Shear Bond Strength Characteristics on Surface Treatment Modalities of CAD-CAM Resin Based Core Materials

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SHEAR BOND STRENGTH CHARACTERESTICS ON SURFACE TREATMENT MODALITIES OF CAD-CAM RESIN BASED CORE MATERIALS

by
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ABSTRACT

SHEAR BOND STRENGTH CHARACTERESTICS ON SURFACE TREATMENT MODALITIES OF CAD-CAM RESIN BASED CORE MATERIALS

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Introduction: Innovations in computer aided design and computer aided manufacture (CAD-CAM) have made the manufacture of new restorative and prosthetic materials possible. They have enabled fabrication of complete arch implant supported fixed dental prosthesis (CAISFDP) in metals and polymers a reality. There are several materials which are available to fabricate a CAISFDP and it is important to find biologically, economically and aesthetically viable options for milled, cast and printed metal and non-metal structures.

Objectives: The purpose of this in-vitro test was to analyze the shear bond strength of composite to Trilor material for CAISFDP restorations.

Material and Methods: A total of 135 CAD- CAM resin composite blocks were cut and obtained from the discs (Trilor 95, Harvest Dental, CA), thickness 10 mm, length 10 mm, width 10 mm. The surfaces were treated with 110 µm Al_2O_3, Rocatec activated with silica-modified alumina oxide treatment (3M, USA), 50µm Al_2O_3, trimmed with a carbide bur, and no treatment. After surface treatment, it was gently cleansed with oil free steam and alcohol wipes. The surface conditioning was performed, and the manufacturer's recommendations were followed for bonding with light cured Visio.link (Bredent). Cylinders of veneering composites (diameter 5 mm, height 4 mm) were polymerized on the Trilor surfaces through a plastic tube. Twenty-seven specimens were used for each testing group and aging test. Thermocycling, shear bond strength and scanning electron microscopic tests were performed. Means and standard deviations were calculated, and statistical analysis was performed with one-way ANOVA and post-hoc tukey tests.

Results: The best shear bond strength was achieved for no surface treatment of Trilor and directly bonded with Visio.link and the least bond strength was found for Trilor surface abraded with 110 µm Al_2O_3.

Conclusions: The results of this study indicated that when Trilor was used along with Visio.link as provided by the manufacturer, it had the best bond-strength. Changing its surface with a carbide bur intra-operatively would not change its bonding characteristic with composite materials.

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CHAPTER I

INTRODUCTION:

Dental implants are considered a predictable procedure for replacement of missing teeth. The effectiveness of rehabilitation of patients with implant supported fixed dental prostheses has been documented for over 40 years(1), and implant-supported fixed detachable complete arch prostheses is one treatment alternative for restoring oral function in edentulous patients.(2) With an increase in life expectancy and the growth in populations aged 65 years and over, these reconstructions have improved a patient's quality of life.(3)

Conventional fabrication of complete arch implant supported fixed dental prosthesis (CAISFDP) includes several laboratory steps, among which is the creation of a pattern resin bar, spruing, investing and casting.(4) These are technique sensitive and are dependent on the technical and laboratory expertise of the clinician, as well as, thelaboratory technician. If done improperly, it could lead to misfit of the prosthesis.(5) Metal-ceramic or all-ceramic restorations on metal frameworks have also been used in prosthetic dentistry for several decades.(6) One of the major disadvantages of the classical workflow is the cost of these reconstructions in terms of economics and labour.

Innovations in computer aided design and computer aided manufacture (CAD-CAM) have made manufacture of new restorative and prosthetic materials possible through additive or subtractive manufacturing. CAD-CAM technologies have eliminated some of the conventional steps and have enabled the production of large frameworks with improved accuracy and less cost.(5, 7-10) In order to improve upon the success of reinforced resin complete arch prostheses and

to minimize technical complications, development of new and innovative polymeric and resin materials is necessary. This would have major relevance to prosthetic dentistry.

Combinations of materials have been used for restorations and typically include a high-strength metal framework veneered with a polymer or ceramic to mask the metal and to allow individual aesthetic design.(11) There are several materials which are available to fabricate a CAISFDPs. It is important to find biologically, economically and aesthetically viable options for milled, cast and printed metal and non-metal structures. CAD-CAM milling machines have commonly been used for manufacturing of dental prostheses. Discs are used for large-size frameworks and may be categorized as dry, wet, or dry and wet mills.(12) Dry milling can be used for the fabrication of partially-sintered zirconia and soft alloys while, hard alloys and titanium (Ti) are processed by wet milling. Today, Ti is the most commonly used millable material for the fabrication of CAISFDPs.(13) Ti may corrode and cause allergy in the oral environment, while complications with esthetics may result because of its color.(13) A frequent complication of zirconia-based restorations on teeth and implants is chipping of veneering ceramic (11, 14-17) and sometimes cannot be solved by ceramic polishing.(18)

Metal-free options for CAD-CAM manufacturing of CAISFDPs have been introduced such as new generations of zirconia and high-performance polymers. It is estimated that one set of CAD-CAM rotary cutting instruments, which are relatively expensive (~$20/bur), could be used to fabricate 5-10 glass-ceramic/ceramic crowns or well over 100 resin-composite crowns.(19) Hence, the cost for milling a CAISFDP from CAD-CAM resin blocks would be much lower than milling a harder material.

The prosthetic material and its capability to transmit stress plays an important role in the survival of ISFDPs following repeated chewing cycles. It also determines the load-bearing capacity of FDPs.(20) Stress generated during function is transferred to implant-framework or implant-bone interfaces, and can lead to mechanical or biological complications.(21) CAISFDPs are subjected to high levels of stress; therefore, material selection becomes much more important with or without a distal cantilever.

