

Mechanical Properties of SDR™ and Biodentine™ as Dentin Replacement Materials: An *In Vitro* Study

Wasiur Rahman Choudhury¹, Sridhar Nekkanti²

ABSTRACT

Aim: The aim of this study is to evaluate the shear bond strength of nanohybrid composite resins (NCR) and microhybrid composite resins (MCR) placed over three different dentin replacement materials: SDR—Smart Dentin Replacement™, Biodentine™, and resin-modified glass ionomer cement (RMGIC).

Methods and materials: Thirty acrylic blocks (50 mm × 20 mm × 15 mm), each with a central hole, were prepared, which were randomly distributed into three equal groups, each corresponding to one of the three dentin replacement materials—SDR, Biodentine, and RMGIC. The central holes were then filled with these materials. After setting and application of the respective adhesive system, the specimens were further divided into two subgroups each of NCR or MCR. The respective composite material was then applied to the dentin replacement materials using a cylindrical plastic matrix. Shear bond strength was tested on a universal testing machine (Instron 3366), at a crosshead speed of 1.0 mm/minute.

Results: SDR attained consistently higher shear bond strength (means: 21.18, 22.19 Mpa) values than RMGIC and Biodentine, with both types of composite resins (MCR and NCR), which were statistically significant ($p < 0.001$). When considering the means of the shear bond strength measurements obtained by the two types of the composite resin, no significant difference ($p < 0.05$) was found between them with all three types of dentin replacement materials.

Conclusion: There is no significant difference in the bond strengths achieved between MCR and NCR to the different dentine replacement materials. Hence, either type of composite resin may be expected to achieve similar bond strengths to the underlying substrate. SDR™ is a suitable dentine replacement material for placing below a composite resin veneer as it can achieve immediate higher bond strengths.

Clinical significance: SDR can be used as an effective bulk fill material in deep dentinal caries which can be capped with composite resins.

Keywords: Dentin replacement materials, Glass ionomer cement, Microhybrid and nanohybrid composite resins, Shear bond strength.

The Journal of Contemporary Dental Practice (2022): 10.5005/jp-journals-10024-3281

INTRODUCTION

The quest for an ideal material to replace the lost dentine has inspired substantial efforts in the field of dental materials, resulting in the formulation of a wide variety of materials available for the clinician today. Three such groups of materials developed for the restoration of teeth that have undergone a significant loss of dentinal structures are glass ionomer cement (GIC), resin-based composites (RBC), and calcium silicate-based cement.

Incorporation of a resin component resulted in the development of resin-modified glass ionomer cement (RMGIC), which had lowered the initial setting time, better handling, increased wear resistance and physical strength without compromising fluoride release, biocompatibility, and physiochemical bonding to the tooth structure.^{1,2} Croll and Nicholson in 2002 have argued that based on the principles of “biomimesis” (replacement of tissue or a part using materials that most closely replicate the original essence), the properties of particular GIC make them the best direct application dentin replacement material available.¹ However, GICs are brittle and prone to fracture and wear² and this may preclude their use in load-bearing areas. Additionally, RMGIC cannot be used as a direct pulp capping agent as it has been shown to initiate a persistent inflammatory response without pulp repair or dentin bridge formation even 300 days after pulp capping.³ Furthermore, the handling characteristics of this class of materials make it difficult to use in children who do not display optimal cooperation during dental treatment.

Several improvements have been made to the composition of RBCs since their initial development, leading to the development of

^{1,2}Department of Pediatric and Preventive Dentistry, Manipal College of Dental Sciences, Manipal Academy of Higher Education, Manipal, Karnataka, India

Corresponding Author: Sridhar Nekkanti, Department of Pediatric and Preventive Dentistry, Manipal College of Dental Sciences, Manipal Academy of Higher Education, Manipal, Karnataka, India, Phone: +91 9886932642, e-mail: drsri.pedo@manipal.edu

How to cite this article: Choudhury WR, Nekkanti S. Mechanical Properties of SDR™ and Biodentine™ as Dentin Replacement Materials: An *In Vitro* Study. *J Contemp Dent Pract* 2022;23(1):43–48.

