

An In vitro Evaluation of Flexural Bond Strength of Indirect Composites Fused to Metal

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Abstract With the advent of newer indirect composite resin materials for crown and bridge prosthesis, it has become imperative to evaluate their strength to serve as long term replacements as a substitute to metal ceramic restorations. This study aimed to evaluate and compare the flexural bond strength of three composite resin veneering material to metal, cured by different methods. Specimen were fabricated with pattern resin by duplicating it with machined metal die and divided into three groups. Three composite resin materials were used in this study. Group (A) received Adoro, Group (B) received Targis and Group (C) received Tescera. The bond strength of all specimens was tested with Lloyd's universal testing machine under three point loading. The highest values for fracture resistance were displayed by light, heat and pressure cured composites followed by composites cured using a temperature of 104 °C and composites with curing temperature of 95 °C. The results indicate that there is a significant difference between the three groups, with the Tescera group specimens exhibiting the highest flexural bond strength. Of the other two groups, Adoro group exhibited higher flexural bond strength than Targis group. The results of this study suggest that Tescera group with curing temperature of 130 °C and pressure of 80 Psi, cured with metal halide unit exhibited the highest flexural bond strength when compared to Adoro and Targis groups.

Keywords Flexural bond strength · Indirect composites · Crown and bridge

Introduction

Composite resin veneered crowns have generated interest as an alternative to metal-ceramic restorations due to their ease of fabrication and economical considerations. To overcome the disadvantages encountered with composites such as fluid leakage at the metal resin interface, discoloration, poor wear resistance and poor bond strength, several composite resin-metal bonding systems have been developed to enhance the bonding capacity of composite resin veneers to metal, to enable their use as anterior and posterior restorations similar to a metal-ceramic restoration [1]. These systems may require surface preparation (heating, tinplating, ion coating, and silicoating), micro mechanical retention (sandblasting and chemical or electrolytic etching), macro mechanical retention (incorporation of metal beads, mesh, pitted metal), chemical bonding using primers (silane coupling agents) and the use of opaque resins that promotes adhesion and facilitates bonding [2–4].

Laboratory processed composite materials vary in the type, amount and particle size of fillers incorporated in them, the primers used, techniques to improve retention and bonding, the method of polymerisation (heat, light and pressure) and the curing units employed according to the manufacturer. The clinical application of composite veneered metal crowns requires a strong and a stable resin bond to metal. A stable bond to the metal is also advantageous for other clinical applications. Flexural bond strength is an important property with respect to resistance to deformation or fracture of the restoration by occlusal loads as well as maintenance of the marginal seal [5].

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The aim of this study was to evaluate and compare the flexural bond strength of three commercially available composite resin systems bonded to metal using different curing techniques.

Materials and Methods

Three different veneering composites were used in this study: SR Adoro (Ivoclar vivadent), Targis (Ivoclar vivadent), Tescera (Bisco) and were named as Group A, Group B, Group C respectively. Thirty samples were fabricated and ten samples were used for each group.

Fabrication of Metal Framework

A standardized metal die was machined for duplicating the wax patterns for fabrication of study samples to a uniform size. The base of the die was 75 mm in length and 45 mm in width. This area within the die was divided into five sections of equal dimensions using four removable brass bars of 5 mm height, 5 mm width and 40 mm length. Each section in between the brass bars contained three raised platforms separated by two troughs. The floor of these troughs were placed at a height of 2 mm from the base of the die. The central raised platform was at a height of 3.5 mm from the base of the die, while the outer two raised platforms were at a height of 5 mm from the base of the die. The wall of the trough formed by the central raised platform was 1.5 mm in height, while the wall formed by the outer raised platform and the brass bar was 3 mm in height.

Wax Pattern, Investing, Burnout and Casting Procedures

With the horizontal bars in place, wax patterns were fabricated using pattern resin (GC Fuji, Japan). The resin patterns were made in the second, third and fourth chambers of the machined die, the first and fifth chambers were not used as they lacked lateral walls for fabrication of the

wax patterns. They served the purpose of stabilizing the adjacent horizontal bars. Pressure was applied using a flat surface made out of metal. The patterns were then retrieved from the chambers, checked for accuracy, trimmed and polished. Thickness at the centre was measured using an Ivanson Wax Caliper (Hu-Friedy, U.S.A). Thirty patterns were fabricated in a similar manner and ten patterns were used for each sample. The samples were grouped as A, B and C (Table 1). In Group A, retention beads were attached to the wax patterns using SR retention adhesive (Ivoclar Vivadent, Switzerland) and allowed to dry for 20 s as recommended by the manufacturer and in Groups B and C, retention beads were not used. The patterns were invested, burnt out and cast.