Studies regarding CAD-CAM CAISFDPs mainly evaluate passivity of fit (22) or marginal discrepancy.(8, 22-24) New biomaterials and polymers developed for clinical use must follow national and international standards.(25) Risks, which relate to the newly developed biomaterials can be controlled by selecting the first applications to be for short-term of use or the device should be removable in nature.(25) Some of the materials which have been introduced for complete mouth reconstructions are polymers, such as, poly ether ether ketone (PEEK), poly-aryl-ether ketone (PAEK), poly ether aryl ketone (PEAK), poly ether ketone ketone (PEKK), fiber reinforced composites, and resin composites like Trilor and Trinia.

Purpose of the study:

The purpose of this study was to evaluate the bond strength of a veneering composite resin to a milled CAD-CAM resin block of CAISFDP that received different surface treatments.

The null hypothesis was that surface treatment would have no effect on the shear bond strength of a CAD-CAM resin block of Trilor1 to veneering composite resin.

Clinical Significance:

The results of the study contributes to the understanding of the use of CAD-CAM resin substructure frameworks as a prosthodontic material and could assist clinicians with decisions on choosing the surface treatment for optimal clinical outcomes.

CHAPTER II

LITERATURE REVIEW:

HISTORY OF RESIN COMPOSITES:

The first commercial resin-composite for CAD-CAM applications was Paradigm MZ100 (3M ESPE, St. Paul, MN, USA), obtained by the factory polymerization of their successful Z100 direct restorative resin-composite.(19) The factory polymerization resulted in restorations having superior properties to those of Z100 [flexural strength ~130 MPa and fracture toughness ~0.8 MPa·m$^{1/2}$].(26) In vitro studies reported satisfactory fatigue performance of the material.(27, 28) Paradigm MZ100 was replaced by Lava Ultimate (3M ESPE), which was likely polymerized under different temperature and pressure conditions than Paradigm and had slightly improved mechanical properties [flexural strength ~155 MPa and fracture toughness ~0.9 MPa·m$^{1/2}$].(19)

3M ESPE materials have been manufactured by the classic incorporation of filler particles into a monomer mixture. In early 2013, VITA (VITA Zahnfabrik, Bad Säckingen, Germany) introduced Enamic, a resin-composite material obtained by infiltration of a pre-sintered ceramic network by a monomer mixture. Through this process, a higher volume fraction filler was achieved (~70%) and, consequently, superior mechanical properties were obtained compared with those of Lava Ultimate.(19, 29)

Enamic, the resin-infiltrated ceramic network, had properties superior to those of the "classic" resin composite. The determined properties were less affected by storage in water. Ruse et al. conducted polymerization reactions of commercial and experimental direct restorative resin-composites under high pressure (HP, 300 MPa) and high temperature (HT, 180-200°C). It was hypothesized that this process would significantly improve the properties of resin-composites for CAD-CAM applications.(26) The flexural strength of the HP/HT-polymerized materials was over 200 MPa as evaluated in the study and was significantly higher than that of any previously determined values for dental resin-composites and even better than that of some glass-ceramic materials. So, it was indicated that while HP/HT polymerization affected the polymer matrix, it most likely had a significant effect on the filler-matrix interaction as well. The presence of an initiator was considered to be beneficial and that the monomer release was dramatically reduced, often below the detection limit of the high-performance liquid chromatograph used.(30) It should be emphasized, however, that the properties of resin-composite materials, have not surpassed the properties of glass-ceramic/ceramic blocks and that advantages and disadvantages of the available materials have to be considered on a case-by-case basis before decisions are made regarding patient treatment.(19)

RESIN COMPOSITES:

Two main types of materials are currently available for esthetic CAD-CAM processed indirect dental restorations: glass-ceramics/ceramics and resin-composites. Ceramics are defined as crystalline, non-metallic materials, containing metallic and non-metallic elements bonded by ionic and/or covalent bonds, while glasses share the same definition but are amorphous.(31)

Glass-ceramics are composite-type materials in which the glassy phase is the matrix and the ceramic is the reinforcing filler.(32) Resin composites consist of a polymeric matrix reinforced by fillers that could be inorganic (ceramics or glass-ceramics or glasses), organic, or a composite.(33) The properties of glass-ceramics and polymers vary with flexural modulus, flexural strength, hardness of glass-ceramics being greater than those of resin composites.(26, 33) Glass-ceramics/ceramics are strong, stiff, brittle materials, with low fracture toughness (K_{IC}) and high susceptibility to failure in the presence of flaws. The optical properties, for example, translucency, fluorescence, and opalescence of glass-ceramics/ceramics are superior to those of resin-based materials (34, 35), while glass-ceramics/ceramics, depending on their composition, might be adversely affected by the pH of the oral environment and/or of the diet. Water sorption/desorption could lead to degradation of the polymer matrix and/or of the coupling-agent-mediated polymer-filler bond.(36)

The intra-oral repair of resin-composite crowns could be accomplished by preconditioning, by sandblasting, or rotary cutting instrument-roughening, followed by the placement of a resin-composite with similar mechanical and optical properties. Moreover, resin-composite materials may be less susceptible to chipping during the milling procedure.(37)

Fiber reinforced composites (FRC) materials have been successfully used in a variety of direct and indirect dental applications. The use of fiber composite technology in implant prostheses has been previously presented, since they solve many problems associated with metal alloy frameworks such as corrosion, complexity of fabrication and high cost.(38) Superstructures on dental implants commonly consist of a metal-framework veneered with ceramic facings/veneers. In spite of the proven clinical success of these restorations, there has been an increase in the use of metal-free ceramic systems because of their superior esthetics, chemical durability and biocompatibility. (39) A novel alternative to metal–ceramic and complete ceramic restorations in implant-supported FPDs is fiber reinforced composite (FRC) designs which have proven to be successful.(25) The most common engineering composites are composed of strong fibers retained by a matrix.(40) The type of resin matrix and the process used to promote chemical bonding between fibers and resin has shown to be one of the most important factors in the strength of fiber posts.(41) Fiber posts are used in dentistry and factors influencing the intrinsic mechanical properties include: the elastic and flexural moduli, surface treatment of the fibers and their impregnation in resin, bonding between the fibers and the matrix, fiber density, diameter, orientation, position and water absorption by the matrix.(40, 42, 43) The mechanical characteristics and performance of composite resins increases when the bond between the inorganic filler and the organic matrix is optimized. The bond may be improved by applying a layer of silane to the inorganic fibers and by carefully selecting the type of resin matrix and the process used to promote chemical bonding between fibers and resin. The bond between fiber and resin matrix may be one of the most important factors in the strength of fiber posts.(41) Properties of the veneering composite resin influence the bond strength between the core and the veneering resin.(44) Increased viscosity of the adhesive resin may prohibit the material's penetration into the roughened resin surface.(45)

