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RESEARCH AND EDUCATION

Effect of surface finish and resin cement on the bond strength to CAD-CAM ceramics for interim resin-bonded prostheses

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ABSTRACT

Statement of problem. Resin-bonded prostheses, including interim resin-bonded prostheses, are effective in preserving tooth structure compared with other types of fixed dental prostheses for the replacement of missing teeth. However, loss of retention remains a notable concern with these types of prostheses.

Purpose. The purpose of this in vitro study was to investigate the influence of glass-ceramic type, resin type, and surface finish on the shear bond strength (SBS) to the CAD-CAM ceramics used to fabricate interim resin-bonded prostheses.

Material and methods. Eighty 10×2-mm glass-ceramic disks were fabricated by using a diamond saw (IsoMet 1000), 40 from feldspathic porcelain blocks (Vita Mark II) and 40 from lithium disilicate blocks (IPS e.max CAD). Half of the specimens in each group were left with a dull or matte surface finish after cutting, while the other half were glazed with an add-on glaze (VitaAkzento Plus Glaze Spray and IPS e.max CAD Glaze Spray, respectively). The disks were mounted in acrylic resin, and each group was subdivided into 2, with 1 receiving a photopolymerized resin cement (RelyX Veneer) and the other receiving a flowable composite resin (Filtek Supreme Ultimate Flow) to form 2.38×2-mm cylinders. SBS was determined using a universal testing machine (Instron 4411) in accordance with the International Organization for Standardization (ISO) 29022:2013 standard, and failure modes were analyzed by using a stereomicroscope with ×40 magnification. The data were analyzed with a 3-way analysis of variance and Tukey post hoc analysis. The chi-squared test was used to analyze the failure mode (α=.05 for all tests).

Results. Ceramic type, resin type, and surface finish significantly impacted SBS (P<.001, P=.003, P<.001, respectively). Lithium disilicate showed higher SBS than feldspathic porcelain, and flowable composite resin exhibited higher SBS than resin cement. Glazed surfaces displayed lower SBS compared with the dull or matte surfaces. The combinations among the 3 materials also impacted SBS (P=.03). In addition, the combinations between ceramic type and surface finish affected SBS (P<.001), regardless of resin cement type. No other combinations affected the SBS (P>.05). The mode of failure was different among the groups (P<.001). In comparison with all other groups, cohesive failures were most prevalent in feldspathic porcelain with a dull or matte surface finish, regardless of the resin type used.

Conclusions. The SBS to glass-ceramics was influenced by ceramic material, resin cement type, and surface finish. Flowable composite resin showed higher SBS than resin cement. A dull or matte surface finish exhibited greater bond strength than a glazed surface. Lithium disilicate had higher SBS than feldspathic porcelain. (J Prosthet Dent 2024;131:458.e1-e7)

Resin-bonded prostheses, including interim resin-bonded prostheses,[1] are an effective treatment option for the replacement of a missing tooth, with less tooth reduction than for other types of fixed dental prosthesis.[2,3] Resin-bonded prostheses consist of a pontic fabricated from glass-ceramic that relies on composite resin connectors between the pontic and the abutment teeth for retention.[1] These minimally invasive restorations offer

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Clinical Implications

This study provides guidance for dentists in selecting the most appropriate materials and protocols to improve the longevity and performance of interim resin-bonded prostheses. Understanding the impact of ceramic type, resin type, and surface finish on bond strength enables more informed decisions for successful and durable restorations.

advantages that include enhanced esthetics,[4] improved preservation of healthy tooth structure,[5] and minimal risk of pulpal complications.[6] However, a significant concern with these restorations is loss of retention,[7] leading to a success rate over 6 years of only 42.3%. The survival rate of interim resin-bonded prostheses over the same period is 26.9% with single re-bonding and 23.1% with multiple re-bonding. Resin-bonded prostheses have an overall failure rate of 7.6%.[7,8]

