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Contamination of Composite Resin by Glove Powder and Saliva Contaminants: Impact on Mechanical Properties and Incremental Layer Debonding

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Clinical Relevance

The handling technique is important for the mechanical performance and incremental layer bond strength of composite restorations. Composites can be digitally manipulated, but gloves should be clean to avoid the negative effects of contamination.

SUMMARY

This study investigated the influence of digital manipulation of a composite resin (Z250; 3M ESPE, St Paul, MN, USA) with gloves contaminated with powder and/or human stimulated saliva on the mechanical properties and incremental layer debonding of the restorative. The six groups tested were powdered gloves with or without saliva, powder-free gloves with or without saliva, powdered gloves with saliva cleaned with 70% ethanol, and no digital manipulation or contamination (control). Diametral tensile strength, flexural strength, flexural modulus, and incremental layer shear bond strength were evaluated. Each composite increment was digitally manipulated for 10 seconds. Data from each test were separately analyzed using analysis of variance and the Student-Newman-Keuls test (α=0.05). No significant differences for diametral tensile strength were observed. Manipulation of the composite using powder-free gloves with saliva or using gloves cleaned with ethanol generated higher flexural strength and modulus

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compared to the other groups. The control group and the group manipulated using powdered gloves with saliva generally showed lower mechanical performances. Lower incremental layer bond strength was observed for the group manipulated with powdered gloves without saliva. The control group and the groups manipulated with powdered gloves with saliva or cleaned with ethanol showed higher shear bond strengths. Most of the failures were cohesive. In conclusion, digital manipulation might be important for the composite resin to achieve better mechanical performance and incremental layer bond strength, provided that the gloves are not contaminated. Cleaning the gloves with ethanol might avoid the negative effects of digital manipulation using contaminated gloves.

INTRODUCTION

The insertion of composite resin into a cavity preparation is one of the most important factors affecting the clinical performance of adhesive direct restorations. This insertion can be carried out through direct application of the material with special devices, such as capsules or compules, or the composite can be removed from its container (eg, syringes) and placed in the cavity with a hand instrument.[1] When the material is removed from the syringe with a hand instrument, clinicians might perform unintentional digital manipulation of the composite or even intentionally manipulate the material in order to homogenize it and facilitate its insertion and accommodation into the cavity. This direct contact with gloves used for restorative procedures could, however, cause contamination of the restorative material by powder from the gloves, by saliva, or by other sources.

Direct digital manipulation of composite resins could affect their mechanical properties because it might introduce organic and inorganic debris[2-7] and leave porosities[8-10] inside the materials. In this context, a major reason for the failure of composite restorations is fracture of the restorative material,[11-13] which has been hypothesized to potentially occur due to the propagation of pre-existing cracks between increments of the restorative[14] or the incorporation of air bubbles during its insertion into the cavities. Therefore, the variables related to the presence of these defects into restoratives should be further explored.

Although some studies have reported on the contamination of composite resins by organic or inorganic agents,[2-7] these studies have usually focused on the effects of surface contamination of the composite and its consequences on the bond strength to the dental substrata/adhesive systems[2,3,5-7] or to the composite increments.[4,15] However, the literature does not address the effects of this contamination on the cohesive strength of the material, which could be contaminated by intentional or unintentional direct contact with the gloves used during the restorative procedure. In addition, there is no evidence that protocols for cleaning/decontaminating the gloves could reduce the potential harm from contamination to the composites' mechanical properties.

The aim of this study was to evaluate the influence of digital manipulation of a composite resin with powdered and powder-free gloves, contaminated or not with saliva, on the mechanical properties and the incremental layer bond strength of the restorative. The null hypothesis tested was that contamination is not detrimental to the material's properties.

METHODS AND MATERIALS

Experimental Design

This *in vitro* study involved a completely randomized and blinded design, considering the effect of different contamination conditions of latex gloves for clinical procedures used to digitally manipulate a composite resin on the mechanical properties of the restorative. The factor under investigation was "glove contamination" at six levels: powdered glove without saliva, powder-free glove without saliva, powdered glove with saliva, powder-free glove with saliva, powdered glove with saliva cleaned with 70% ethanol, and the control group, which was defined by no digital manipulation or contamination. The response variables assessed were diametral tensile strength, flexural strength, flexural modulus, and shear bond strength between composite increments. Sixty specimens were prepared for each test with a photoactivated microhybrid composite resin (Z250, 3M ESPE, St Paul, MN, USA; shade A2), according to the specifications of each test (n=10 per group for each test, with a total of 180 specimens).

