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"Shear Bond Comparison Between Four Bioceramic Materials and Dual Cure Composite Resin"

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[redacted]

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24 July 2018

DEPARTMENT OF THE AIR FORCE
AIR EDUCATION AND TRAINING COMMAND

Date: 20 Dec 2016

MEMORANDUM FOR 81 MDG IRB CHAIRPERSON, MAJ JOSHUA TYLER

FROM: 81 DS/SGD

SUBJECT: Research Determination Request

1. The attached protocol entitled, **"Shear bond comparison between eight bioceramic materials and composite resin or resin-modified glass ionomer",** is submitted for your review from Maj Kelley Hursh to make a formal determination as to whether this does or does not constitute human research, and therefore the requirement for further review by the IRB.

2. Previously, it was established after consultation with AFMSA/SGE-C, Research Oversight and Compliance Division, Office of the Surgeon General, that this form of research generally does not constitute use of human subjects per the Common Rule (32 CFR 219), and therefore is not human research and does not require a formal research protocol. Guidance is attached for review.

3. I am asking that you review the attached protocol and the guidance from AFMSA/SGE-C and make a formal determination as to whether this does or does not constitute human research and therefore the requirement for further review by the IRB. We contend that is does not require full IRB approval or protocol oversight.

4. If the determination that the proposed activity is not human research, a study folder will be kept by the IRB Protocol Administrator to maintain documentation of the activity and the ruling for future inspection purposes. The assigned tracking number will be **FKE20170008N.**

[redacted]

JOHN BREWSTER, Lt Col, USAF, DC
Director Graduate Dental Research

Attachments:
1. Protocol #FKE20170008N
2. AFMSA/SGE-C Non-Human Research Guidance Checklist

1st Ind, IRB Chairperson

MEMORANDUM FOR 81 DS/SGD, Lt Col Brewster

I reviewed the submitted proposal, #**FKE20170008N**, and have made the following determination:

_____ This protocol does constitute human research and therefore requires review by the 81 MDG IRB.

_____ This protocol does not constitute human research and therefore does not require review by the 81 MDG IRB. Please notify the 81 MDG IRB of this determination at the next convened meeting.

JOSHUA TYLER, Maj, USAF, MC
Chairperson, 81 MDG Institutional Review Board

_____
Date

Shear bond comparison between four bioceramic materials and dual cure composite resin

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Steven W. Black, DDS, Van T. Himel, DDS, and Kent A. Sabey, DDS

Abstract

Introduction: Bioceramic materials have demonstrated biologic and physical properties favorable for regenerative treatment. A key contributor to treatment success is an adequate restoration to prevent microleakage; however, research is limited regarding the bond strength between bioceramic materials used in regenerative procedures and restorative materials. Objective: The purpose of this study was to compare the bond strength between four bioceramic materials and a dual cure composite resin. Methods: Eighty wells in Teflon blocks were divided evenly into 4 groups and filled with a bioceramic material: Group 1: White ProRoot MTA; Group 2: Biodentine; Group 3: EndoSequence RRM Fast Set Putty; Group 4: NeoMTA. After allowing the materials to set according to manufacturer's instructions, the exposed surfaces of the bioceramic materials were prepared using ClearFil SE Bond followed by restoration with ClearFil DC Core Plus. To test shear bond strength, each block was secured in a universal testing machine and the crosshead was advanced at 0.5mm/min until fracture. Newton peak force was recorded and MPa calculated. Data was analyzed by Independent Kruskal-Wallis Test and Dunn's Post Hoc Test ($p<0.05$). Results: Mean shear bond strengths between ClearFil DC Core Plus and the bioceramic material groups were: White ProRoot MTA – 7.96 MPa; Biodentine – 9.18 MPa; EndoSequence RRM Fast Set Putty – 4.47 MPa; NeoMTA – 5.72 MPa. White ProRoot MTA and Biodentine were statistically similar, with higher stress bond strength than NeoMTA which had a statistically greater bond strength than Endo Sequence Root Repair Material. However, these differences are clinically insignificant. Conclusion: The choice of which bioceramic material to use in regenerative procedures should be based on factors other than the bond between that material and the overlying coronal resin restoration.

