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Effect of Imaging Powders on the Bond Strength of Resin Cement

ABSTRACT

The application and incomplete removal of a CAD/CAM imaging powder may affect the dentin surface prior to bonding a ceramic restoration**.** The purpose of this study was to compare the effect of imaging powder residue on the shear-bond strength of a self-adhesive resin cement to dentin. Mounted human third molars were sectioned coronally with a diamond saw to expose dentin and prepared with a diamond bur mounted in a custom jig. The dentin surface was sprayed with three different imaging powders. The powders were treated in three different modes (no rinse, 1-second rinse, and 10-second rinse of water). A control group was also created with no application of imaging powder. A self-adhesive resin cement was bonded to the surface and loaded to failure in a universal testing machine after 24 hours of storage. Data was analyzed with Kruskal-Wallis/Mann-Whitney non-parametric tests. The dentin surfaces rinsed for one or ten seconds were not significantly different from the control or from each other. The type of imaging powder did not significantly affect the bond strength. The non-rinsed powdered dentin surface had a significant reduction in bond strength compared to the control or the rinsed powdered surfaces.

INTRODUCTION

The notion of computer-aided design / computer-aided manufacture (CAD/CAM) dentistry was first introduced in the late 1970s by Francois Duret. In 1987, Sirona Dental Systems (Bensheim, Germany) released the first version of CEREC (Chairside Economical Restoration of Esthetic Ceramics).[1] The most advantageous aspect of this technology is the capability to create and mill a restoration in the dental office, thus reducing costs and streamlining treatment. As of 2009, there were approximately 25,000 CEREC users worldwide.[2] Since then, all-ceramic restoration treatment has been simplified and improved and numerous systems have been developed and marketed.[1] CAD/CAM is also being used to restore endodontically treated teeth with endocrowns and in conjunction with cone beam volumetric tomography to plan and restore dental implants.[3,4]

Very little research, however, has been done to support specific methods and standard processes for the restorative dentist. Additionally, manufacturers produce a variety of materials that can be used at different steps. The practitioner is tasked to select the appropriate imaging powder and cement with the best performance properties. The majority of the research to date has been focused on the properties of the restoration itself as well as the marginal adaptation, retention, or durability of a particular cement.[5-25] A review of clinical studies found that the longevity of posterior dental restorations was dependent upon many different factors that were related to materials, the patient, and the dentist. Annual failure rates in posterior stress-bearing restorations were: 0 – 7% amalgam, 0 – 9% direct composite, 0 – 11.8% composite inlays, 0 – 7.5% for ceramic restorations, 0 – 4.4% for CAD/CAM ceramic restorations, and 0 – 5.9% cast gold inlays and onlays. The principle reasons for failure were secondary caries, fracture, marginal deficiencies, wear, and post-operative sensitivity.[20] The type of luting agent is considered to be one of the key factors in determining a restoration's longevity.[26, 27]

A critical step in any indirect restoration is the capture of the preparation in an impression. When using a CAD/CAM system to mill a restoration, the impression is made by using a camera to digitally scan the tooth (or a cast) and a computer program is used to virtually design the restoration. The CEREC 3D AC system uses a camera that projects blue wavelength light over the area to capture all of the dimensions of the preparation and surrounding teeth and tissues. The blue wavelength light reportedly provides a higher resolution image than the infrared camera (CEREC 3D AU) used in earlier systems.[28] In order for the blue or red wavelength CEREC cameras to capture an accurate image, the surface or object must be as uniform as possible in its reflectivity. To accomplish this, a titanium dioxide powder is typically used to coat the area. The E4D system (D4D Technologies LLC, Dallas, TX) is a chairside imaging and milling system that creates a digital impression from an intraoral scan without the use of reflective powder. The new CEREC Omnicam also functions without application of imaging powder. Other systems, such as iTero and Lava C.O.S., are used exclusively for digital impressions. iTero does not require powder, but the Lava system requires a light dusting (Cadent, Carlstadt, NJ; 3M ESPE, St. Paul, MN).

The improper use of the imaging powder is one of the possible sources of error when fabricating a CEREC 3D restoration.[29] The coating can be sprayed with a delivery unit such as PowderPro (Advanced Dental Instruments, Haworth, NJ), painted, as with Scan'film by Dentaco (Hamburg, Germany) or sprayed with a self-contained propellant and powder system such as OptiSpray (Sirona Dental Systems, Charlotte, NC).[30] An over-powdered surface is recorded as uneven, whereas one with too little powder does not adequately reflect light. The CEREC 3D camera must be positioned appropriately as well. If the camera is not properly oriented in the path of insertion to allow capturing all margins, without undercuts, the scan will not capture the necessary data to accurately allow the restoration to be properly designed. As an alternative to intra-oral scanning, the practitioner can make a conventional impression and the prosthesis can be designed from an image captured indirectly. A cast may be fabricated using a scannable stone material, made specifically for indirect optical imaging (Diamond Die, HI-TEC Dental Products, Greenback, TN). The clinician is able to eliminate intraoral use of a powder spray and scanning. However, the impression and cast fabrication requires addition of a step, and adds time to the procedure. A study conducted by da Costa compared the marginal gap created with a direct intraoral scan with that of an indirect scan of a model and found no significant difference.[31] Another study, however, found that the extra-oral optical scanning methods provided the highest precision.[32] When using powder, Sirona recommends the use of Optispray. There are products on the market that contain a reflective compound other than titanium dioxide powder. Possible alternatives include an economical magnesium stearate spray marketed specifically as an aid for seating castings (Occlude, Pascal International Inc, Bellevue WA). No research has been published evaluating the use of Occlude as an alternative intraoral imaging powder for use with CEREC 3D.