Preparation of the Gloves and Digital Manipulation of the Composite

Powdered and powder-free disposable latex gloves were used (Supermax Glove Manufacturing, Selangor, Malaysia). The classification of the gloves was based on the manufacturer's information, with cornstarch powder in powdered gloves. Each glove was removed from its respective pack immediately before use. In the groups contaminated with saliva, in order to simulate the clinical condition of using a contaminated glove, the gloves were prepared by wetting the surface with stimulated human saliva collected using paraffin film (Parafilm M, American National Can, Chicago, IL, USA) from a single healthy donor. The gloves were allowed to dry at room temperature for 24 hours to simulate the conditions where the gloves were contaminated but not soaked in saliva. For the other experimental conditions, the gloves were removed from the box and immediately used. Digital manipulation of each composite increment was carried for 10 seconds, obtaining a final round shape for the increment. In the control group, the composite was removed from the syringe with a titanium-coated spatula and placed into the molds (according to the test) without any digital manipulation.

Diametral Tensile Strength

Disc-shaped specimens (diameter 4 mm, thickness 2 mm) were prepared by filling a cylindrical metal mold using three increments of the composite resin. Each increment was photoactivated for 20 seconds using a light-emitting-diode curing unit (Radii, SDI, Bayswater, VIC, Australia) with 600-mW/cm^2 irradiance. The top surface of the specimens was covered with a polyester strip and a glass slide, and hand pressure was applied before photoactivation. The specimens were wet polished with 600-grit SiC abrasive papers and stored in distilled water at 37°C. After 24 hours, the diametral compressive test was carried out in a mechanical testing machine (DL500, EMIC, São José dos Pinhais, PR, Brazil) at a crosshead speed of 0.5 mm/min until fracture of the specimen. Diametral tensile strength was calculated in MPa.

Flexural Strength and Modulus

Bar-shaped specimens (25 × 2 × 2 mm) were prepared by filling a split metal mold using four increments of the composite resin. Each increment was photoactivated for 20 seconds. The top surface of the specimens was covered with a polyester strip and a glass slide, and hand pressure was applied before photoactivation. The specimens were wet polished with 600-grit SiC abrasive papers and stored in distilled water at 37°C. After 24 hours, a three-point bending test was carried out in the mechanical testing machine at a crosshead speed of 0.5 mm/min until fracture of the specimen. Flexural strength (MPa) and modulus (GPa) were calculated from the load-displacement curve.

Incremental Layer Bond Strength

Epoxy resin molds with a square-shaped cavity (5 × 5 mm, thickness 2 mm) were used. The cavities were filled with the composite resin and covered with a polyester strip and a glass slide. Hand pressure was applied in order to create a flat composite surface, and the material was photoactivated for 20 seconds. In order to obtain specimens for evaluating the incremental layer bond strength by shear testing, elastomer molds with a cylindrical-shaped orifice (diameter 1.2 mm, thickness 0.5 mm) were positioned onto the composite surfaces. The orifices were filled with composite resin, which was manipulated according to the different contamination conditions, and photoactivated for 20 seconds. The specimens were stored in distilled water at 37°C. After 24 hours, a thin steel wire (diameter 0.2 mm) was looped around each resin cylinder and aligned with the bonded interface. The shear bond strength test was conducted in the mechanical testing machine at a crosshead speed of 0.5 mm/min until failure of the bonding. Bond strength data were calculated in MPa. The fractured specimens were examined under a stereomicroscope at 40× magnification for classification of the failure modes: interfacial (adhesive) failure or cohesive failure within the composite. Representative fractured surfaces were gold coated and analyzed by scanning electron microscopy (SEM; SSX-550, Shimadzu, Tokyo, Japan).

Statistical Analysis

Data from each response variable of all tests were separately analyzed using one-way analysis of variance followed by the Student-Newman-Keuls *post hoc* test at a 5% significance level.