Introduction

Calcium silicate-based cements, or bioceramics, have received increased attention in the dental literature, to include the specialty of endodontics. Mineral Trioxide Aggregate (MTA) and other bioceramic materials demonstrate physical and biological properties that are favorable for clinical procedures such as preservation of pulp vitality, or regenerative techniques. They have the ability to set in the presence of blood and other biological fluids and have demonstrated excellent biocompatibility (1-4). Additionally, these materials support the reconstitution of a cementum-like covering over root surfaces, have low solubility after setting, can contribute to antibacterial activity, and have the ability to induce mineralized tissue formation (1-4). These physical and chemical characteristics afford them wide versatility for endodontic providers; they can function as cements, root-end restorations, perforation repair materials, root canal sealers, obturation materials, and have found a contemporary niche in regenerative endodontics. The sealing ability, biocompatibility, and dentinogenic activity of MTA has been attributed to the physiochemical reactions between dentin and MTA (5).

Regenerative endodontics has been defined as “biologically based procedures designed to replace damaged structures, including dentin and root structures, as well as cells of the pulp-dentin complex (6).” Regenerative endodontic procedures often involve two steps aimed at creating an environment capable of revascularization. In a review of case studies, Law found that one commonality amongst successful regenerative endodontic procedures was an effective coronal seal after treatment with a pulp space barrier and final restoration. The aim is to inhibit microbial invasion of the pulp space through creation of a “double seal” by placing MTA or similar bioceramic material below the CEJ, and covering that with a bonded restoration. This allows the revascularization of the pulp-dentin complex to proceed unimpeded (7). MTA has been the material of choice as a pulp space barrier due to its characteristics of biocompatibility, excellent seal, and conductive and inductive properties.

New bioceramic products continue to be released into the marketplace, each having slight differences in formulation and manufacturer’s instructions. There is a scarcity of research evaluating the interface between these new bioceramic materials and the composite resin restorative materials commonly bonded over them.

This study compared the bond strength of four bioceramic materials to composite resin. If one or more of the tested materials were to demonstrate a higher bond strength, this may indicate a potentially improved seal from the coronal restoration. An improved seal may correlate with less potential for contamination of the pulp space that is undergoing the regenerative activity. This could solidify the clinical choice for a regenerative attempt as one of several treatment options.

Materials and Methods

Teflon blocks were created and eighty 3mm diameter by 3mm deep wells were drilled into the Teflon. A small pilot hole was also drilled perpendicular to the long access of the well at the base. A paper point could then be placed in contact with the bioceramic material to wick moisture to the material in an attempt to duplicate the moist environment required for the material to set. The wells were divided evenly into 4 groups of twenty: Group 1: White ProRoot MTA (wMTA, Dentsply Tulsa Dental, Tulsa, OK), Group 2: Biodentine (Septodont, Saint Maur des Fosses, France), Group 3: EndoSequence Root Repair Material – Fast Set Putty (ERRM; Brasseler USA, Savannah, GA), and Group 4: NeoMTA (Avalon Biomed Inc, Houston, TX). Each bioceramic material was mixed according to manufacturer's instructions and placed in a well within the Teflon block. The bioceramic was leveled using a mixing spatula to be flush with the surface of the Teflon block. The base of the Teflon blocks were submerged in water so that the paper point was moistened. Each bioceramic was allowed to set for recommended set time in the Humidor at 37^{o}C and 100 percent humidity before bonding. Clearfil SE Primer was applied to the entire bioceramic surface for 20 seconds, and then gently air dried for 5 seconds to evaporate the solvent. Clearfil SE Bond was applied to the entire bioceramic surface, and then gently air dried for 5 seconds to uniformly disperse bond over the entire bioceramic surface. Visible light polymerization was completed using a Polywave LED-based visible light curing (VLC) unit (Bluephase G2, Ivoclar-Vivadent, Amherst, NY, USA). Irradiance was periodically verified (1000 mW/cm2) for 20 seconds. The Teflon block was inserted into an Ultradent bonding jig containing a plastic mold with hole diameter of (2.38 ± 0.03) mm. The mold was centered over the bioceramic material to ensure that the bonding area consisted only of the bioceramic material. The mold was lowered to contact the surface of the Teflon block, and the bonding jig screws were tightened until one-half of the wave spring was compressed with no arching of the plastic button mold positioned on the Teflon block. Clearfil DC Core Plus was placed by syringe into