Preparation of Metal Specimens for Bonding to the Composites

Group A cast specimens with retention beads (Fig. 1a) and Group B (Fig. 1b) and Group C (Fig. 1c) cast specimens without retention beads were prepared according to metal resin bonding technique and all samples were sandblasted with type 100 μm (Bego) aluminium oxide at two bar pressure. Metal primer (SR Link, Targis Link, Aeliltefil) was applied and allowed to react for 3 minutes after which laboratory composite was applied (Fig. 2) and all samples were cured as recommended by the manufacturer. Among the three groups, Group A received SR Adoro (Ivoclar Vivadent, Liechtenstein), Group B received Targis (Ivoclar Vivadent, Liechtenstein) and Group C received Tescera (Bisco, U.S.A).

Veneering the Metal Specimens

In Group A specimens, two opaque layers were applied and cured for 20 s with a quick light curing unit and then polymerised directly in the Lumamat 100 or Targis power upgrade furnace (Ivoclar Vivadent, Liechtenstein) at 104 °C for 11 min. The dentin layer was added and again cured for 20 s. A gel (SR Gel, Ivoclar Vivadent, Liechtenstein) was added onto the entire veneering surface to

Table 1 Description of materials used for the three groups

	Group A	Group B	Group C
Product	SR Adoro	Targis	Tescera
Company	Ivoclar Vivadent	Ivoclar vivadent	Bisco
Composition	Dimethacrylate, Copolymer and Silicon Dioxide	BIS-GMA, decandiol dimethacrylate, triethylene glycol dimethacrylate, catalysts, stabilizers and pigments	Ethoxylated bisphenol A dimethacrylate, bisphenol A diglycidyl methacrylate, amorphous silica
Primer	SR Link	Targis link	Aelitefil
Opaque	Adoro	Targis	Tescera
Fillers	Inorganic	Sialinized barium glass	Reinforced microfill

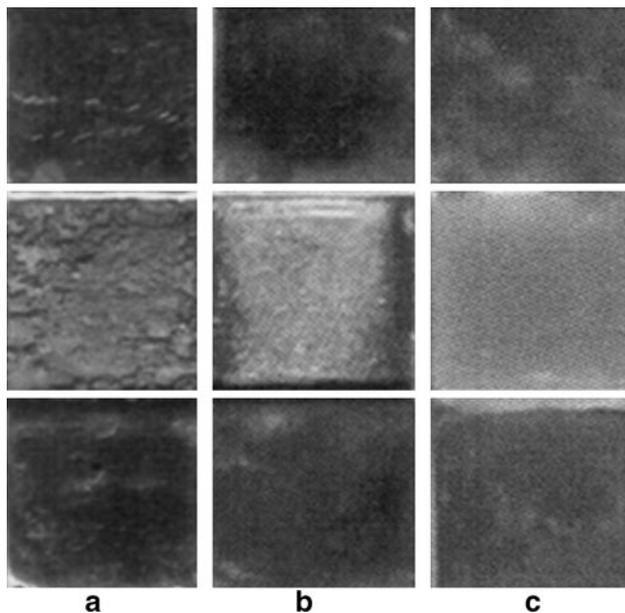


Fig. 1 **a** Metal specimen for Group A with retention beads. **b** Metal specimen for Group B without retention beads. **c** Metal specimen for Group C without retention beads

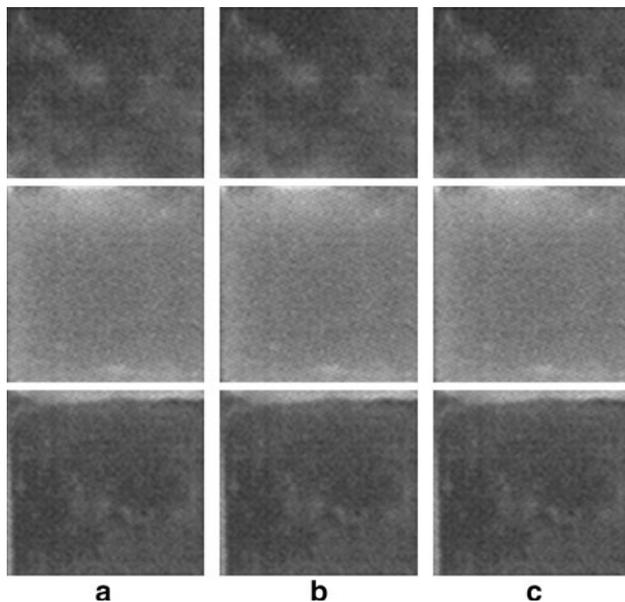


Fig. 2 Samples of **a** group A, **b** group B and **c** group C specimens after application of composites

prevent an inhibition layer. After the application of gel, a diethylene glycol/water based paste (SR Adoro thermo guard, Ivoclar Vivadent, Liechtenstein) was applied over the exposed metal parts and over veneering surface, to minimize internal tension at the interface between the metal and composite. The sample was then polymerised as cured for 20 s with a quick light curing unit and then polymerised directly in the Lumamat 100 or Targis power

upgrade furnace (Ivoclar Vivadent, Liechtenstein) at 104 °C for 11 min.