TRILOR®:

The material selected for study was Trilor® (Bioloren®, Saronno, VA, Italy) which consists of a thermo-hardening resin with multi-directional fiberglass reinforcement. It is approved for definitive CAD-CAM prostheses. (46) The mechanical characteristics of Trilor are close to natural dentin as it has an elastic modulus of 26 GPa and it has been proposed as a promising material.(47, 48) Trilor exhibits natural flexure and load parameters making it potentially a suitable replacement for metal and zirconia frameworks. It can create lightweight and resilient frames and substructures for zirconia, lithium disilicate, acrylics and composites.

Trilor has been widely used in endodontics for fabrication of post and cores.(47, 49-52) The multi-directional and woven configuration of the glass fibers enhance the performance in terms of the distribution of loads and tension within the structure. The most critical point of the composite structure is the matrix/fiber interface. Extremely precise and reliable industrial production method of the techno polymer Trilor, has offered a level of adhesion between the fibers of the resinous matrix that amplifies the technological feature according to the manufacturer. The manufacturer also states that Trilor maintains its size; is free from bimetallism; free from metal and zirconia; resists corrosion and oxidation; offers chemical stability; has a compatible coating; binds with esthetic materials; is white ivory in color, camouflage material; esthetic; durable; weighs 3-5 times less than metal and zirconia; made with a technology that minimizes fluid absorption; and exhibits color stability. It is available as Trilor® Arch, Trilor® Block, Trior® Disc, Trilor® Disk Pink and Trilor® Disk Zirkonzahn compatible. The available thicknesses are 3.5, 5.5, and 7.5 mm.

Due to its low translucency and greyish or pearl-white opaque color of resins and polymers, these materials are not suitable for monolithic dental restorations in the esthetic zone and require a resin-composite surface veneer to achieve satisfactory esthetics.(53)

Digital dentistry and advances in CAD-CAM milling technique have resulted in high precision, efficient and accurate workflows that have reduced processing time and decreased the accumulation of errors sometimes observed with conventional fabrication of dental appliances.(54) Trilor Block® and poly ether ether ketone (PEEK) could be an optimal CAD-CAM solution for the manufacturing of metal free interim and definitive prostheses. Its main advantages are durability, elastic property, lightweight, biocompatibility, repairability and it is easy to work with. It is compatible with Cerec/Sirona machines and is indicated for crowns, bridges, pontics and making of structures on implants. The chemical inertness, low surface energy and resistance to surface modification of HPP materials has made it difficult to bond materials to HPP materials, which in part, explains why HPPs are not yet commonly used in restorative and prosthetic dentistry. However, Trilor can be modified chair-side or in the laboratory, making it a versatile option for CAISFDP's.(55, 56) The fiberglass discs have a special weave and epoxy resin that offers high performance. Trilor disc can be used as a substructure under a composite material that provides strength and durability to the overlying wrap-around esthetic supra-structure for complete mouth reconstructions.

MECHANICAL PROPERTIES AND BIOCOMPATABILITY OF TRILOR:

Trilor® exhibits a fracture resistance of 380 MPa; elastic modulus of 26 GPa; compression resistance (perpendicular) up to 530 MPa and impact resistance of 300KJ/cm^2 in Charpy test. Barcol and Shore D hardness values were 70 and 90, respectively. The density of the material is 1.8 g/cm^3. Resistance to fatigue of Trilor after 1.2 million cycles was stable according to the manufacturer. Trilor has been tested for biocompatibility and has received ISO certification. Tests for genotoxicity, carcinogenicity, reproductive toxicity (ISO 10993-3 and cert. Japanese), cytotoxicity test (ISO 10993-11:2006), acute and systemic toxicity (ISO 10993-10:2010), delayed hypersensitivity test (ISO 10993-10:2010) and irritation(ISO 10993-10:2010) have all proved to be negative.(46) Studies have concluded that implants supported with FRC could eliminate excessive stresses at the bone–implant interface and maintain normal physiological loading of the surrounding bone, therefore minimizing the risk of peri-implant bone loss due to stress-shielding.(38)

SURFACE ROUGHNESS:

Surface roughness is an important parameter for adhesive procedures and has been shown to play an important role in adhesion of veneering composite to metal surfaces, resin and zirconia.(47, 57-59) Therefore, various surface mechanical and chemical pretreatments have been used to increase microroughness and bonding area of the material.(60) Mechanical treatments include airborne-particle (silica or aluminum oxide) abrasion (APA), laser and plasma applications, and grinding with a rotary cutting instrument. Chemical treatments include etching with sulphuric acid and piranha solution, as well as, the application of adhesive primers, such as Visio.link (Bredent, Senden, GE) and Signum PEEK Bond® (Heraeus Kulzer, Hanau, GE).(53)

APA is considered the easiest method for surface treatment of a restoration.(55) It increases the surface roughness, creates a fresh and active surface layer by removing organic contaminants from the material surface and advances micromechanical interlocking of polymer-based dental materials.(44, 55, 56, 61) Previous studies have shown that APA can change the resin composite surface morphology, helping the luting cement penetrate into the composite material to enhance micro-mechanical interlocks and ultimately increasing bond strength.(62) In dentistry, APA has been widely applied for implant surface treatment; porcelain fused to metal restorations and orthodontic bracket. In the bonding process, sufficient surface roughness of polymer resins should be produced in order to obtain sufficient mechanical retention.(55) Trilor is considered a high-strength resin material and its high hardness and strength could possibly limit the expected beneficial effects produced by surface roughening methods. In this study, 5 different surface pre-treatment methods were applied to analyze the bond strength of the CAD-CAM resin composite material. Per the manufacturer, acid etching was not a suggested surface pre-treatment method.