the cylindrical shaped plastic matrix with an internal diameter of 2mm and height of 2mm and visible light polymerization was completed for 20 seconds. The screws were loosened on the bonding clamp and the specimen was carefully removed. The diameter of one composite button per group was measured as near to the bonding surface as possible to confirm the diameter of the bonding area. If present, excess composite was removed from around the composite button using a scalpel blade. The base of the Teflon blocks were again submerged in water so that the paper point was moistened. The samples were allowed to set for 7 days at 37^{o}C and 100 percent humidity to complete setting of the bioceramic material. To perform the shear bond test, the bonded sample was placed into the test base clamp so that the bonding surface of the bioceramic was flush with the front of the clamp and the composite button was aligned along the vertical central axis of the clamp. The clamp was placed on the base of the universal testing machine, and the bonded sample was aligned in the holder under the testing crosshead with the notched edge centered over the composite and flush against the bioceramic material. The crosshead was lowered until just in contact with the composite button, and the sample was loaded at a crosshead speed of 0.5mm/min until failure. The maximum force in Newtons (N) applied to the sample prior to failure was recorded. Shear bond strength (stress) was calculated using the formula: stress (MPa) = Force (N)/bonding area (mm^2). After the test, the fractured surfaces were examined by two calibrated evaluators using 3.8X magnification to determine the location of fracture. When difference in opinion occurred, the evaluators discussed and re-evaluated until they concurred. Random samples were photographed with a Hirox 770 Digital Microscope (Hirox-USA, Inc. Hackensack, NJ USA). The location of failure was recorded as 1 = adhesive fracture; failure at the interface between the bioceramic and the restorative material, 2 = cohesive fracture, failure within the bioceramic material, 3 = cohesive fracture, failure within the restorative material, 4 = mixed fracture, a combination of adhesive and cohesive fracture.

Results

Table 1 shows the descriptive statistics of shear bond strength for each group. The mean bond strengths of the groups were analyzed by Independent Kruskal-Wallis Test and Dunn's Post Hoc Test ($p<0.05$). The Kruskal-Wallis test identified statistically significant differences amongst the groups. Dunn's Post Hoc test revealed that White ProRoot MTA and Biodentine were statistically similar, with

higher shear bond strengths than NeoMTA which had a statistically greater bond strength than Endo Sequence Root Repair Material – Fast Set Putty.

Overall, there were no fractures within the composite restorative material. All fractures occurred either within the bioceramic, at the interface of the composite and bioceramic, or a combination of the two. In the White ProRoot MTA group, 30% of the samples were adhesive fractures, and 70% were mixed fractures. In the Biodentine group, 10% of the samples were adhesive fractures**,** 80% were cohesive fractures within the bioceramic, and the remaining 10% were mixed fractures. In the EndoSequence Root Repair Material – Fast Set Putty group, 60% of samples were cohesive fractures within the bioceramic, and 40% were mixed fractures. In the Neo MTA group, 20% of the samples were adhesive fractures**,** 30% were cohesive fractures within the bioceramic, and the remaining 50% were mixed fractures.

Bioceramic Material	**N**	**Mean (MPa)**	**Min (MPa)**	**Max (MPa)**
Biodentine	**20**	**9.175 ± 4.99**	**0.7**	**21.6**
White ProRoot MTA	**20**	**7.96 ± 3.43**	**3.3**	**17.1**
NeoMTA	**20**	**5.715 ± 1.98**	**2.8**	**10.1**
EndoSequence RRM	**20**	**4.465 ± 2.00**	**2.0**	**9.7**

Table 1 – Shear bond strength values of Bioceramics and Clearfil DC Core Plus composite resin