RESULTS

Results for the mechanical properties tested are shown in Table 1. No significant differences for diametral tensile strength were observed between groups; however, the power of the performed statistical test was below 0.8. For flexural strength and modulus, the power of the performed statistical test was 1. Manipulation of the composite using powder-free gloves with saliva or using gloves cleaned with ethanol generated significantly higher flexural strength and modulus compared with the other groups. The control group (no digital manipulation) and the group defined by digital manipulation using powdered gloves with saliva generally showed

Table 1: *Means (Standard Deviations) for the Mechanical Properties Tested (n=10)*[a]

Contamination Condition	Diametral Tensile Strength, MPa	Flexural Strength, MPa	Flexural Modulus, GPa
Powdered glove without saliva	41.8 (7.0) A	87 (25) B	9.4 (1.4) B
Powder-free glove without saliva	42.0 (7.3) A	59 (18) C	8.4 (6.4) BC
Powdered glove with saliva	44.0 (9.0) A	51 (20) C	7.5 (2.9) CD
Powder-free glove with saliva	36.3 (8.5) A	131 (31) A	13.6 (1.5) A
Powdered glove with saliva cleaned with ethanol	45.7 (5.7) A	150 (26) A	13.8 (1.9) A
Control (no digital manipulation)	45.5 (12.8) A	49 (29) C	6.0 (1.1) D

[a] *Distinct letters in each column indicate significant differences ($p<0.05$).*

significantly lower flexural strength and modulus than the other groups.

Results for incremental layer bond strength are shown in Figure 1 (the power of the performed statistical test was 0.854). Significantly lower bond strength between composite increments was observed for the group manipulated with powdered gloves without saliva. The control group and the groups manipulated with powdered gloves with saliva or cleaned with ethanol showed higher bond strengths. The groups manipulated with powder-free gloves, either contaminated or not by saliva, showed intermediate results. SEM pictures illustrating the failure modes are shown in Figure 2. The failure analysis showed that most of the failures (~92%) were mainly cohesive, with only one interfacial debonding observed for each group, except for the group defined by manipulation with powdered gloves without saliva, which showed only cohesive failures.

DISCUSSION

The present study showed that composite resins can be handled with gloves used for procedures, but these gloves should be cleaned to remove powder remains and other contaminants. This is important because in several countries, composite resins are sold mainly in syringes or other packs, and clinicians have to remove the material with hand instruments from their containers. During this procedure, some dentists may digitally manipulate composites in order to facilitate the placement of the material into the cavity preparation, whereas others may unintentionally touch them with the gloves during the placement of restorations. There are no specific studies in the literature reporting the effects of contamination of composites through digital manip-