Successful bonding of interim resin-bonded prostheses relies on the establishment of durable and reliable interfaces between the tooth structure and the restoration.[9] This bonding process involves multiple steps, encompassing 2 crucial interfaces: the tooth structure interface, which involves the enamel and dentin, and the indirect restoration interface.[10] Extensive research has been conducted to explore the bonding to enamel and dentin, leading to the development of reliable bonding agents and techniques.[11–13]

However, the interface between ceramics and resin materials, particularly glass-ceramics, has drawn comparatively less attention.[14,15] This underexplored area is of paramount importance, as the adhesive strength of dental ceramics could directly influence the overall longevity and clinical performance of adhesive restorations.[16] Factors influencing the efficacy of this interface include the type of ceramic material used,[17–20] the resin type used,[20–22] and the surface finish of the ceramics.[23–26] Moreover, the combined effects of these elements can also play a significant role in determining the strength of this bond.[27–30]

To address these critical knowledge gaps, the present study aimed to investigate the influence of glass-ceramic type, resin type, and surface finish on the shear bond strength (SBS) to CAD-CAM ceramics used for interim resin-bonded prostheses. The null hypotheses were that the SBS to glass-ceramics would not be affected by ceramic type, resin type, or by surface finish.

MATERIAL AND METHODS

Specimen preparation and testing were done by 1 operator (Z.B.) in the University of North Carolina dental materials research laboratory. Eighty 10×2-mm glass-ceramic disks were fabricated using a diamond saw (IsoMet 1000; Buehler Ltd), 40 from feldspathic porcelain (FP) blocks (Vita Mark II; Vita Zahnfabrik), and 40 from lithium disilicate (LD) blocks (IPS e.max CAD; Ivoclar AG). Half the specimens in each group were left with the dull or matte surface finish (D) that was produced after cutting, while the other half were glazed (G) using an add-on glaze (VitaAkzento Plus Glaze Spray; VITA Zahnfabrik or IPS e.max CAD Glaze Spray; Ivoclar AG). The disks were mounted in acrylic resin. The specimens in each group were further subdivided into 2 groups, 1 cemented with a light-polymerized resin cement (RC) (RelyX Veneer; 3M) and the other with a flowable composite resin (FCR) (Filtek Supreme Ultimate Flow; 3M). The experimental groups are presented in Figure 1.

The resin was bonded to the FP blocks according to the manufacturer's recommendations: 9.5% hydrofluoric acid (Porcelain Etch Gel; Vista Apex) was applied for 90 seconds to both the matte and glazed surfaces and then

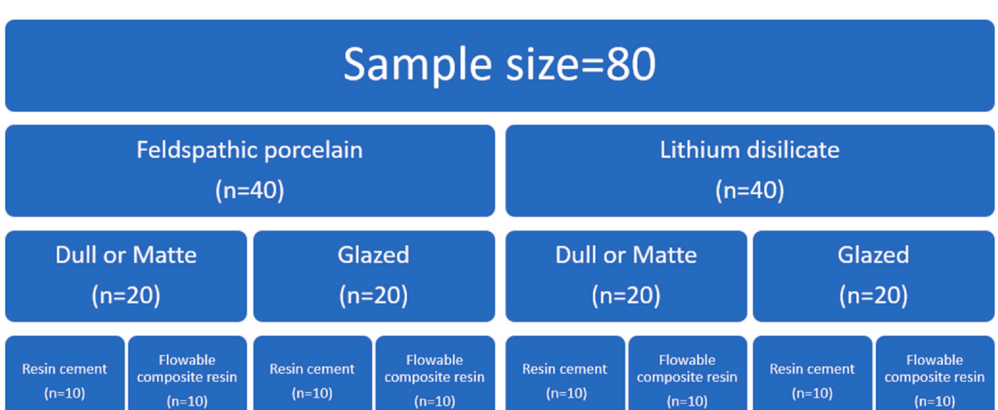

Figure 1. Experimental groups.