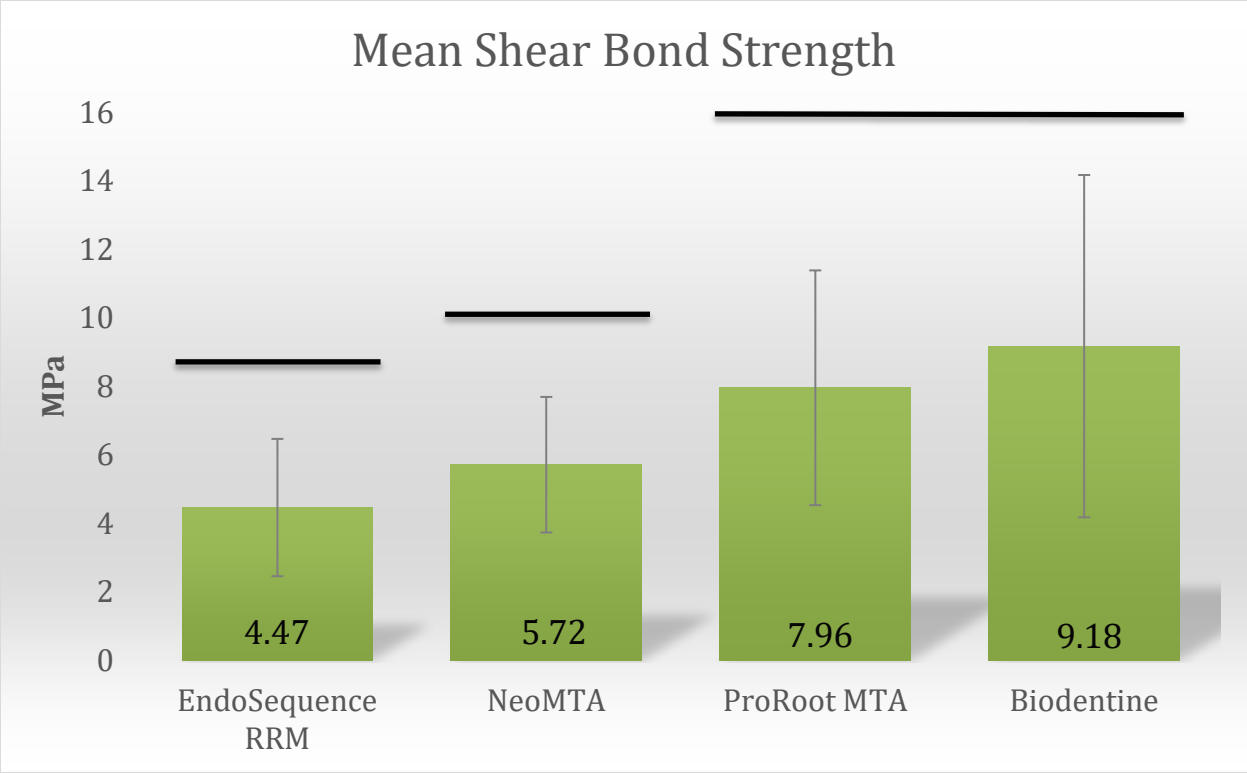

Figure 1 – Shear bond strength values of Bioceramics and Clearfil DC Core Plus composite resin