Source of support: Nil

Conflict of interest: None

numerous new materials. One such example is a flowable bulk-fill RBC, marketed as SDR™—Smart Dentin Replacement (DENTSPLY DeTrey, Konstanz, Germany), indicated as a bulk-fill material and as a liner in Class I and Class II restorations. The ability to place it in 4 mm bulks instead of smaller increments without negatively affecting the polymerization shrinkage, cavity adaptation, or the degree of conversion is considered a significant advantage of SDR. Since it can be syringed directly into cavities, placement is made much more comfortable, and the restoration can be completed in a single appointment by placing a veneer of conventional composite resin over it. This characteristic can be particularly useful in pediatric patients, where the behavioral considerations necessitate faster placement of restorations. Since the material is closely related to composite resins, the strength properties

are expectedly superior.⁴ However, due to the similar chemistry and mode of application as conventional composite resins, the biocompatibility of this material may be questioned, primarily when used in deep cavities with minimal remaining dentin thickness, or when the pulp is exposed.

Progress in material science has also led to the development of calcium silicate-based cement, which attempt repair and regeneration, in addition to the restoration of lost tooth structure. Biodentine™ (Septodont, Saint Maur des Fosses, France) builds on the therapeutic properties of MTA. It consists of a powder with tricalcium silicate, zirconium oxide, and calcium carbonate and liquid with water, calcium chloride, and a hydrosoluble polymer.⁵ The release of calcium hydroxide from the set material will have the beneficial effects of a liner material while the calcium silicate matrix will act as a rigid structure replacing the dentine in bulk.⁶ Biodentine™ has been shown to perform as well as the RMGIC in open-sandwich restorations.⁷ The physical and chemical properties of Biodentine™ include excellent sealing ability, high compressive strength, short setting time, biocompatibility, bioactivity, and biomineralization. This indicates its use as a dentine substitute under restorations and as a repair material.⁸

Irrespective of their other biological and physicochemical attributes, an overlying veneer of conventional RBC is recommended for all three groups of materials. However, since these classes of materials have widely differing chemical compositions, their bond to the RBC veneer is a subject of interest, as a reliable bond between the overlying RBC and the base material will add to the longevity and reliability of the final laminate restoration.

The aim of this study is to evaluate the shear bond strength (SBS) of microhybrid universal composite resin and nanohybrid flowable composite resin to three different dentin replacement materials. We hypothesize that there is no difference in SBSs achieved between the different types of dentin replacement materials with the composite resin. Further, no difference exists between the SBSs achieved between the two types of composite resin with the dentin replacement material.

MATERIALS AND METHODS

The study was conducted in the Department of Pedodontics and Preventive Dentistry, Manipal College of Dental Sciences, Manipal, Karnataka, in collaboration with the Department of Dental Materials, Manipal College of Dental Sciences, Manipal, Karnataka. The sample size at a 95% confidence level with a power of 80 was estimated as ten samples per group.

Specimen Preparation

An acrylic block measuring 50 mm × 20 mm × 15 mm thickness was prepared using cold cure methyl methacrylate resin and polished with 220, 320, 400, and 600 grit carbide polishing paper. Following this, a central hole 4 mm deep and 6 mm in diameter was drilled into the polished surface of the acrylic block, with grooves added for additional retention (Fig. 1). An impression of this block was taken using silicone elastomeric impression material, which was used as a mold for the fabrication of the acrylic blocks ($n = 60$) to maintain uniformity between all the blocks. The acrylic blocks were then randomly distributed into three groups of 20 blocks each. Group I—RMGIC (Fuji II LCTM), group II—SDR (SDR™), group III—Biodentine (Biodentine™).

Preparation of Samples with RMGIC as the Base Material (Group I)

The material was mixed as per manufacturer's instructions. The central hole of the acrylic block was then filled with GIC and covered with a glass microscope slide to produce a smooth surface and permit light curing. Finger pressure was immediately applied to the specimens for 5 minutes, to compact the GIC mass and minimize surface porosity. Upon removal of the load, the cement was light-cured with a blue LED light-curing unit for 40 seconds. The surface of the RMGIC was then etched with 37% phosphoric acid etchant (Eco-Etch™, Vivadent, Lichtenstein). A single layer of total etching adhesive (Prime and Bond NT, Dentsply Caulk, Milford, Del.) was applied over the surface and light-cured with a blue LED light-curing unit for 20 seconds. The surface was then gently air dried using a dental syringe, following which the overlying layer of RBC was placed after acid etching and placement of bonding agent.

Preparation of Samples with SDR™ as the Base Material (Group II)

The SDR™ compule was loaded onto the compule tip gun supplied by the same manufacturer. The material was then injected into the central hole of the acrylic resin block, covered by a glass microscope slide, and then cured for 40 seconds using the blue LED light-curing unit. Without acid etching or application of a bonding agent, the overlying layer of RBC was immediately placed over the surface.