The chemical mechanism of adhesion and successful bonding is known to be a complex phenomenon that depends on many parameters and the interaction of chemical, physical, and mechanical effects can be influenced in unexpected ways by changing only one parameter during the bonding process. Visio.link (Bredent) was chosen as the adhesive system in this study per manufacturer recommendations. Investigations have indicated that the adhesive system Pekk Bond (Anaxdent) resulted in a significant higher bond strength when the CAD-CAM polymer surface was airborne particle-abraded with higher pressure (0.4 MPa).(62) The recommended sandblasting pressure is 0.1–0.2 MPa, which is lower than the pressure commonly recommended for ceramic and metal restorations.(63) Such reduced pressure is desired because composite CAD–CAM blocks have a lower Vickers hardness than glasses or glass-ceramics.(64)

Visio.link adhesive system resulted in the highest bond strength irrespective of the air-abrasion pressure when it was applied as recommended by the manufacturer.(53)

Since Visio.link has been the most frequently investigated adhesive system on resin polymers, resulting in the highest bond strength,(45, 53, 61, 65-67) it was selected as an adhesive in this study. The effectiveness of Visio.link is based on the chemical composition of the photo-initiator (diphenyl 2,4,6, -trimethylbenzoyl phosphine oxide) which requires a certain wavelength to polymerize successfully. The photo-initiator, acrylphosphinoxide is used for dental materials and shows the corresponding absorption maximum at a wavelength of 380 nm. The results and technical details show this certain range of wavelength is only provided by the halogen LCUs but not by LED-LCUs. Alternatively, to acrylphosphinoxide, camphor quinone is another well-established photo-initiator often used in dentistry. Compared to acrylphosphinoxide, camphor quinone shows the absorption maximum at higher wavelengths (468 nm). This range of wavelength in turn is provided by LED-LCUs but also by HAL-LCUs and shows that HAL-LCUs provided a wider range of wavelength and thus are applicable for curing different photo-initiator systems successfully.(62) The chemical composition of the adhesive system has an influence on the chemical bond between the polymer matrix and veneering composite resins.(45, 53) Without using an adhesive system, minimal or a small bond strength can be achieved between the polymers.(53, 67)

SHEAR BOND STRENGTH:

The bond strength between the core and the veneering resin interface has been reported to be influenced by viscosity, filler content of the veneering resin and chemical composition of the adhesive material used.(53, 61) Surface pre-treatment is essential for increasing the bond strength between both of the interfaces mentioned above.(45, 61) Surface modifications by silicoating mainly focused on Zr_2O_3 and metal-based materials.

Several studies have investigated the effect of silicoating on polymer-based materials.(68) The results indicated that silicoating on a polymer-based surface had similar surface roughness values as compared to the untreated high-performance polymer; however, the wettability was considerably increased in silicoated specimens. A marginal increase was seen in silicoated surfaces when shear bond strength was evaluated. This could indicate a possible physical and chemical change in the material.(69)

THERMOCYCLING:

Thermocycling has been reported to be appropriate to simulate oral conditions.(70) Because its effect is standardized and reproducible, thermocycling is a recommended method for in vitro artificial aging of specimens prior to a test of bonding properties.(61) Studies that evaluated bond strength without thermocycling may only report limited information.(61, 70) This study attempted to simulate the oral environment by thermocycling the specimens.

CHAPTER III

MATERIALS AND METHODS:

G*Power 3.1 (University of Düsseldorf, Germany) was used to calculate the required sample size. A total sample size of 135 specimens, 27 samples per group, was determined to be sufficient to detect an effect size of 0.4 with 80% power at a 5% significance level.

A total of 135 CAD-CAM resin blocks (Trilor95, Harvest Dental, CA) discs were cut in a cutting machine in the following dimensions: thickness 5.5 mm, length 10 mm, width 10 mm. The surfaces were untreated, air-abraded with Al_2O_3 50µm, Al_2O_3 110µm, activated with silica-modified alumina oxide treatment (Rocatec soft 30 µm, 3M ESPE, USA) and cut with carbide rotary cutting instruments. They were steam-cleaned and wiped with alcohol wipes to remove any oil contamination and sandblasted at 0.2 MPa. The group roughened with rotary cutting instruments were modified slightly on the bonding surface with a carbide rotarty cutting instrument in the laboratory. After surface treatment, surface conditioning was performed, and the manufacturer's recommendations were followed for bonding with light cured Visio.link (Bredent). Cylinders of veneering composites (Anaxdent, GC America) with diameter 5 mm, height 2 mm were photo polymerized on the Trilor surfaces through a plastic tube from 2 opposite directions for 40 seconds each (UniXS, Heraeus Kulzer) totaling to a final curing time of 80 sec.

Twenty-five specimens were used for each testing group and aging test. For investigating the influence of storage and aging, all other specimens were thermocycled (Sabri Dental Research Instruments Co., Downers Grove, IL, USA)12,000 times in distilled water alternating between 5 and 55 °C. The holding time of each bath was 2 min with a transport time of 5 seconds. Tests were performed consecutively after thermocycling and 24 hours of storage at 37°C to mimic intraoral temperature. Shear bond strength (SBS) was determined following ISO TR 11405:2015. Specimens were fixed in a universal testing machine (Model 5500R, Instron Corp., Norwood, MA, USA) that allowed the loading die to strike the composite cylinder with a distance of 0.1 mm between the chisel and the Trilor block with the cured composite cylinder. This technique was used for avoiding cantilever effects on the adhesive surface. The crosshead speed was 1 mm min^{-1} (Zwick 1446; Zwick, Ulm, G). Means and standard deviations were calculated, and statistical analysis was performed with one-way ANOVA/Bonferroni ($\alpha = 0.05$) and post-hoc tukey test.

CHAPTER IV

RESULTS:

Please refer to Appendix A for these tables:

Table 1: Raw values obtained for specimens which had no treatment and bonded to Visio.link.