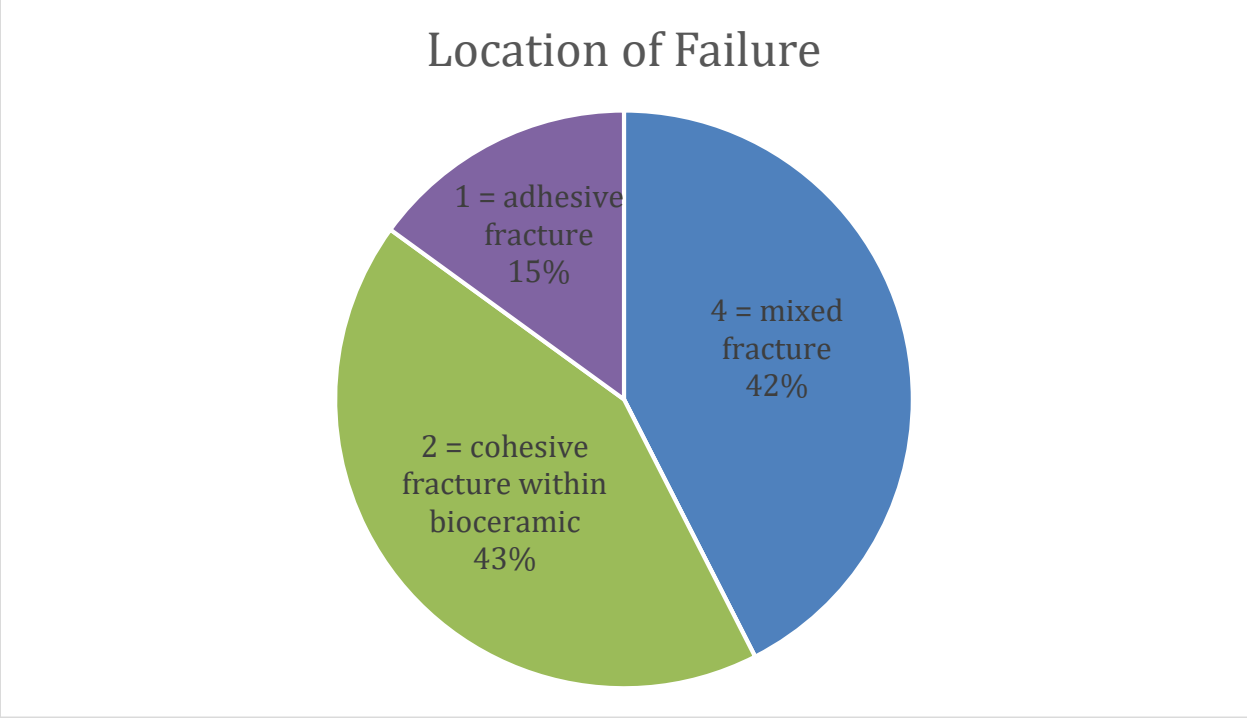

Figure 2 – Pie graph representing the distribution of location of failure amongst all groups