rinsed off with water. The specimens were cleaned in an ultrasonic bath (TriClean Ultrasonic Cleaner U-10LHREC, BrandMax) containing 99.5% isopropyl alcohol. Then, an adhesive (Scotchbond Universal; 3M) containing a silane coupling agent was applied. Specimens were inserted into a bonding clamp (Ultradent Products, Inc) containing a white polypropylene bonding mold insert (Ultradent Products, Inc) with a Ø2.38 ±0.03-mm hole. The resin was injected through the hole making a 2.38×2-mm cylinder. The resin was light polymerized for 40 seconds using a dental light-polymerization unit (Elipar DeepCure-S LED Curing Light; 3M) with a mean light irradiance of 1470 mW/cm^2. The polymerization light was applied directly over the resin. The specimens were polymerized for an additional 20 seconds from each side to ensure complete polymerization.

The resin was bonded to the LD blocks according to the manufacturer's recommendations: 5% hydrofluoric acid (IPS Ceramic Etching Gel; Ivoclar AG) was applied for 20 seconds both the matte and glazed surfaces and then rinsed off with water. The specimens were cleaned in an ultrasonic bath (TriClean Ultrasonic Cleaner U-10LHREC: BrandMax) containing 99.5% isopropyl alcohol. Then, an adhesive (Scotchbond Universal; 3M) containing a silane coupling agent was applied. Specimens were inserted into a bonding clamp (Ultradent Products, Inc) containing a white polypropylene bonding mold insert (Ultradent Products, Inc) with a Ø2.38 ±0.03-mm hole. The resin was injected through the hole to make a 2.38×2-mm cylinder. The resin was light polymerized for 40 seconds using a dental light-polymerization unit (Elipar DeepCure-S LED Curing Light; 3M) with a mean light irradiance of 1470 mW/cm^2 while the polymerization light was applied directly over the resin. The specimens were polymerized for an additional 20 seconds from each side to ensure complete polymerization. An illustration of the specimens is shown in Figure 2.

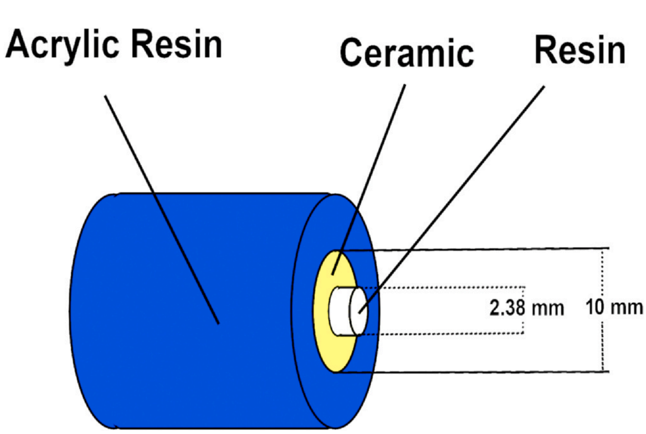

Figure 2. Illustration of specimens.

Before SBS testing, the specimens were stored in water at 37 ±2 °C for 24 hours. The SBS testing was determined in accordance with the International Organization for Standardization (ISO) 29022:2013 standard.[31] A universal testing machine (Instron 4411; Instron) was used with a crosshead speed set at 1.00 ±0.1 mm/minute. The force was applied at the junction between the resin and ceramic, specifically at the base of the resin cylinder, until failure.

After SBS testing, the specimens were examined under a stereomicroscope (SZ51; Olympus) with ×40 magnification to determine the mode of failure, which was classified as adhesive failure at the interface between the resin and ceramic; cohesive failure within the resin or ceramic; or mixed failure, a combination of the 2 modes of failure.

The SBS data were analyzed with a statistical software program (IBM SPSS Statistics, v24; IBM Corp) with a 3-way analysis of variance and the Tukey post hoc analysis. The failure mode data were analyzed using the chi-squared test (α=.05).