Table 2: Raw values obtained for specimens which had APA with 110 µm Al_2O_3 and Visio.link.

Table 3: Raw values obtained for specimens which had APA with 50 µm Al_2O_3 and Visio.link.

Table 4: Raw values obtained for specimens which had APA with Rocatec soft and Visio.link.

Table 5: Raw values obtained for specimens which had abrasion with carbide rotary cutting instrument and Visio.link.

Table 6: Total number of specimens under each sub- group which underwent analysis.

Table 7: Descriptive statistics.

Table 8: Means and standard deviations obtained for each subset which was checked.

Surface Treatment	Mean	Std. Deviation	N
110 µm	117.03	97.75	24
50 µm	149.34	66.37	24
None	270.47	65.27	25
Rocatec	122.48	92.32	25
Trimmed with bur	182.72	52.22	27
Total	169.20	93.73	125

Some specimens underwent spontaneous debonding during thermocycling. Upon analysis, it was found that while the composite was delivered into the plastic PTFE tube, there was an air-bubble entrapment which could have led to the weak bond between the Trilor-Visio.link-composite interface.

The total number of specimens tested and the means and standard deviations for the SBS is given in Table 8 for each group. The highest SBS value was found for the specimens which did not receive APA but were directly bonded with Visio.link and the lowest mean SBS value was found to be with APA using 10 µm Al_2O_3.

Scanning electron microscopic images of fracture surfaces at 400X were obtained. Images represent different pre-treatment methods, Visio.link application and the site of fracture after the shear bond strength test was conducted in a universal testing machine. Figure 1a represents surface after pre-treatment with 50 µm Al_2O_3, which demonstrated irregular porosities of the specimens. Figure 1b represents surface pre-treatment with 110 µm Al_2O_3 which showed circular porosities of the specimens. Figure 1c represents no surface pre-treatment which possessed a roughened and rectangular patterns of irregularities. Figure 1d shows pre-treatment with Rocatec aluminum oxide particles and silane application. Figure 1e shows pre-treatment with a carbide rotary cutting instrument.

Figure 1a: Surface after pre-treatment with 50 µm Al_2O_3, depicting irregular porosities of the specimens, Visio.link application and the site of fracture after the shear bond strength test was conducted.

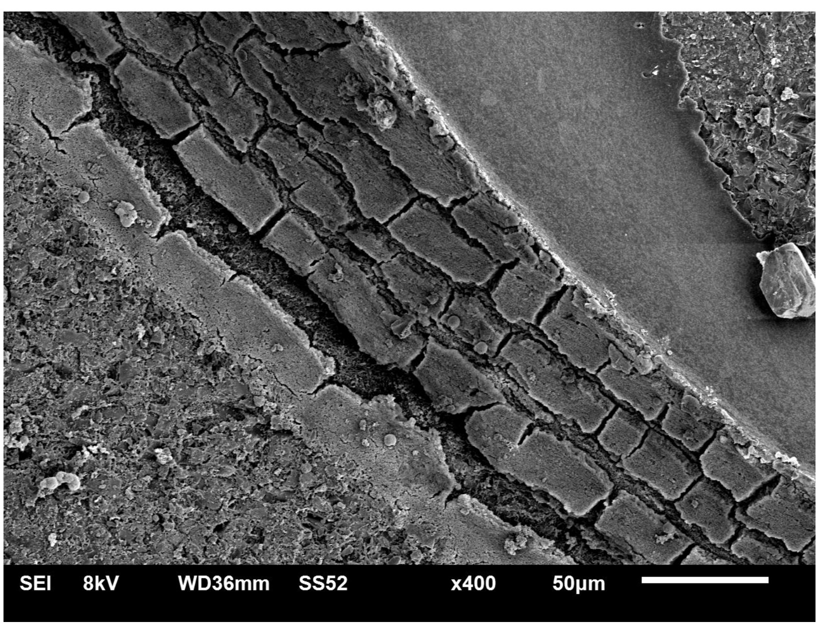

Figure 1b depicts surface pre-treatment with 110 µm Al_2O_3 showing circular porosities of the specimens Visio.link application and the site of fracture after the shear bond strength test was conducted.

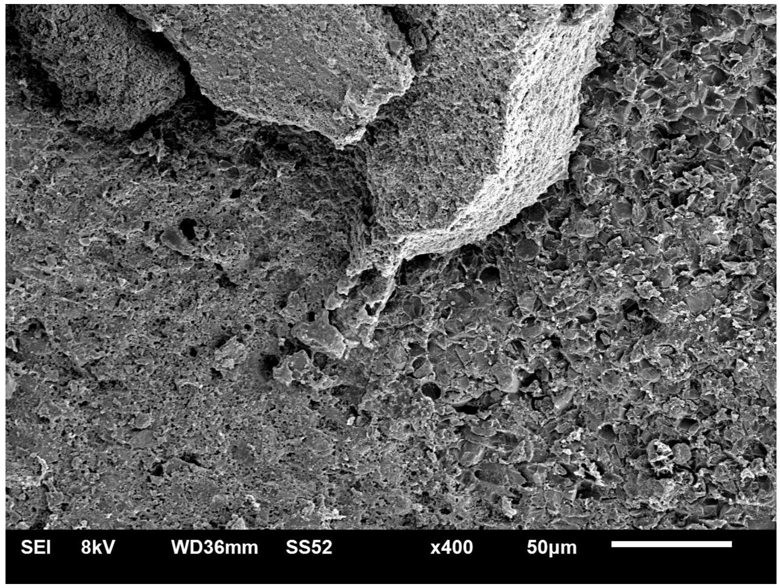

Figure 1c depicts no surface pre-treatment which showed rough rectangular patterns of irregularities Visio.link application and the site of fracture after the shear bond strength test was conducted.