Preparation of Samples with Biodentine™ as the Base Material (Group III)

Biodentine™ was mixed per manufacturer's instructions. The capsule was opened and placed in the capsule holder provided. Five drops of liquid were poured from the single-dose container into the capsule. The capsule was then closed and placed on a standard amalgamator (Duomat®3) at a speed of 4,000 rotations per minute for 30 seconds. The Biodentine™ was collected with the spatula provided by the manufacturer and placed in the central hole of the acrylic block. To achieve smooth surface, a glass microscope slide was placed over it and gentle finger pressure applied and waited for 12 minutes, which is the setting time according to the manufacturer.

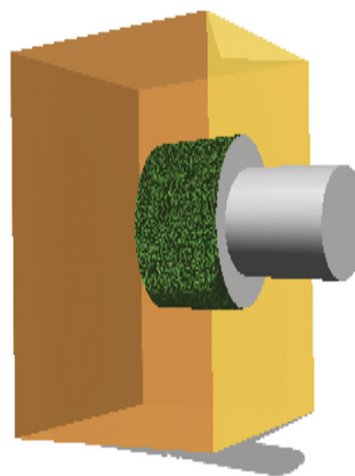


Fig. 1: Representative figure of an acrylic block with 4-mm hole filled with dentin replacement material which is capped with composite resin

In groups I and III, the surface was etched with 37% phosphoric acid etchant (Eco-Etch™, Vivadent, Lichtenstein). A single layer of the total etching adhesive (Prime and Bond NT, Dentsply Caulk, Milford, Del.) was applied over the surface and light-cured with a blue LED light-curing unit for 20 seconds. The surface was then gently air dried using a dental syringe. Following this, placement of the overlying composite resin was done.

Placement of Restorative Material

Samples from all three groups were subsequently randomly divided into two subgroups of 10 specimens each (Flowchart 1). In subgroups IA, IIA, and IIIA, microhybrid composite resin (MCR) (Spectrum™) was placed over the dentin replacement material. In subgroups IB, IIB, and IIIB, nanohybrid composite resin (NCR) (Tetric-N Flow™) was placed over the dentin replacement material. The composite material (MCR and NCR) was applied into a cylindrical-shaped plastic matrix with an internal diameter of 4 mm and a height of 2 mm. This was followed by light curing for 20 seconds with an LED light-curing unit (Fig. 1 and Flowchart 1).

SBS Test: For SBS testing, the specimens were held in a holder placed on a universal testing machine (Instron® 3366), and the measurement was carried out at a crosshead speed of 1.0 mm/minute. SBS in MPa was calculated by dividing the peak load at failure by the specimen surface area ($F/\pi r^2$). The results displayed on the computerized readout were then recorded for statistical analysis (Fig. 2).

The results obtained from the computerized readout connected to the Instron® machine for the various groups of specimens were recorded. Specimens that underwent pretest failures were excluded from the statistical analysis. Statistical analysis was done using SPSS version 18. A *p* value of <0.05 was considered statistically significant. Comparison of mean values was done using independent sample *t*-test, ANOVA with *post hoc* Games–Howell test and *post hoc* Tukey’s test. ANOVA with *post hoc* Games–Howell test was done to determine variation in SBS between the three groups.

RESULTS

Upon considering the mean SBS values among all subgroups, it was seen that values of bond strengths obtained followed the order: IIB (21.18 MPa) > IIA (22.19 MPa) > IB (13.37 MPa) > IA (10.97 MPa) > IIIA

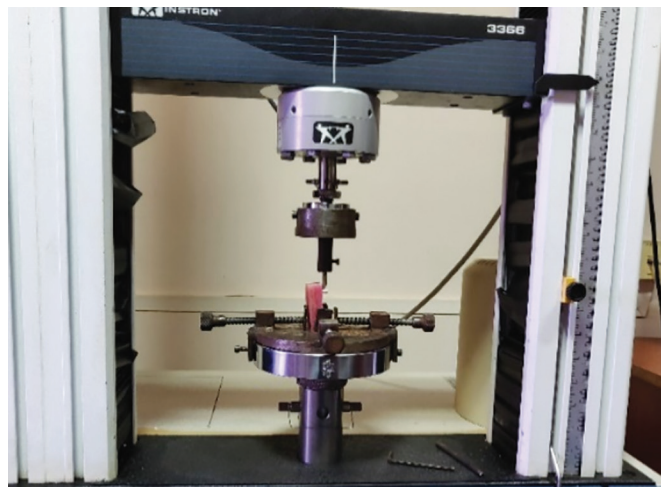


Fig. 2: Shear bond strength testing using Instron machine

(6.80 MPa) > IIB (5.23 MPa). Hence, SDR bonded to NCR showed the highest bond strengths among all the subgroups and Biodentine bonded to NCR showed the least bond strength.