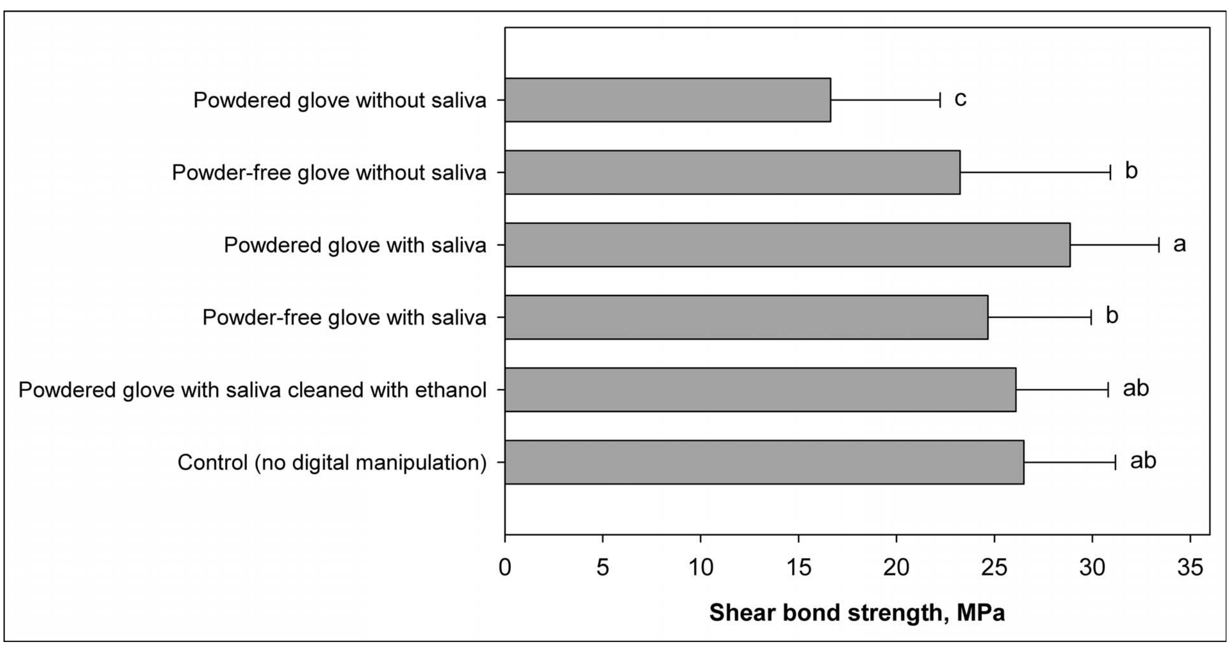

Figure 1. *Results for the bond strength between composite increments (bars are means + standard deviations, n=10). Distinct letters indicate significant differences ($p<0.05$).*

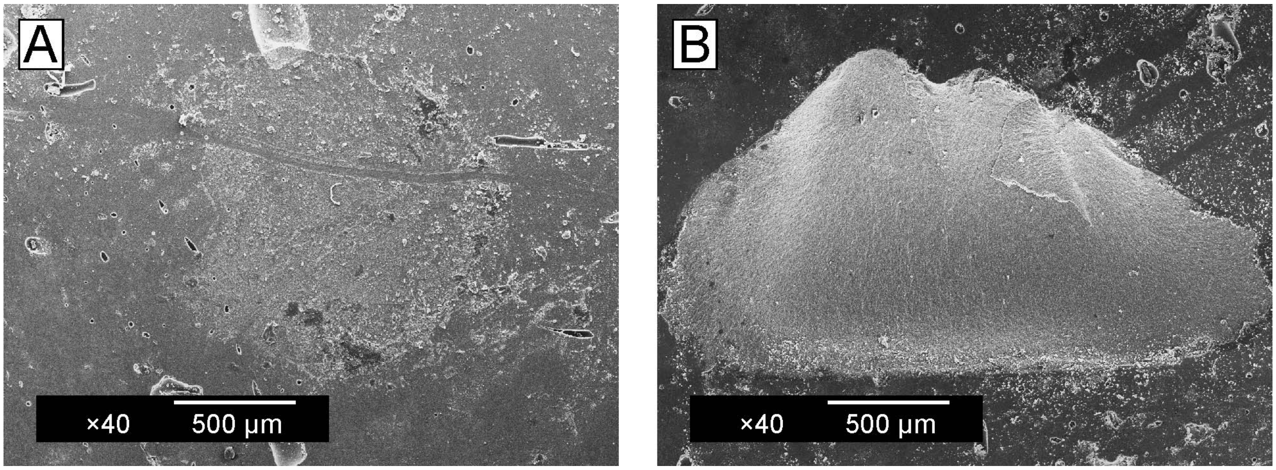

Figure 2. *SEM pictures illustrating the failures modes. (A): Adhesive failure characterized by an interfacial failure between the increments. (B): Cohesive failure within the composite.*

ulation with latex gloves in the mechanical properties of the composite resins. Some studies, however, show the negative influence of contamination by blood,[2] saliva,[3,4,15] latex gloves[5,7] and cleaning agents in the adhesive properties of restoratives to the dental substrata. Moreover, there is some evidence that the technique used for composite placement can directly affect the incorporation of bubbles and porosities in the material.[1,8-10,16-18]

The contamination with saliva and/or blood has been cited in the literature as one of the main problems during adhesive procedures,[19,20] and digital manipulation of composites with powder-containing gloves or contaminated by saliva is a form of contamination between the increments of the composite resin. A direct comparison to our results with data from previous studies was not possible because most studies analyze different variables, such as contamination and decontamination of dental substrate, contamination and decontamination between increments of composites, and the effects of techniques for insertion of restorative material on the formation of voids or porosities, while the present study assessed the effects of contamination sources on the mechanical properties of composite resins.