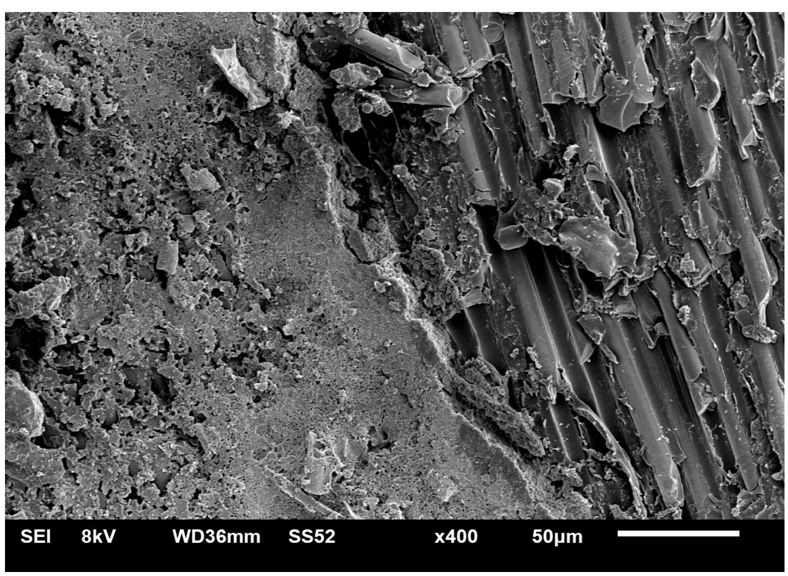

Figure 1d shows pre-treatment with Rocatec aluminum oxide particles and Silane application; Visio.link application and the site of fracture after the shear bond strength test was conducted.

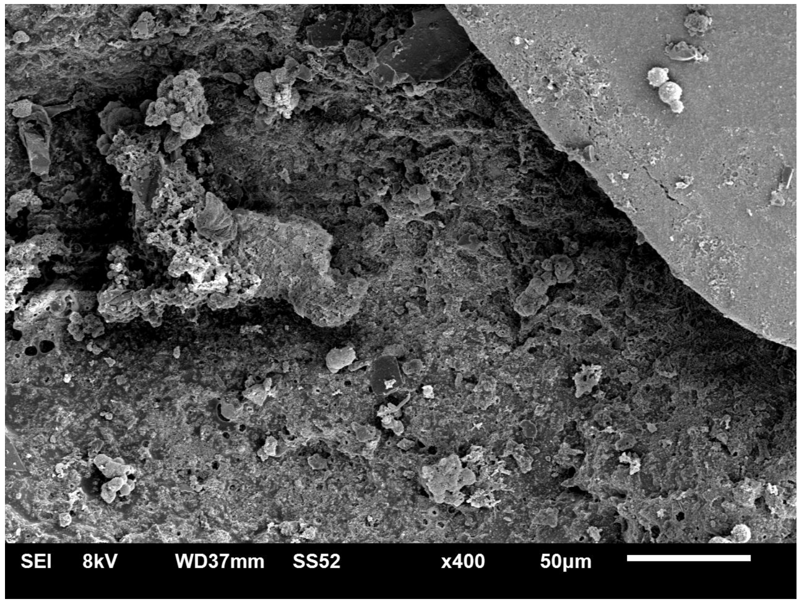

Figure 1e shows pre-treatment with a carbide rotary cutting instrument, Visio.link application and the site of fracture after the shear bond strength test was conducted.

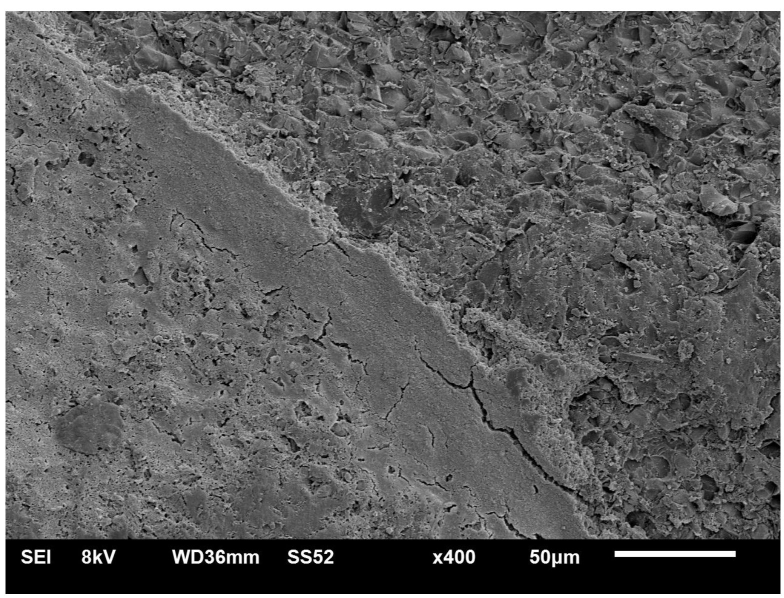

Table 9: Post Hoc Tests: Post Hoc, Homogenous subsets

		Subsets:		
Surface Treatment	N	1	2	3
110 µm	24	117.03[a]		
Rocatec	25	122.48[a]		
50 µm	24	149.34[a,b]	149.34[a,b]	
Trimmed with rotary cutting instrument	27		182.72[b]	
None	25			270.48[c]

a. Used harmonic mean sample size = 24.95
b. The group sizes were unequal. The harmonic mean of the group sizes was used. Type I error levels were not guaranteed.
c. Alpha= .05.

Means for groups in homogenous subsets are displayed. Based on observed means, the error term is mean square (error)= 5832.95. Specific differences between the sub-groups were conducted as the analysis (ANOVA) was found to be significant at p value of less than 0.05 significance level (Alpha = .05.) Through results obtained after the post-hoc tukey analysis, there were 4 subsets of results as follows:

The different letters represent subsets of significant differences among the SBS values obtained for different surface pre-treatment protocols. Subset with [a] belonged to the group which had similar bond strength measurements, i.e. 110 µm, 50 µm and Rocatec which were not significantly different from each other. They had different values individually, but their means were found to be under a similar subset of mean bond strength. 50 µm and trimming with a rotary cutting instrument fell into similar subset as well, although the values obtained were different from each other- subset [a, b.] Subset [b] was the group with next highest bond strength and subset [c] with the highest bond strength values obtained in this study.