It was seen that SDR attained consistently higher SBS (means: 21.18, 22.19 Mpa) values than RMGIC and Biodentine, with both types of composite resin (MCR and NCR), which was statistically significant ($p < 0.001$). Biodentine showed the least SBS values (means: 6.80, 5.23 MPa) with both types of composite resin, as compared to SDR and RMGIC, which was considered statistically significant ($p < 0.001$). Hence, a trend was seen, whereby SDR showed the highest SBSs with the overlying composite resin, followed by RMGIC, and finally Biodentine, which showed the least bond strength with both types of composite resin (Table 1).

When considering the means of the SBS measurements obtained by the two types of composite resin, no significant difference ($p < 0.05$) was found between them with all three types of dentin replacement materials. NCR attained higher mean bond strengths with both RMGIC and SDR. However, this was not considered statistically significant ($p = 0.191$ and $p = 0.793$, respectively). MCR showed higher SBS values than NCR when bonded to Biodentine. This too was not considered statistically significant ($p = 0.238$) (Table 2).

DISCUSSION

A wide range of different classes of materials has been introduced into the dental armamentarium for the replacement of lost dentin, with each type having its peculiarities concerning chemistry, biocompatibility, ease of placement, and mechanical properties. Three different kinds of such materials examined in this study are: 1. RMGIC, 2. bulk-fill composite resins (SDR™), and 3. calcium silicate-based cement (Biodentine™). Since it is recommended that these materials, when used for the restoration of teeth, be capped by a layer of composite resin as a laminate, the SBS between these materials and two different types of composite resin (nanohybrid flowable vs. microhybrid universal) was investigated in this study.

GIC as a base material has been widely used as a base below RBCs since the introduction of the sandwich technique or the laminate technique by McLean et al.^{9,10} The primary advantages of using GICs have been their excellent biocompatibility, chemical bonding to the tooth structure, and fluoride release. However, the strength properties of this class of materials are insufficient.² An

Flowchart 1: Groups and subgroups of specimens

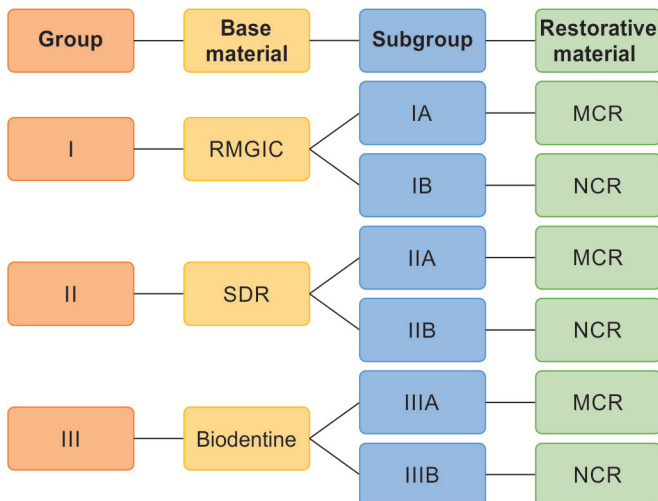


Table 1: Comparison of shear bond strength between the dentin replacement materials and MCR and NCR

| Restorative material | Base | | | | | | p value |
|----------------------|-------|------|-------|-------|------------|------|-------------|
| | RMGIC | | SDR | | Biodentine | | |
| | Mean | SD | Mean | SD | Mean | SD | |
| MCR | 10.97 | 1.61 | 21.18 | 10.60 | 6.80 | 1.95 | <0.001; Sig |
| NCR | 13.37 | 4.54 | 22.19 | 5.43 | 5.23 | 3.57 | <0.001; Sig |

ANOVA with *post hoc* Games–Howell test. MCR, microhybrid composite resin; NCR, nanohybrid composite resin

Table 2: Comparison of shear bond strength of base materials to MCR and NCR

| Base | Restorative material | | | | p value |
|------------|----------------------|-------|-------|------|-----------|
| | MCR | | NCR | | |
| | Mean | SD | Mean | SD | |
| RMGIC | 10.97 | 1.61 | 13.37 | 4.54 | 0.191; NS |
| SDR | 21.18 | 10.60 | 22.19 | 5.43 | 0.793; NS |
| Biodentine | 6.80 | 1.95 | 5.23 | 3.57 | 0.238; NS |