The application and incomplete removal of a imaging powder may affect the surface prior to bonding a restoration. The manufacturers instruct the dentist to clean the surface with air/water spray, but do not provide detailed instruction. Current literature has not shown whether air/water rinse adequately removes the powder residue and whether that will affect the cement bond. Some systems, like CEREC Powder, rely on the application of glycerin to coat the surface prior to applying the powder. Most other self-contained systems, such as Optispray, do not require the separate application of a coating. The intent of this study was to provide guidance for the use of imaging powder and resin cements with a milled all-ceramic restoration using CEREC 3D.

RelyX Unicem (3M ESPE, St Paul, MN) is a dual-curing, self-adhesive resin luting cement for adhesive cementation of indirect composite, metal or ceramic restorations. Self-adhesive resin cements do not require a separate adhesive or etchant and appear to have a major benefit compared to more traditional resin cements due to their simplicity of application. Relatively little information exists about the composition and adhesive mechanism of these materials. The current self-adhesive cements are two-part materials that require hand mixing, capsule trituration or auto-mixing with a dispenser. Bond strengths vary among self-adhesive resin cements. Etch-and-rinse cements generally provide the greatest retention. Self-etching cements provide an intermediate level, while self-adhesive cements are the least retentive.[33] The vast majority of the published literature describes one cement, Rely-X Unicem, which was the first commercial self-adhesive resin cement. The components of Rely-X Unicem are a powder comprised of glass, silica, calcium hydroxide, pyrimidine, peroxy compound and initiator; and a liquid comprised of methacrylated phosphoric ester, dimethacrylate, acetate, stabilizer, and initiator.[34] Studies suggest that Unicem shows nearly equivalent results to other resin cements in terms of marginal sealing and adaptation. However, a separate phosphoric-acid etch of enamel margins has been shown to improve bond strength.[35] A review of studies evaluating the physical properties of self-adhesive resin cements suggest that these materials may be expected to show similar clinical performance as other dental cements, but clinical studies are lacking, so long-term conclusions are not possible.[34] Self-adhesive cements have a significant reduction in dentin bond strength when the dentin is etched with phosphoric acid and a bonding agent is applied.[33] The effect of imaging powder and its removal on the bond strength of resin cement to dentin is unknown. The purpose of this study was to compare the effects of imaging powder residue on the shear-bond strength of a self-adhesive resin cement to dentin. The null hypotheses to be tested were that there would be no significant differences in the bond strength of the self-adhesive resin cement to dentin based on (1) amount of rinsing or (2) type of imaging powder.

METHODS AND MATERIALS

Extracted human third molars stored in 0.5% Chloramine-T were used within 6 months following extraction. Teeth were mounted in dental stone in plastic pipe with the crown exposed and accessible. A diamond saw (Isomet, Buehler, Lake Forest, IL) was used to remove 2mm or more coronal tooth structure to ensure dentin exposure and the proper orientation of the surface relative to the direction of shear force applied. Each specimen was examined under a stereomicroscope (SMZ-1B, Nikon, Melville, NY) at 10X magnification to ensure complete exposure of the dentin surface with no residual enamel. To simulate a prepared surface, the flat dentin was roughened with a fine diamond bur (#837, Brasseler, Savannah, GA) under water spray with a jig used to support the height of the handpiece head with the surface of the tooth specimen. The mounted specimens were divided into three groups, one per powder: CEREC Powder, Optispray, and Occlude. Additionally, one group of specimens was not powdered and served as a control. Manufacturer's directions were followed in the application of the powder. For the CEREC Powder application, the glycerin coating was first placed with a brush and gently air thinned. Next, the powder was applied using the PowderPro system (Advanced Dental Instruments, LLC, Haworth, NJ). The PowderPro system was attached to the handpiece hose of a dental delivery unit and the powder was delivered through a nozzle on the handpiece with the use of the foot pedal. Optispray and Occlude are self-contained canister systems and do not require an adhesive-type coating. The powders were applied according to the manufacturer's instructions with the applicator tip at a standardized distance of one inch.