RESULTS

Ceramic type had a statistically significant impact on the SBS (P<.001). LD showed higher SBS when compared with FP. Resin type had a statistically significant impact on the SBS (P=.003). FRC exhibited higher SBS than RC. In addition, surface finish had a significant impact on SBS (P<.001). The dull or matte surface finish showed higher SBS compared with the glazed surface, as shown in Figure 3. The combinations among the 3 factors showed statistically significant results (P=.03). The SBS from highest to lowest was [LD+FCR+D] > [LD+RC+D] = [FP+RC+D] = [FP+FL+D] > [LD+FCR+G] = [LD+RC+G] = [FP+RC+G] = [FP+FL+G] as shown in Figure 4. In addition, the combination between ceramic type and surface finish affected SBS (P<.001), regardless of resin type. The SBS from highest to lowest was [LD+D] > [FP+D] > [FP+G] = [LD +D] as shown in Figure 5. Nonetheless, the combination of ceramic and resin type and the combination of resin type and surface finish did not affect the SBS (P=.08, P=.09, respectively).

The results for the mode of failure are shown in Figure 6. The chi-squared test showed a statistically significant difference in failure mode among the groups (P<.001). Two combinations showed a different mode of failure compared with the other combinations. The combinations of FP, flowable composite resin, and dull or matte surface, and the combinations of FP, resin cement, and dull or matte surface groups showed higher cohesive failures within the ceramic itself (80% and 70% respectively). All other combinations showed adhesive

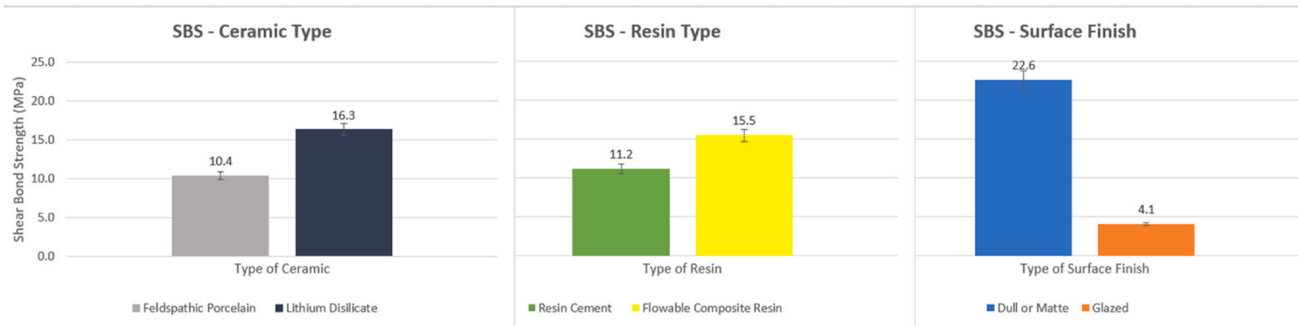

Figure 3. Effect of ceramic type, resin type, and surface finish on shear bond strength (SBS) to glass-ceramics.