Independent sample *t* test. MCR, microhybrid composite resin; NCR, nanohybrid composite resin

overlay of resin composite is placed over GIC to provide mechanical strength, wear resistance, and esthetics, while the GIC can seal the cavity, reduce microleakage, and provide fluoride release. This technique is especially useful in deep approximal box cavities where radicular dentin is involved and has been advocated widely.^{11–15} Resin monomers were added to the original GIC composition, leading to the development of RMGIC, leading to improved handling characteristics and bonding with RBCs.^{16–19} The problems of weak strength and relative lack of pharmacotherapeutic action on the pulp–dentin complex, however, persist even with this class of materials.

Another recent class of materials introduced in the market is flowable bulk-fill composites (SDR™). SDR™ has been marketed as a dentin replacement material that is characterized by ease of placement, as it can be directly injected into the cavity and cured in 4 mm increments, with minimal polymerization shrinkage. Additionally, altered rheology of this material affords it a self-leveling behavior and better adaptation to cavity walls, which facilitates faster completion of the restorative procedure. Conventional RBCs require a layering technique for restoration, whereby 2 mm increments are cured at a time to offset the adverse effects of polymerization shrinkage. Hence, SDR™ affords the clinician an immense advantage, especially in the pediatric dentistry setting, where behavior management considerations necessitate faster completion of restorative work. However, SDR™, being a resin-based material, is not indicated for use as a direct pulp capping agent.²⁰ Further, the use of this material is still a multistage process whereby the material is placed into the cavity only after the use of an etchant and a bonding system. In a scenario where the remaining dentinal thickness is low, the use of this material without an intervening pulp protective material may be questionable as studies have shown a fairly high degree of monomer elution and incomplete degree of conversion of the monomer after curing.^{21,22} Both the manufacturer’s recommendations, as well as studies, have advocated the use of an overlying composite resin veneer over the surface of SDR due to its low wear resistance and poor esthetics.²³

Two different types of RBCs were used in this study. The packable composite resin (Spectrum™) is composed of microhybrid filler particles, while the flowable composite resin (Tetric N-Flow)

is described as a NCR. Major changes that occur in the evolution of RBCs are related to the change in the size and loading of filler particles. NCRs are a newer kind of RBCs, characterized by reduced viscosity and increased polishability. This study also sought to investigate if there is a difference in bonding characteristics between the two types of RBCs with different substrates.

Macro-shear bond strength test on a universal testing machine (Instron 3366) using a knife-edge shearing force under a crosshead speed of 1 mm/minute was employed in this *in vitro* study. The knife-edge was placed as closely as possible to the bonded interface between the materials, as recommended by numerous authors.^{24,25} According to Salza and Bockb,²⁵ macro-shear bond strength tests may not accurately depict the fracture mechanics due to the uneven distribution of stresses in the specimens tested. However, macro-shear bond test is the most commonly used technique to test bonding,²⁶ used in 26% of scientific papers reporting on bond strength. The popularity of this testing method is a result of its ease and speed, as well as the lack of specimen processing requirements as seen in other approaches. This method was thus chosen for testing the bond strengths, as our goal is to find the bond strengths of various materials, which belong to vastly different categories of restorative materials, relative to each other.

During sample preparation, we followed manufacturer’s instructions as provided in the literature on the packaging. No changes were made regarding the manipulation and mode of application. Further, the layer of laminate RBC was placed either immediately (RMGIC and SDR) or after 12 minutes (Biodentine), as recommended by the manufacturer. This was done to ensure that the set material in the *in vitro* study mimics as closely as possible the clinical scenario, where the clinician follows the manufacturer’s guidelines in the placement of the material. Furthermore, testing of the samples was done after storage in 100% relative humidity for 24 hours. Hence, findings from this study will not accurately reflect the effect of maturation of the set substrate or bonding agent. According to Hashem et al.,²⁷ Biodentine achieved higher bond strength values when testing was delayed. The authors attribute this finding to the maturation process of Biodentine, which may continue for up to 2 weeks after placement. We chose to test the bond strength immediately, as our goal was to evaluate the suitability of various dentin replacement materials to be used as a base below RBCs in a single-stage process, obviating the need for a second appointment for placement of the composite resin veneer.