In the present study, saliva-contaminated gloves were left to dry before digital manipulation of the composite. This procedure was chosen because the study did not focus on the moisture effects of saliva on properties of composite resins. It is unlikely to expect that clinicians would deliberately use a moist, saliva-contaminated glove for touching the composite; however, the glove could be contaminated with saliva and dry before the composite is manipulated. In such a situation, only the solid saliva components, such as proteins, amino acids, and enzymes, would be present on the gloves to act as contaminants,[15] and the dentist would not be aware of that contamination source.

The results from the diametral tensile strength test showed no statistically significant difference among groups, demonstrating that contamination by powder and/or saliva did not directly affect this property. This result supports the null hypothesis of the study. The diametral tensile test examines the ability of the material to support multidirectional forces, and in the present study, all groups had values above 34 MPa, fulfilling the recommendation of the American Dental Association for direct restorative composites to be used in posterior restorations.[21] In addition, the diametral tensile strength values reported here are in line with other results reported in the literature for different commercial composite resins.[22] However, this test might not be sensitive enough to detect the effects of contamination among the layers of the composite placed with an incremental technique, explaining the lack of differences among groups under this test. However, it should be acknowledged that the power of the performed statistical test for diametral tensile strength data was below 0.8 and that different results might be observed if a larger sample size was used.

The overall results found from the flexural strength and flexural modulus evaluations showed that gloves not cleaned before digital manipulation can cause negative effects on these properties of composites. Even the manipulation with powder-free gloves seems to cause adverse effects on the flexural strength and modulus of composites, and this could be explained by the presence of contaminants in the gloves other than just the powder. Also, the control group without digital manipulation presented lower flexural strength and modulus, which could be attributed to the presence of voids and porosities among composite increments. This finding was previously reported in the literature for the direct placement of the composites into the cavity.[16] It is interesting to note that the disinfection of contaminated gloves with ethanol seems to have a positive effect on flexural strength and modulus; this finding indicates that digital manipulation procedures could be performed if the gloves are decontaminated. These results also reinforce the negative influence of contamination on the properties of composite resins, rejecting the null hypothesis of the study.

Regarding the incremental layer bond strength test, results supported that the presence of powder in procedure gloves interfered negatively in the union between the increments, which was also showed by Oskoee and others,[7] who compared the effects of contamination of the adhesive surface (bovine enamel) from latex gloves with and without powder used to place composite restorations. The presence of saliva on the gloves may counteract the negative effect produced by the presence of powder, and it could be speculated that the presence of small remains of saliva proteins between the increments is not as damaging as the presence of powder from the gloves. As for the results of flexural strength and flexural modulus, cleaning the gloves with alcohol seems to be a good option to avoid negative effects from contamination by the gloves.

Results of this study provide evidence that the digital manipulation of composite resins with gloves might influence their mechanical properties. Clinicians should bear this in mind during placement of adhesive restorations and avoid touching the adhesive materials and composites with contaminated gloves. It is important to acknowledge the limitations of this *in vitro* study, which represents only an indication of the performance of the specific materials tested here. While there may be a correlation between laboratory tests and the clinical performance of restorations, the former are used primarily to guide the effects of changes in composition or the evolution of their properties. Knowledge of the mechanical properties is essential for the correct use of these materials and to estimate the clinical long-term performance,[23] but the best evidence would be achieved with randomized and controlled clinical trials or long-term prospective and retrospective studies on the longevity of restorations.

CONCLUSIONS

Within the limitation of this *in vitro* study, the following conclusions can be drawn:

- The presence of powder in the gloves seems to be more damaging for the mechanical properties and incremental layer bond strength than the presence of saliva.
- Cleaning the gloves with ethanol might be an alternative to avoid the negative effects of digital manipulation of the composite using contaminated gloves.
- Digital manipulation might be indicated for composite resin restorations to achieve improved mechanical properties, provided that the gloves are not contaminated.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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