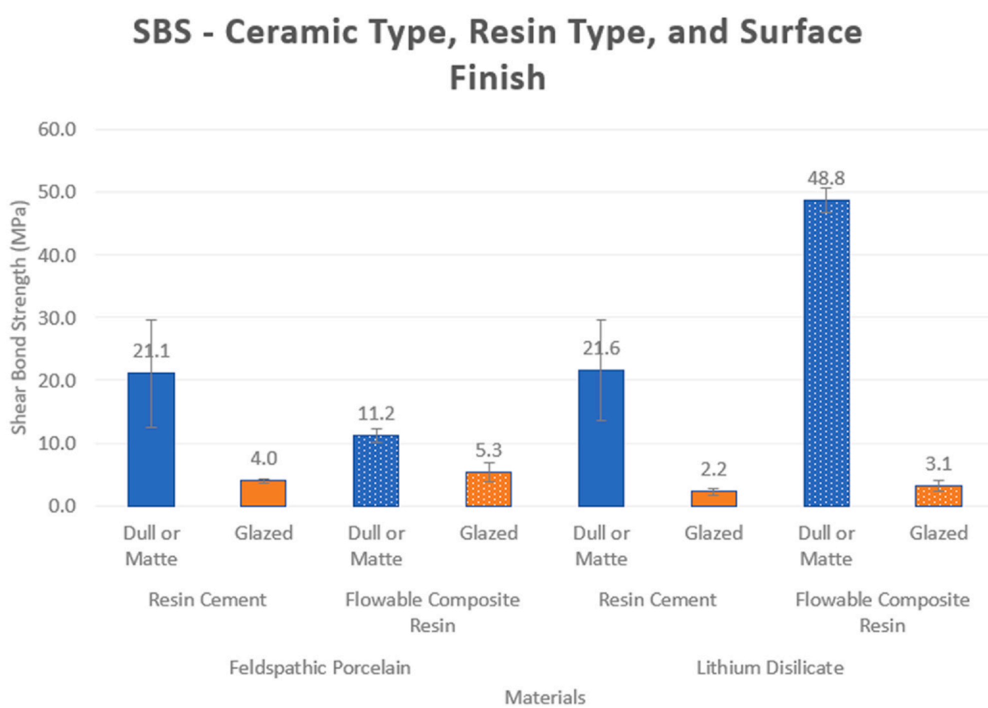

Figure 4. Effect of combinations of ceramic type, resin type, and surface finish on shear bond strength to glass-ceramics.

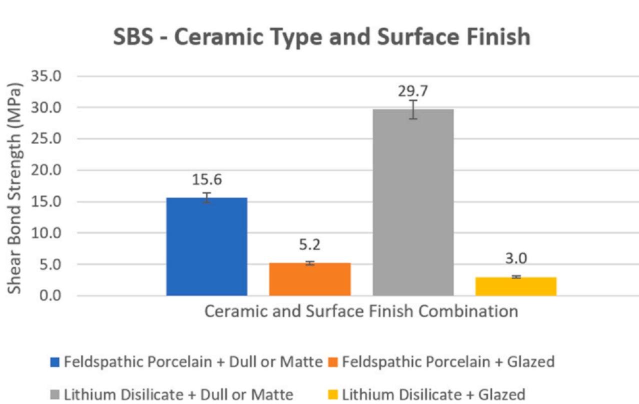

Figure 5. Effect of combinations of ceramic type and surface finish on shear bond strength to glass-ceramics.

failures exclusively. No mixed failures were detected. Examples of the mode of failure are shown in Figure 7.

DISCUSSION

This study investigated the SBS to glass-ceramics by analyzing the impact of ceramic type, resin type, and surface finish on the bonding interface of the CAD-CAM ceramics used for interim resin-bonded prostheses. The results revealed that SBS to dental ceramics varied significantly based on these 3 factors. The study found that lithium disilicate exhibited higher SBS values than feldspathic porcelain. Flowable composite resin

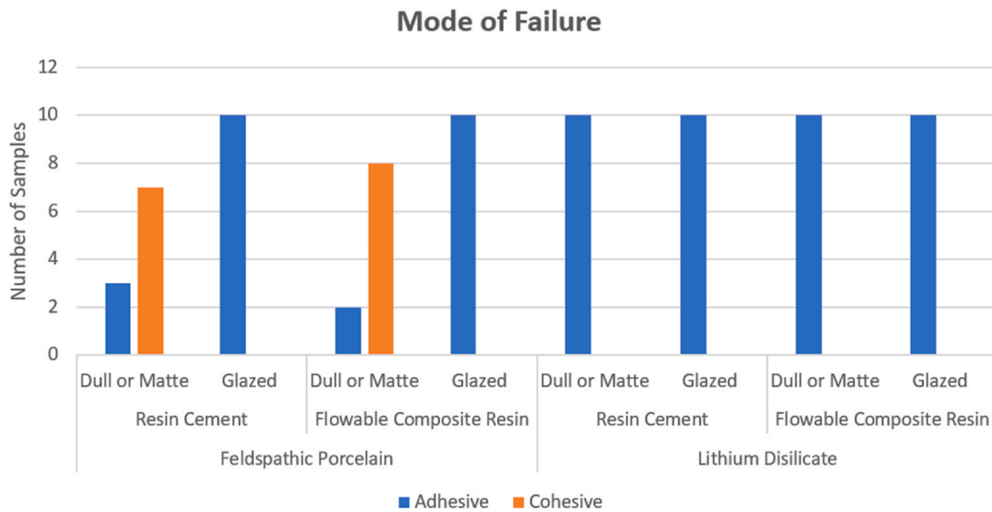

Figure 6. Mode of failure in each group.