The total etch (TE) technique, using Prime N Bond® NT™, was used for bonding the composite laminate over both RMGIC and Biodentine. The bonding agent and technique were kept constant for the materials to eliminate the effect of another material variable on the study outcome. One advantage of SDR™ is that there is no need to etch or place a bonding agent before the placement of the overlying composite veneer. Hence, the bonding agent was not applied to the SDR group.

It has been observed that etching alters the structural and chemical composition of Biodentine™, without affecting the microhardness of the material. Etching caused surface modifications on the GIC and to a lesser extent on the RMGIC but with no physical or chemical changes to both materials.⁷ According to the findings of Hashem et al.,²⁷ there is no significant difference in the reliability of bond strength of resin composite to Biodentine™, GIC, and RMGIC when different bonding techniques—self etch (SE) and total etch (TE)—were used using the same bonding agent. They also stated that the similar μ SBS values between SE and TE adhesive modes might be due to the porous nature of the Biodentine™ surface which may have nullified the effect of the differences between SE and TE bonding techniques. Furthermore, the acidity from the bonding techniques may have been buffered by the alkalinity of the Biodentine™, also reducing its effect.

SBS tests performed in this study showed that the difference in bond strengths achieved between the two types of RBCs to the underlying substrate was not statistically significant. Both the flowable NCR, as well as the universal MCR showed bond strengths similar to each other when bonded to the respective dentin replacement materials. Our results show that SBS is similar when either NCR or MCR is bonded to either one of SDR/RMGIC/Biodentine. Hence, the null hypothesis, which states that no difference exists in the SBS of flowable NCR and Universal MCR to the dentin replacement materials, was accepted. This result shows a similar trend to a study by Camile et al.²⁸ who found no significant difference in SBS when either hybrid or microfilled resin composite was bonded to RMGIC. To date, however, it has not been investigated if a difference exists in the bond strength achieved by MCR and NCR to either flowable bulk-fill composite resin or Biodentine.

When SBS values obtained among the various dentin replacement materials to the RBCs were compared, SDR™ attained the highest bond strength values among the three groups. According to Ilie et al.,²³ bulk-fill RBCs are fundamentally similar in their chemical composition to regular nanohybrid and microhybrid RBCs, despite being marketed as a new material class. They contain monomers like Bis-GMA, UDMA, TEGDMA, and EBPDMA in their organic matrix as well as regular filler systems. In SDR, the organic matrix also contains a patent-registered urethane dimethacrylate with incorporated photoactive groups able to control polymerization kinetics (SDR technology = stress-decreasing resin). Hence, the high bond strengths achieved by SDR with the nanohybrid and microhybrid RBCs can be attributed to the presence of monomer groups that ensure a stable and comprehensive chemical bonding between the substrates. It is significant to note that SDR™ attained high bond strengths without the use of a bonding agent. In the clinical situation, this can be immensely helpful and reduce chairside times.

In our study, RMGIC achieved bond strengths that, although lower than SDR, were higher than Biodentine. According to Camile et al.,²⁸ RMGIC attains high bond strengths to resin composite due to the curing process, whereby a light-activated free radical polymerization of methacrylate groups of the polymer and hydroxyethyl methacrylate (HEMA) occurs in addition to an acid/base reaction identical to that of conventional GIC. The presence of a resin component in the composition of RMGIC substantiates the bond strength with composite resin. Etching the surface of RMGIC prior to the application of a bonding agent has been a subject of debate. In our view, acid etching on the smooth surface of the RMGIC affords some degree of

micromechanical bonding in addition to the bond established between the resin components of the RMGIC and RBC.

Several mechanisms are thought to be involved in the chemical adhesive bond between resin-modified glass ionomers and resin composites.²⁹ The presence of unsaturated double bonds in the air-inhibited layer of the RMGIC may contribute toward chemical bonding to the resin bonding agent and resin composite. Unpolymerized HEMA on the surface of RMGIC intensifies the surface wetting capability of the bonding agent, leading to increased bond strength when polymerized. Unsaturated methacrylate groups on the polyacid chain within the polymerized RMGIC may also form covalent bonds with the resin bonding agent. RMGIC also contains modified polyacrylic acids which polymerize to form cross-links that play a part in increasing not only the strength of the set cement but also the degree of bonding to the composite resin. A chemical bond is more stable and less likely to separate than a micromechanical one²⁹ and hence is the preferred mode of bonding for a successful “sandwich” restoration.