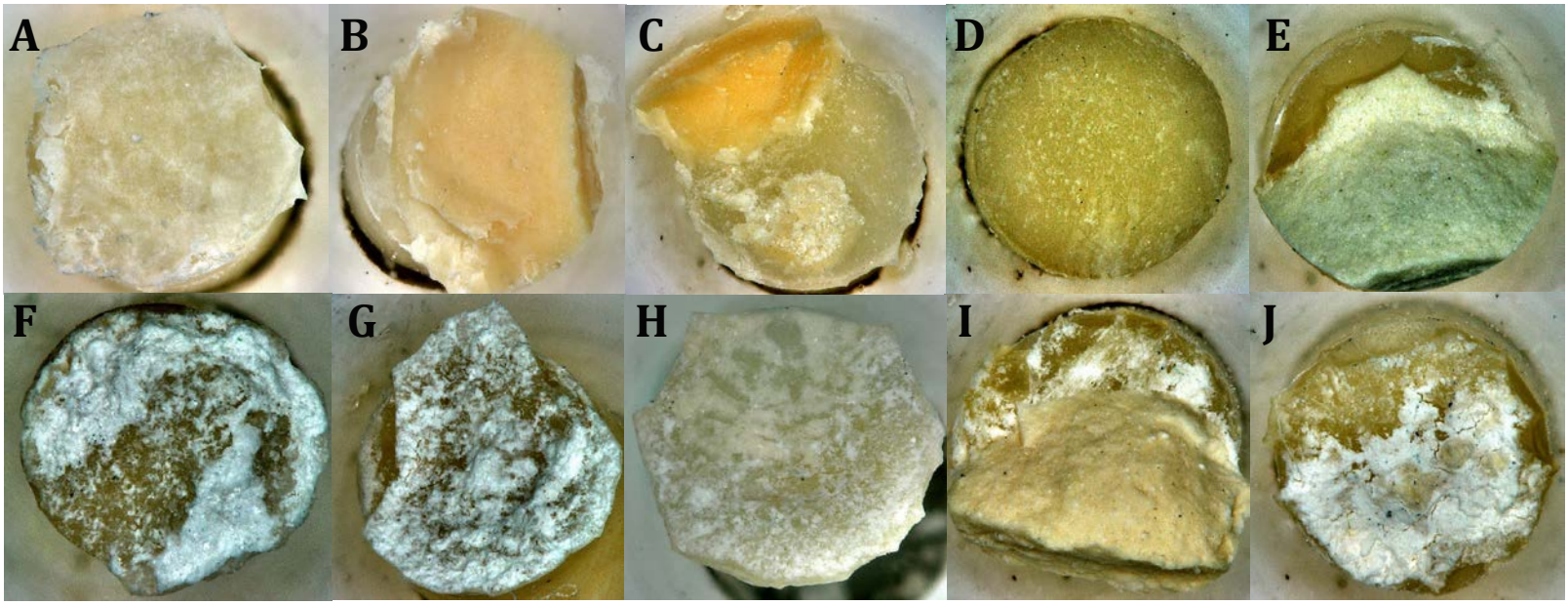

Figure 2 – Photographs of samples representing location of fracture. Photographs taken using Hirox 770 Digital Microscope. A. Biodentine adhesive fracture, B. Biodentine cohesive fracture within the bioceramic, C. Biodentine mixed fracture, D. White ProRoot MTA adhesive fracture, E. White ProRoot MTA mixed fracture, F. EndoSequence Root Repair Material – Fast Set Putty cohesive fracture within the bioceramic, G. EndoSequence Root Repair Material – Fast Set Putty mixed fracture, H. Neo MTA adhesive fracture, I. Neo MTA cohesive fractures within the bioceramic, J. Neo MTA mixed fracture.

Discussion

Regenerative endodontic procedures provide a means to save the natural dentition while having the potential to restore the sensory, immunologic, and defensive properties of the pulp-dentin complex. AAE regeneration guidelines measure the degree of success of regenerative endodontic procedures by the extent to which it is possible to attain primary, secondary, and tertiary goals. The primary goal is the elimination of symptoms and the evidence of bony healing. The secondary goal is increased root wall thickness and/or increased root length, and the tertiary goal is a positive response to vitality testing (8).

In the last decade, regenerative endodontics has become a popular treatment option for teeth with necrotic pulps and immature apices. Two case reports, by Iwaya et al. and Banchs and Trope ignited an interest by demonstrating continued root development and reinnervation following treatment (9, 10). Three important principles of regenerative endodontics are recognized: 1. Elimination of bacteria from the canal system, 2. Creation of a scaffold for ingrowth of new tissues, and 3. Prevention of reinfection by creating a bacteria-tight seal (7).

In 2017 Verma et al. demonstrated that residual bacteria had a critical negative effect on the amount of root growth as evaluated by radiographs and on the amount of dentin associated mineralized tissue formed (11). Additionally, in a review of root canal revascularization by Conde et al., it was determined that most failures were associated with reinfection of the root canal (12). The conclusions of these studies provide relevance to the present study and reinforces the importance of a bacteria-tight seal following regenerative procedures.

Following disinfection of the canal space and formation of a blood clot, it is necessary to place a barrier over the blood clot. MTA (or similar a bioceramic) is the material of choice for this purpose. In addition to creating a bacteria-tight seal, these materials have advantages over other materials because of their biocompatibility and conductive and inductive properties. (1-3). A 3-4mm layer of MTA is recommended; after placement of a pulp space barrier, a final restoration is placed (7).

Historically, following placement of MTA a moistened cotton pellet was placed in the pulp chamber and an interim restoration placed. The patient returned to confirm set of the MTA and for placement of the final restoration. New bioceramic materials introduced in recent years have several advantages, including significantly shorter set times. Shorter setting times and improved handling properties have improved clinical efficiency, and in the clinical setting, allow for placement of the final restoration immediately upon completion of regenerative procedures. In the present study, bonding procedures were performed immediately following the respective manufactures' set time to reproduce common clinical applications,

Although the results of this study demonstrated significant differences in bond strength, there was a broad range and wide standard deviation. Additionally, the bond strengths demonstrated in this study are low when compared to the shear bond strength of ClearFil SE bond to dentin which was reported by Brandt to be 26.2 MPa (13). This suggests that the differences between the bioceramic materials in this study may be of little clinical significance.