The analysis revealed that Trilor blocks could be used without any surface modifications done to them. However, in the clinical situation the blocks would require trimming. The surface of the polymer blocks must be modified so that it conforms to the contours in the oral environment and to support a fixed dental prosthesis. This would be accomplished with help of a carbide rotary cutting instrument in a laboratory or clinical setting. Following no treatment, the results found that the next highest bond strength would be achieved when the blocks were trimmed with a carbide rotary cutting instrument. From the results of the study, when Trilor is used as a substructure material and requires recontouring, it could be trimmed with rotary cutting instrument only and without having to undergo a separate APA to increase bond strength of veneering composite. The results of post-hoc Tukey analysis confirmed that subset [c], the bond-strength achieved after bonding with Visio.link resulted in higher values than the other APA methods utilized. However, it would be interesting to determine the results of APA after trimming the blocks with a carbide rotary cutting instrument.

CHAPTER V:

DISCUSSION:

In the present study, the null hypothesis was rejected because surface treatment did influence the shear bond strength of composite resin to Trilor. It was found that surface treatment with particulate aluminum oxide would not be required to increase the bond strength of composite to Trilor.

The data could be divided into 3 sub-sets. A similarity of bond-strength values was observed for the 50 µm, 110 µm and Rocatec specimens (149.34;117.03;122.48 respectively). The second subset which achieved similar values were Rocatec and those trimmed with carbide rotary cutting instrument (122.48; 149.34 respectively). The greatest values were found for un-altered Trilor, directly cleaned and bonded with Visio.link (270.48). This outcome was unexpected and suggested higher confidence in using un-altered Trilor for bonding with Visio.link when compared to 50 µm or 110 µm alumina.

In routine dental practice, APA is a common procedure to clean and increase the surface energy of the internal side of ceramic and metal crown restorations, with intention to improve bonding retentiveness. (63) APA has been shown to improve bond strength by exposing a fresh surface, free of contaminants, and by providing enhanced micro-mechanical retention of the cement at the roughened surface. Compared with dental composite intended for direct intra-oral use, the mechanical properties of composite CAD–CAM blocks are significantly better because these blocks can be industrially polymerized at higher temperature and pressure.(19)

Composite blocks are highly polymerized and there is a necessity to adequately pre-treat the block surface for bonding purposes(63). Differences in filler-matrix configuration/composition among the composite CAD–CAM blocks must also be expressed in different mechanical properties for these blocks. In previous tests, surface treatments have been suggested to improve retention of FRC posts and composite resins for direct and indirect restorations. APA using Al_2O_3 particles (71), etching treatment with organic solvent using dichloromethane, etching treatment with acid solution using hydrogen fluoride, silane coupling treatment, plasma treatment, and ultraviolet light (UV) irradiation treatment are known to increase surface microroughness and to create mechanical interlockings at the cement interface. The surface treatments increase the bond strength by exposing a fresh surface, free of contaminants as well. Silane coupling treatment is possible to establish chemical bonding between fiberglass surfaces of FRC post and core build-up materials in direct dental restorations.

Plasma and ultraviolet treatments have a surface cleaning effect, due to removal of organic contamination, and change in the molecular structure of the surface area. (72, 73) The surfaces of commercial FRC direct restorations are grooved or primed making it difficult to characterize the simple effect of surface treatments on bonding. A smooth surface of FRC restoration without priming could be desirable to elucidate effects of surface treatments on the bonding of FRC.(71)

CAD-CAM blocks have been used to fabricate semi-direct and indirect restorations. Semi-direct restorations can be processed by CAD-CAM by the dentist or the laboratory technician (in milling centers) as part of indirect restorations. Complete arch implant supported restorations having a substructure made from CAD-CAM resin discs would be considered under this category. In some studies, APA has also caused damage to composite the CAD-CAM block surface and similar to the effects on bond strength obtained in this in-vitro study. The effect of APA composite block surfaces has not been thoroughly investigated (63). However, 5 different CAD-CAM blocks were studied through structural and chemical composition using X-ray diffraction (XRD), energy dispersion spectroscopy (EDS), scanning electron microscopy (SEM) and scanning transmission electron microscopy (STEM). It was found that results varied with APA and the damage produced on the composite CAD-CAM block surface. For the Shofu Block HC composite CAD-CAM block, the damage was so severe that silanization did not improve bond strength. In addition, it produced surface and sub-surface cracks. Furthermore, the matrix resins of several commercial FRC are thermosetting polymers which are not easily etched with organic solvents. (71) As a result, effects of surface treatment were considered to vary due to the components of FRC direct and indirect restorations. Different filler configurations are said to be responsible for observed differences in the shear bond strengths of different composite CAD–CAM blocks investigated.

In the current study, a few specimens from each of the groups spontaneously debonded prior to testing and could not be considered in evaluation of the shear bond-strength. Premature failure was probably due to the entrapment of an air bubble in the specimen while filling the plastic tube. All the specimens, which were not considered in the study, had a macroscopic air bubble present at the junction of veneering composite and CAD-CAM resin block.

The study design attempted to simulate clinical/laboratory conditions where the clinician would have to contour the disc with a carbide rotary cutting instrument to anatomically define the receptive surface for veneering composite. Future possibilities include testing specimens which are trimmed with carbide rotary cutting instruments to conform to the anatomy of the ISFDP substructure and then later are surface roughened with APA.

There are many reports that have investigated the influence of HPP and veneering composites. However, to the investigator’s knowledge, there are no reported studies that have evaluated the effect of surface treatment on Trilor and Trinia CAD-CAM resin composite discs. This study is the first of its kind, and could make it easier for clinicians to select resin composite materials as a framework material for CAISFDP.