The findings of this study imply that Biodentine™ bonds weakly to immediately placed RBC when compared to RMGIC and SDR. This agrees with the findings of Hashem et al.²⁷ who found significantly higher μ SBS of GIC and RMGIC as compared to Biodentine™. During their study, the investigators found higher μ SBS when the Biodentine™ was allowed a period of maturation of the set material before the placement of composite resin. Biodentine™ passes through an initial setting reaction which takes approximately 12 minutes following mixing the powder with the liquid where a hydrated calcium silicate gel structure is formed which has weak physicochemical properties. Surface set is achieved at this stage. There is a continuous maturation of Biodentine™ where crystallization of the calcium silicate hydrate gel structure continues for up to 2 weeks. Bulk set is achieved at this stage with improved physicochemical properties.⁹ Hence, the authors have recommended that the placement of composite resin laminate over the Biodentine should be delayed for 2 weeks. We agree with their recommendation, as the immediate placement of composite resin over the Biodentine showed the weakest bond strengths. The freshly set mass of Biodentine cannot sufficiently withstand the stresses induced due to polymerization shrinkage of the overlying composite resin. This can be one of the limitations of this study.

Hence, the findings from our study show that there is a significant difference between the SBS of SDR, Biodentine, and RMGIC with composite resin. When bonded to either NCR or MCR, a trend was seen where SDR showed the highest early bond strengths, followed by RMGIC and finally by Biodentine. The null hypothesis that no difference exists in the bond strengths attained by the various dentin replacement materials to the overlying RBC was rejected. While the high SBS values attained by SDR may be attributed to the similarity in composition with conventional composite resins, the SBS achieved by RMGIC may be attributed to the presence of resin components, which may facilitate a significant degree of chemical bonding with the composite resin. Future research may be directed at improving the immediate bond strengths achieved by calcium silicate-based materials with composite resin. Although this may be possible through the incorporation of a resin component in the composition to facilitate chemical bonding, the excellent biocompatibility and bioactivity of this class of materials should not be compromised in the process.

CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions were drawn. There is no significant difference in the bond strengths achieved between MCR and NCR to the different dentine replacement materials. Hence, either type of composite resin may be expected to achieve similar bond strengths to the underlying substrate. Biodentine™ does not allow reliable bonding to the overlying composite resin when used in the TE technique, and immediate placement of a composite resin veneer over this material should be avoided. SDR™ is a suitable dentine replacement material for placing below a composite resin veneer as it can achieve immediate higher bond strengths, with fewer steps required for completing the restoration. However, long-term clinical trials are required to assess the efficacy of SDR™ and Biodentine™ as dentine replacement materials.