When comparing the location of fractures, significant variability existed within and amongst the groups. The wide variation could mean that the cohesive force is variable, or that other factors are involved including homogeneity of the materials, ease of mixing and application of the materials, and set times. The overall distribution of location of failures was mostly cohesive within the bioceramic or mixed

(85% of samples); this could be indicative of a durable interaction, as the material itself failed before the adhesion between the bioceramic and the resin. Further investigation of the failure zone in mixed failures to determine percentage of cohesive failure and extent of porosity could provide further insight about differences amongst the groups.

Kayahan et al demonstrated that etching MTA resulted in a selective loss of matrix from around the crystalline structures (14). Namazikhah et al studied the effect of pH on surface hardness and microstructure of MTA; conditioning with acidic solution resulted in extensive porosity of MTA (15). These findings are suggestive of increased surface area for micromechanical retention at the interface between the bioceramic material and composite restorative materials. This is also consistent with the relatively low shear bond strengths and location of failures found in the present study.

One limitation of this study is that the bonding was performed on a flat surface with a single interface between the two materials. In a clinical setting, the interfaces between composite and dentin and between MTA and dentin are also present. With relatively low bond strengths between bioceramics and composite, the efficacy of the seal, prevention of bacterial contamination, and the ultimate success of regenerative endodontic procedures are not only reliant upon the interface between the bioceramic material and composite resin, but are also reliant upon the interfaces between the composite resin and dentin and between the bioceramic and dentin.

In the present study, a 2 step self-etching adhesive bonding system, Clearfil SE Bond, and a dual cured composite, Clearfil DC Core Plus, were utilized. The bonding agent utilized in this study was selected based on its excellent laboratory and clinical results in previous studies. The bond strength values of different adhesive systems to dentin have been reported to be 13-35 MPa and the recommended bond strength values to achieve a restoration with no marginal discrepancies and a proper seal has been reported to be 17–20 MPa (16, 17). These values are much higher than the bond strength values between composite resin and bioceramic materials in the present study, which is why the bonding between dentin and composite is critical to optimize the seal following regenerative endodontic procedures. Not only should an ideal material be utilized, but proper technique and isolation should be practiced.

The third variable to influence the seal following regenerative endodontic procedures is the interface between the bioceramic and dentin. Sarkar et al. concluded that hydroxyapatite, formed from the dissolution of minerals in MTA, formed a chemical bond with dentin resulting in the formation of an interfacial layer between MTA and dentin (5).

Because the differences in this study are of little clinical significance, the choice of which bioceramic material to use in regenerative endodontic procedures should be based on factors other than the bond strength between the bioceramic material and the overlying coronal restoration. Factors to be considered are the individual handling properties that are preferred by the clinician, set time, and esthetics. Historically, the use of gray MTA has been demonstrated to result in significant discoloration of the tooth due to the presence of bismuth oxide (18). The potential tooth discoloration associated with the use of MTA led manufactures to search for an alternative endodontic bioceramic materials similar in composition that will not cause tooth discoloration. White ProRoot MTA contains decreased amounts of iron, aluminum, and magnesium, and many of the new bioceramics have replaced the bismuth oxide with alternative ingredients to reduce discoloration. Two of the materials in this study Biodentine and EndoSequence Root Repair Material utilize zirconium oxide powder as the radiopacifying agent, and NeoMTA utilizes tantalite. In a bench top study, Marconyak demonstrated that EndoSequence and Biodentine had significantly less discoloration compared with White ProRoot MTA (19).

Additional research is required to determine whether variable set times effect the bond strength of bioceramic materials to composite resin. Future studies might also consider utilizing different restorative materials, such as glass ionomers which bond chemically to dentin.

Conclusion

Under the conditions of this study, White ProRoot MTA and Biodentine demonstrated statistically higher bond strengths to dual cured composite than NeoMTA and EndoSequence Root Repair Material – Fast Set Putty. However, these differences may be of little clinical significance. Therefore, the choice of which bioceramic material to use in regenerative endodontic procedures should be based on factors other than the bond strength between the bioceramic material and the overlying coronal resin restoration.

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