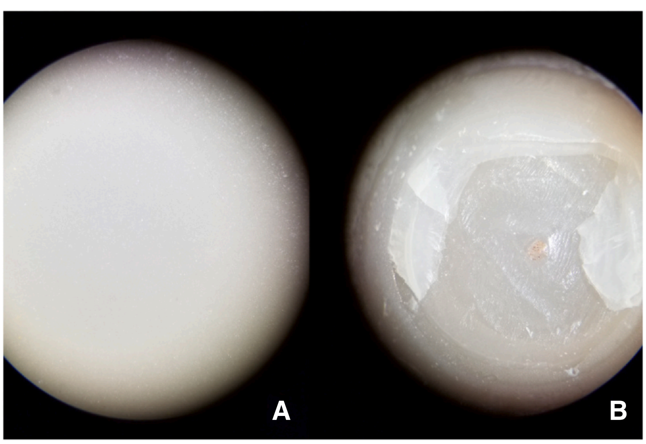

Figure 7. Example of failure mode. A. Adhesive failure between resin and ceramic. B. Cohesive failure within ceramic.

demonstrated higher SBS compared with resin cement, while the dull or matt surface finish exhibited stronger SBS compared with the glazed surface. Also, the combinations of the 3 factors impacted the SBS. Therefore, the null hypotheses that the SBS to glass-ceramics would not be affected by ceramic type, resin type, or by surface finish were rejected.

These findings provide insights into optimizing bonding techniques and material selection in adhesive dental restorations. Lithium disilicate showed higher SBS values when compared with feldspathic porcelain. This finding was consistent with that of a study[18] comparing the effect of different concentrations and etching times of hydrofluoric acid on the SBS to lithium disilicate and feldspathic porcelain. Overall, lithium disilicate showed higher bond strength compared with feldspathic porcelain. Another study[19] that compared the SBS of bonded orthodontic brackets to feldspathic porcelain and lithium disilicate reported similar results. However, this finding should be considered with caution, since feldspathic porcelain showed predominantly cohesive failures within the ceramic, posing challenges in accurately determining the true SBS between feldspathic porcelain and resins. The cohesive failures suggest that the ceramic material's internal strength is weaker than the bond strength at the ceramic-resin interface, causing fractures or deformations within the ceramic before the bond breaks. As a result, the measured SBS may not solely reflect the resin's ability to adhere to the ceramic surface but could also be influenced by the inherent strength of the feldspathic porcelain.

The flowable composite resin showed higher SBS when compared with resin cement. This effect might be attributed to the filler content of each resin type (66% in resin cement and 72.5% in flowable composite resin). This finding was consistent with that of a study[20] comparing the effect of different flowable composite resins and resin cements on the bond strength of zirconia and lithium disilicate, concluding that flowable composite resin and resin cements with higher filler content increased the bond strength. Another study[22] reported increased bond strength to dental ceramics when fillers were added to ceramic primers. However, this finding should be viewed with caution, as the film thickness of flowable composite resin might be higher compared with resin cement. The difference in film thickness was beyond the scope of the present study.

The surface finish affected the SBS to glass-ceramics. A glazed surface finish resulted in considerably lower SBS to both ceramics and with both resins. One of the primary factors contributing to the reduced bond strength on glazed surfaces could be the surface chemistry of the glaze itself. Glazing materials typically consist of a high percentage of glassy phase, which may exhibit different chemical properties compared with the underlying ceramic substrate. The acid resistance of the glaze might compromise the effectiveness of the initial etching step during bonding, leading to reduced micromechanical retention and weaker bonding.[24] Moreover, the glazing process creates a smooth surface, which significantly differs from the rougher surface of the dull or matte finish. The presence of surface irregularities and microstructures on the dull or matte surface can create increased micromechanical retention sites for the resin cement or flowable composite resin, enhancing the bond strength. In contrast, the smooth glazed surface might not offer sufficient mechanical interlocking, resulting in weaker bonding between the glaze and the resin material.[25] In addition, glazed surfaces may exhibit different surface energy properties compared with dull or matte surfaces because of their distinct chemical composition and smoothness. Variations in surface energy can influence wetting behavior and the spreading of the resin material over the ceramic surface during bonding. Since the glazed surface exhibits lower surface energy,[24] it might result in inadequate wetting and reduced intimate contact between the resin and the ceramic, leading to weaker bonding.[26]