REFERENCES

- Croll T, Nicholson J. Glass ionomer cements in pediatric dentistry: Review of the literature. *Pediatr Dent* 2002;24(5):423–429.
- Pamir T, Sen BH, Evcin O. Effects of etching and adhesive applications on the bond strength between composite resin and glass-ionomer cements. *J Appl Oral Sci* 2012;20(6):636–642. DOI: 10.1590/s1678-77572012000600008.
- Do Nascimento AB, Fontana UF, Teixeira HM, et al. Biocompatibility of a resin-modified glass-ionomer cement applied as pulp capping in human teeth. *Am J Dent* 2000;13(1):28–34. PMID: 11763899.
- Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an *in vitro* assessment of their mechanical performance. *Oper Dent* 2013;38(6):618–625. DOI: 10.2341/12-395-L.
- Bachoo IK, Seymour D, Brunton P. A biocompatible and bioactive replacement for dentine: is this a reality? The properties and uses of a novel calcium-based cement. *Br Dent J* 2013;214(2):E5. DOI: 10.1038/sj.bdj.2013.57.
- Research and development department Septodont, Biodentine™; Active Biosilicate Technology™. Internal data; scientific file, 2009.
- Camilleri J. Characterization and hydration kinetics of tricalcium silicate cement for use as a dental biomaterial. *Dent Mater* 2011;27:836–844. DOI: 10.1016/j.dental.2011.04.010.
- Koubi S, Elmerini H, Koubi G, et al. Quantitative evaluation by glucose diffusion of microleakage in aged calcium silicate-based open-sandwich restorations. *Int J Dent* 2012;2012:105863. DOI: 10.1155/2012/105863.
- Raju VG, Venumbaka NR, Mungara J, et al. Comparative evaluation of shear bond strength and microleakage of tricalcium silicate-based restorative material and radioopaque posterior glass ionomer restorative cement in primary and permanent teeth: an *in vitro* study. *J Indian Soc Pedod Prev Dent* 2014;32(4):304–310. DOI: 10.4103/0970-4388.140952.
- McLean JW, Powis DR, Prosser HJ, et al. The use of glass-ionomer cements in bonding composite resins to dentine. *Br Dent J* 1985;158(11):410–414. DOI: 10.1038/sj.bdj.4805621.
- Croll TP. Repair of defective Class I composite resin restorations. *Quintessence Int* 1990;21(9):695–698. PMID: 2094873.
- Croll TP. Light-hardened Class I glass-ionomer–resin cement restoration of a permanent molar. *Quintessence Int* 1993;24(2):109–113. PMID: 8511261.
- Leinfelder KF. Changing restorative traditions: the use of bases and liners. *J Am Dent Assoc* 1994;125(1):65–67. DOI: 10.14219/jada.archive.1994.0016.
- Davidson CL. Glass-ionomer bases under posterior composites. *J Esthet Dent* 1994;6(5):223–224. DOI: 10.1111/j.1708-8240.1994.tb00863.x.
- McLean JW. Dentine bonding agents versus glass-ionomer cements. *Quintessence Int* 1996;27(10):659–667. PMID: 9180401.
- Lin CP, Douglas WH, Mitra SB, et al. Fracture toughness of dental cements using the short rod method. *J Dent Res [Abstract #74]* 1992;71(special issue):524. <https://pubmed.ncbi.nlm.nih.gov/12412956/>.
- Mitra SB, Kedrowski BL. Long-term mechanical properties of glass ionomers. *Dent Mater* 1994;10(2):78–82. DOI: 10.1016/0109-5641(94)90044-2.
- Douglas WH, Lin CP. Strength of the new systems. In Hunt PR, editor. *Glass ionomers: the next generation*. [Proceedings of the Second International Symposium on Glass Ionomers.] Philadelphia: International Symposia in Dentistry, PC; 1994. p. 209–216.
- De Souza Costa CA, Aparecida Giro EM, Lopes do Nascimento AB, et al. Short-term evaluation of the pulpo-dentin complex response to a resin-modified glass-ionomer cement and a bonding agent applied in deep cavities. *Dent Mater* 2003;19(8):739–746. DOI: 10.1016/s0109-5641(03)00021-6.
- Garoushi S, Vallittu P, Shinya A, et al. Influence of increment thickness on light transmission, degree of conversion and micro hardness of bulk fill composites. *Odontology* 2016;104(3):291–297. DOI: 10.1007/s10266-015-0227-0.
- Lempel E, Czibulya Z, Kovács B, et al. Degree of conversion and BisGMA, TEGDMA, UDMA elution from flowable bulk fill composites. *Int J Mol Sci* 2016;17(5):732. DOI: 10.3390/ijms17050732.
- Pereira JC, D'Alpino PH, Lopes LG, et al. Evaluation of internal adaptation of class V resin composite restorations using three techniques of polymerization. *J Appl Oral Sci* 2007;15(1):49–54. DOI: 10.1590/s1678-77572007000100011.
- Placido E, Meira JBC, Lima RG, et al. Shear versus micro-shear bond strength test: a finite element stress analysis. *Dent Mater* 2007;23(9):1086–1092. DOI: 10.1016/j.dental.2006.10.002.
- Roeder L, Pereira PNR, Yamamoto T, et al. Spotlight on bond strength testing—unraveling the complexities. *Dent Mater* 2011;27(12):1197–1203. DOI: 10.1016/j.dental.2011.08.396.
- Salza U, Bockb T. Testing adhesion of direct restoratives to dental hard tissue—a review. *J Adhes Dent* 2010;12(5):343–371. DOI: 10.3290/jjad.a19741.
- Burke FJ, Hussain A, Nolan L, et al. Methods used in dentine bonding tests: an analysis of 102 investigations on bond strength. *Eur J Prosthodont Restor Dent* 2008;16(4):158–165. PMID: 19177726.
- Hashem DF, Foxton R, Manoharan A, et al. The physical characteristics of resin composite–calcium silicate interface as part of a layered/laminate adhesive restoration. *Dent Mater* 2014;30(3):343–349. DOI: 10.1016/j.dental.2013.12.010.
- Camile SF. Shear bond strength of chemical and light-cured glass ionomer cements bonded to resin composites. *Aust Dent J* 1998;43(2):81–86. DOI: 10.1111/j.1834-7819.1998.tb06095.x.
- Costa SB, de Oliveira RVD, Viégas Montenegro R, et al. Bond strength evaluation of composite resin bonded to glass ionomer cements after different periods of setting. *Int J Adhes Adhes* 2013;47:146–150. DOI: 10.1016/j.jadhadh.2013.08.010.