CHAPTER VI

CONCLUSIONS:

Within the limitations of this study of 5 different surface treatments, the following conclusions were drawn:

1) The bond strength of veneering composite to CAD-CAM resin polymer system was affected by presence or absence of surface treatment.
2) The shear bond strength of untreated Trilor with veneering composite, with Visio.link as the bonding agent was significantly greater when compared to airborne particle abrasion.
3) Insignificant bond strength differences were observed between 50 µm, 110 µm Al_2O_3 and Rocatec treated specimens.
4) The greatest bond strength was observed with untreated Trilor specimens bonded with Visio.link followed by surface roughening with carbide rotary cutting instruments.
5) Using Trilor as substructure framework can be clinically acceptable when bonded to composite.

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APPENDIX A:

Table 1. Values obtained for specimens which had no treatment and bonded to Visio.link.

A1	259.71
A2	271.29
A3	313.83
A4	263.42
A5	201.85
A6	217.81
A7	192.73
A8	329.46
A9	363.99
A10	226.78
A11	341.05
A12	178.71
A13	199.68
A14	334.66
A15	395.88
A16	195.18
A17	260.6
A18	192.87
A19	270.46
A20	313.36

A21	290.19
A22	226.98
A23	324.77
A24	381.69
A25	214.99

Table 2. Values obtained for specimens which had APA with 110 μm Al_2O_3 and Visio.link.

B1	128.46
B2	26.5
B3	34.42
B4	112.99
B5	30.6
B6	37.47
B7	135.67
B8	15.87
B9	46.67
B10	139.36
B11	19.57
B12	51.05
B13	86.76
B14	189.24
B15	299.39
B16	286.82
B17	313.84
B18	136.86
B19	139.39
B20	15.98
B21	12.65

B22	95.1
B23	287.46
B24	166.62

Table 3. Values obtained for specimens which had APA with 50 μm Al_2O_3 and Visio.link.

C1	164.77
C2	218.01
C3	224.53
C4	114.37
C5	177.9
C6	126.92
C7	130.32
C8	228.6
C9	293.64
C10	157.39
C11	33.94
C12	26.92
C13	234.39
C14	123.11
C15	110.44
C16	205.55
C17	195.76
C18	81.6
C19	77.8
C20	123.9
C21	171.31

C22	67.24
C23	151.32
C24	144.49

Table 4. Values obtained for specimens which had APA with Rocatec plus and Visio.link.

D1	15.09
D2	223.3
D3	16.67
D4	193.8
D5	259.7
D6	155.34
D7	159.82
D8	19.09
D9	230.58
D10	65.64
D11	18.05
D12	169.43
D13	47.13
D14	17.46
D15	275.83
D16	77.8
D17	95.944
D18	267.13
D19	32.64
D20	45.85
D21	47.27

D22	48.56
D23	234.36
D24	167.18
D25	178.45

Table 5. Values obtained for specimens which had abrasion with carbide rotary cutting instrument and Visio.link.

E1	191.06
E2	229.62
E3	178.37
E4	117.01
E5	200.31
E6	179.26
E7	162.49
E8	203.97
E9	186.53
E10	152.86
E11	156.19
E12	217.11
E13	171.7
E14	228.15
E15	194.06
E16	218.08
E17	162.03
E18	118.35
E19	236.27
E20	136.02
E21	216.84

E22	51.29
E23	198.98
E24	156.09
E25	145.98
E26	345.17
E27	179.72

Table 6. Between-Subjects Factors.

		N
SurfaceTx	110um	24
	50um	24
	None	25
	Rocatec	25
Trimmed with bur		27

Table 7. Profile Plots.

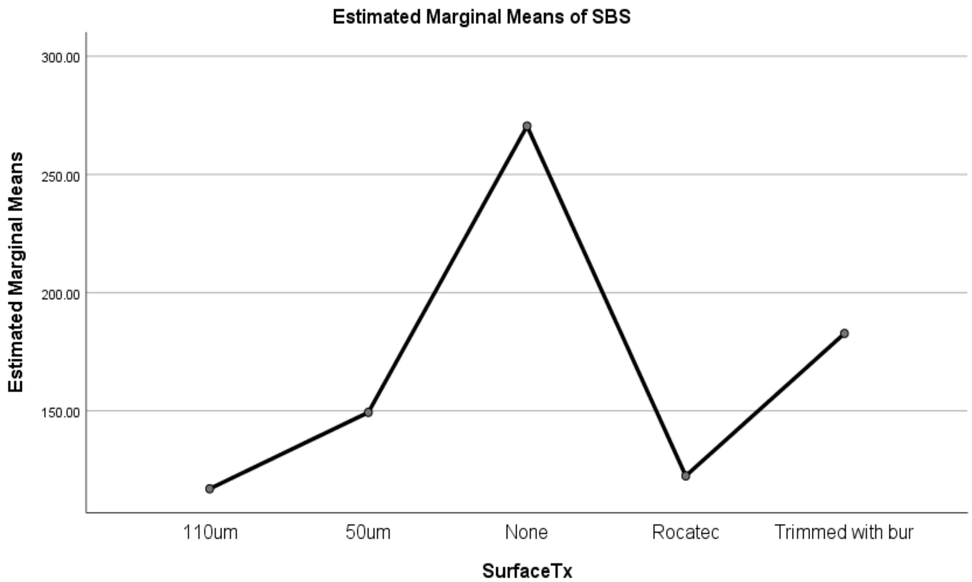

Table 8. Tests of Between-Subject Effects.

Dependent Variable: SBS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	390707.33[a]	4	97676.84	16.77	.000
Intercept	3538754.50	1	3538754.50	607.62	.000
SurfaceTx	390707.33	4	97676.83	16.77	.000
Error	698874.56	120	5823.95		
Total	4668337.87	125			
Corrected Total	1089581.90	124			

a. R Squared = .359 (Adjusted R Squared = .337)

Table 9: Post Hoc Tests: Post Hoc, Homogenous subsets

		Subsets:		
Surface Treatment	N	1	2	3
110 µm	24	117.03[a]		
Rocatec	25	122.48[a]		
50 µm	24	149.34[a,b]	149.34[a,b]	
Trimmed with rotary cutting instrument	27		182.72[b]	
None	25			270.48[c]