Different factor combinations can significantly affect SBS. Specifically, pairing flowable composite resin with a dull lithium disilicate surface yielded the highest SBS among all combinations. In contrast, the combination of resin cement with a dull lithium disilicate surface and both resin types combined with a dull feldspathic porcelain surface produced comparable SBS. In another words, although resin type individually influenced SBS, its effect was nullified when paired with dull feldspathic porcelain. Conversely, it had a pronounced impact on dull lithium disilicate. Moreover, the ceramic material had an influence on SBS primarily with dull surfaces. To illustrate, the combination of lithium disilicate with a dull surface exhibited better SBS than feldspathic porcelain with a similar surface finish, irrespective of the resin used. Yet, both ceramic materials had analogous outcomes when paired with glazed surfaces. These findings underscore the necessity for clinicians to not only choose the optimal materials but to also consider their synergistic effects. Prior research supports these observations, indicating that a subtle switch in ceramic, from glass-ceramic to polycrystalline, demands an entire bonding protocol shift.[27–30]

The novelty of this study lies in its comprehensive investigation of the impact of ceramic type, resin type, and surface finish on the SBS of dental ceramics, specifically focusing on the CAD-CAM ceramics used for interim resin-bonded prostheses. This area of research has been largely underexplored, making the study's findings a valuable addition to the field of dental materials and adhesive dentistry. Moreover, the identification and discussion of cohesive failures predominantly within feldspathic porcelain and the potential influence on the interpretation of the true bond strength present an innovative consideration in evaluating bonding interfaces. The integration of these factors and their implications contribute to the originality of the research, offering valuable insights into material selection and bonding protocols, ultimately enhancing the clinical success of adhesive dental restorations.

Limitations of the study included the selection of only 2 glass-ceramic types and 2 resin types, which may restrict the generalizability of the findings to a broader range of available ceramic and luting materials. Additionally, the study used a simplified bonding protocol recommended by the manufacturer, which may not fully capture the various bonding protocols used in clinical applications. The short-term evaluation of SBS may not reflect the long-term performance and aging effects of the bonded restorations in the oral environment. Moreover, the absence of oral environment simulation and clinical data limits the direct applicability of the results to clinical restorations. Lastly, the presence of predominantly cohesive failures within the feldspathic porcelain may impede the accurate determination of the true bond strength at the ceramic-resin interface. Despite these limitations, the study's robust methodology and novel considerations enhance the understanding of bonding interfaces in dental ceramics, offering a foundation for further research and the optimization of bonding techniques in clinical practice.

Future studies should consider expanding the sample size to include a broader range of dental ceramics and resins commonly used in clinical practice. Long-term evaluations and in vivo studies are recommended to assess the bond stability and performance of adhesive restorations over extended periods in actual patients. Additionally, investigating alternative bonding techniques tailored to feldspathic porcelain's characteristics can optimize bonding outcomes and enhance the clinical success of adhesive restorations.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The SBS to glass-ceramics was affected by the type of resin cement, surface finish, and ceramic.
2. When compared with resin cement, flowable composite resin had a higher SBS.
3. Bond strength to a dull or matte surface finish was greater than bond strength to a glazed surface.
4. When compared with feldspathic porcelain, lithium disilicate had higher SBS values. This conclusion, however, should be interpreted with caution, since feldspathic porcelain exhibited predominantly cohesive

failures within the ceramic itself, suggesting that the material was weaker than the bond.

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