1063 N) and Elmougy *et al*. [41] (about 1127 N).

According to earlier research, the average clenching occlusal load is 660 N, the mean maximum load at fracture of the crowns in all groups was significantly higher than the average occlusal load, and the total occlusal forces applied to posterior teeth during closing and swallowing are approximately 100 N, ranging from 40 N for a light bite to 200 N for a hard bite [47, 48]. Therefore, it can be said that PICN hybrid ceramic molar crowns are appropriate for the restoration of posterior teeth, even when clenching is present. Although the difference in maximum load between the groups was not statistically significant, it may have clinical significance because it was greater than the light bite 40 N and closer to the lead of closing and swallowing. The mean maximum load at fracture of group C (self-bonding resin luting agent) was above 1000N, indicating the beneficial effect of self-boning resin luting on PICN hybrid ceramic crowns in cases of bruxism and other parafunctional habits. Stress or parafunctional habits like bruxism may cause the maximum biting force in the posterior region of the mouth to reach over 1000 Newtons [49].

The present investigation did not incorporate thermal aging or mechanical fatigue, and it simply employed a static load test. However, it would be beneficial for future research to include dynamic load testing with chewing simulation to better replicate real-life conditions, since crown dislodgement is a common cause of failure in full-coverage restorative clinical cases [27]. Future studies should therefore address this problem. An in-vivo study might be conducted to assess the clinical performance of PICN hybrid ceramics in various situations, such as with different opposing dentitions, crown thicknesses, and cement thicknesses. It is important to acknowledge that the study has several limitations, especially concerning how luting cement affects the bond strength and marginal fit of different crown designs. Additionally, not thoroughly investigated were the impacts of occlusal architecture and thickness, as well as the methods of polishing and finishing that were applied to hybrid ceramic crowns. Furthermore, the impact of axial thicknesses was not fully investigated. The failure of a full-coverage crown treatment due to a fracture is a major problem that requires careful consideration. The locations of greatest stress distribution concerning the cement space or luting agent defined in CAD software may be identified with the use of finite element analysis (FEA).

Conclusion

It is possible to conclude that, within the constraints of the research, the use of self-bonding luting resin improved the PICN hybrid ceramic crowns' ability to support loads, particularly for molars. It seems that the kind of luting agent has little effect on the fracture loads of CAD/CAM crowns. Regardless of the cement type, the CAD/CAM PICN hybrid ceramic is an excellent choice for posterior tooth restoration. This is because the maximal stresses necessary to shatter the crowns were greater than the loads that molars normally encounter in clinical settings. Visual examination revealed that, in comparison to both resin-luting agents, GIC had more catastrophic fractures in the crowns. Evidence, however, points to resin as a potentially better choice than GIC.

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