The three powder groups were divided into three subgroups of ten each based on the method of powder removal: no rinse, 1-second rinse, and 10-second rinse. The teeth were rinsed with distilled water using a three-way syringe tip at a standardized distance of 1-inch. A custom-made vinyl polysiloxane jig was used to maintain distance and angle. The tooth specimens were placed in an Ultradent Jig and secured beneath the white non-stick Delrin insert (Ultradent, South Jordan, UT). The dual-curing resin cement was mixed and applied into the mold according to manufacturer's instructions to a height of 4mm. The cement was light-cured as recommended by the manufacturer using the Bluephase 16i (Ivoclar, Amherst, NY) light-curing unit. Irradiance of the curing light was monitored with a radiometer (LED Radiometer, Kerr) to verify irradiance levels above 1200mW/cm^2. The bonding area was limited to a 2.4mm diameter circle determined by the Delrin insert. Following the application of the resin cement, all specimens were stored for 24 hours in distilled water at 37 degrees centigrade. The specimens were then loaded perpendicularly at the interface with a customized probe (Ultradent) in a universal testing machine (Instron, Norwood, MA) and tested with a crosshead speed of 1.0 mm/min until bonding failure occurred. Shear-bond strength values in megapascals (MPa) were calculated from the peak load of failure (newtons) divided by the specimen surface area. The mean and standard deviation were determined for each group. Data was analyzed with the Kruskal-Wallis and Mann-Whitney statistical tests. Non-parametric data analysis was used because exploratory graphical analysis found a non-normal distribution of the data. A Bonferroni correction was applied because multiple comparison tests were performed (alpha=0.008).

Following shear-bond strength testing, each specimen was examined using 10X stereomicroscope to determine failure mode as either: 1) adhesive fracture at the cement/adhesive/dentin interface, 2) cohesive fracture in cement, 3) mixed (combined adhesive and cohesive) in the cement and bonded interface or dentin and bonded interface, or 4) cohesive fracture in dentin.

RESULTS

The non-rinsed powdered dentin surface had a significant reduction in bond strength compared to the control or the rinsed powdered surfaces ($p<0.008$). The dentin surfaces rinsed for one or ten seconds were not significantly different from the control or from each other. There was no significant difference in bond strength of resin cement to dentin based on the type of powder ($p>0.086$). See Figure 1. The non-rinsed groups failed primarily with adhesive fractures while the rinsed groups failed with primarily adhesive and mixed fractures as shown in Figure 2.

DISCUSSION

The manufacturer's instructions for CEREC Optispray advise the user that "as soon as the optical impression has been taken, the surface should be cleaned with air/water spray." No published articles could be found that had studied the amount of rinse time required for imaging powders. The first null hypothesis was rejected. There was a significant difference in bond strength of resin cement to dentin based on rinse time. The results of this study suggest that a rinse time of one second or more is sufficient to remove imaging powder residue. However, a rinse time of zero, or the non-rinsed groups, displayed significantly lower bond strengths. The failure mode for the non-rinsed groups was almost entirely adhesive fracture, suggesting a weaker interface, while the 1- and 10-second rinse groups displayed primarily adhesive and mixed fractures, similar to the control group.

The second null hypothesis was not rejected in this study. There was not a significant difference in bond strength of resin cement to dentin based on the type of powder. The three imaging powders differed greatly, however. While Optispray is a self-contained propellant, CEREC Powder is applied with a delivery unit such as the PowderPro after the application of a glycerin coating. Occlude has not been marketed as an imaging powder and contains magnesium stearate instead of titanium dioxide as found in traditional imaging powders. Occlude was utilized in this study as it has been considered an economic alternative to existing imaging powders. This study did not attempt to evaluate Occlude as an imaging powder and cannot make any conclusion as to its efficacy for that purpose. Future research could focus on magnesium stearate reflectivity on preparation surfaces and margins.

Self-adhesive resin cements such as Unicem do not require an acid-etch step prior to bonding. When using etch-and-rinse type resin cements, imaging powder may be removed more thoroughly than with self-adhesive cements. Remaining residue was observed to result in more adhesive type failures. The dentin surfaces tested were relatively flat, but roughened with a diamond bur to simulate intraoral tooth preparation. Clinically, less efficient powder removal may be encountered when rinsing three-dimensional preparations (with vertical surfaces and more box-like forms). However, treating the surfaces with flour of pumice and prophy cup prior to cementation would likely further reduce remnants of imaging powder.

CONCLUSION

The CAD/CAM imaging powders did not affect the shear-bond strength of the self-adhesive resin cement to dentin if the powders were rinsed with water. This study showed that the manufacturer instructions, while nonspecific, were adequate for removal of the three tested powders. The amount of residue that remained did not significantly affect bond strength after rinsing with water.

DISCLOSURE

The views expressed in this study are those of the authors and do not reflect the official policy of the United States Air Force, the Department of Defense, or the United States Government. The authors do not have any financial interest in the companies whose materials are discussed in this article.

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