In Group B specimens, two opaque layers were applied and light cured for 20 s using Targis quick (Ivoclar Vivadent, Liechtenstein) and processed. A disposable sponge was used to remove the unpolymerized superficial layer, later three more dentin layers were added and subjected to polymerization cycle in the Targis power upgrade furnace using light and heat at 95 °C.

In Group C specimens, opaque composite was applied to metal specimen, followed by body and incisal composite and cured in a light cup (Bisco, U.S.A) which cures the composite under light and pressure. The restoration was then placed in a heat cup (Bisco, U.S.A) which cures the composite under light, pressure and heat of 130 °C. This cup was filled with water and an oxygen scavenger capsule was added to fully polymerize the composite and remove the oxygen inhibiting layer on composite surface. The restoration was finally glazed with a glazing resin supplied by manufacturer.

Testing the Bond Strength

The bond strength was tested with Lloyd's Universal Testing machine under three point loading. The specimens were placed in the bending apparatus with the composite portion positioned on the side opposite to the applied load with 25 mm distance between the supports. Load was applied at a speed of 0.5 mm/min. An indication of the failure of specimen was noted by a sudden change in the digital signal, the magnitude of load at which fractured occurred was recorded as applied load (P). The outer span length was obtained by measuring the distance between the two supports (25 mm) on which the specimen was placed. Width of the sample specimen was 10 mm and height was 3 mm.

Flexural bond strength was calculated using the formula, $\text{Psi} = \frac{3PI}{2} \frac{wh^2N}{\text{mm}^2}$ where,

Psi, flexural strength; P, applied load (N); I, outer span length (mm); W, specimen width (mm); h, specimen height.

All the values were statistically analysed using ANOVA, Duncan's test and student *t* test

Results

The observations were tabulated. Highest force was required to fracture the heat, light and pressure cured Group C Tescera specimens. Least force was required to fracture Group B Targis specimens cured with temperature of 95 °C.

Fracture load (N) at which the composite debonded from metal was determined and flexural strength was calculated.

ANOVA test reveals that the mean flexural bond strength is not the same in all the three types (Table 2), the Duncan’s multiple range tests (Table 3) would rank the means of the groups being tested and indicate the location of difference. The mean flexural bond strength of Group C was found to exceed Group A which in turn exceeds that of Group B. Student *t* test (Table 4) is used when there are more than two mean values to be compared. In this study, the results indicate that there is a significant difference between the three groups, with the Group C specimens exhibiting greater flexural bond strength as compared to Group A which in turn exhibits greater flexural bond strength as compared to Group B (Fig. 3). In this study the level of significance was ($p < \text{or} = 0.05 \%$) and power of the study was at 80 %.

Table 2 ANOVA-analyses of variance

Source of variation	Sum of squares	Degree of freedom	Mean sum of squares
Total	67736.02	29	
Groups	65250.62	2	32625.31
Error	2485.40	27	92.05

Table 3 Duncan’s multiple range test

Comparison	Difference	Q _{0.05}	Critical range
B versus C	112.54	3.486	14.957
B versus A	48.856	2.888	12.392
A versus C	63.68	2.888	12.392

Table 4 Student *t* test

Groups	<i>t</i> value	<i>p</i> value	Inference
C and A	12.908	0.0000	Significant
C and B	23.4323	0.0000	Significant
B and C	15.0815	0.0000	Significant

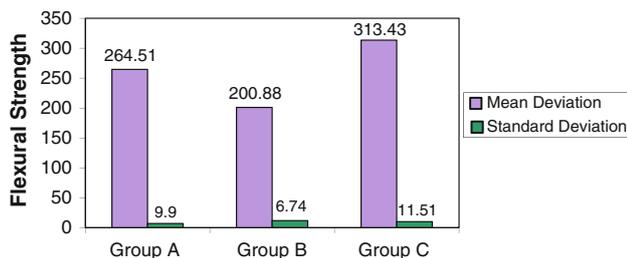


Fig. 3 Graph showing comparison of mean and standard deviations of flexural bond strength, between the groups

Discussion

Among the materials used in this study, Targis (Group B) was one of the first materials to be developed for use as a veneer composite. To overcome the short coming of Targis, Adoro (Group A) was developed by the same company with improved post curing properties. The quest for further improvement has led to the development of Tescera (Group C) where in ‘pressure’ was introduced for post curing in addition to high intensity heat.

The flexural bond strength is influenced by modulus of elasticity. It has been suggested that the areas of high stress concentration are caused at the interface of the bonded structure in which the elastic moduli of the two components are different [6]. The elastic modulus of metal is 0.205 GPa as compared to composite which is 10 GPa. When composite is bonded to metal and load applied, stress is transferred to the material with higher elastic modulus, thus causing the composite to debond from metal.

Statistical analysis has shown that the flexural bond strength of Group C was significantly higher than that of Groups A and B. Group C specimens were polymerised using light, temperature of 130 °C and pressure of 80 psi. Research has shown that the material undergoes changes in properties during post curing which may be beneficial. The application of heat increased the mobility of both polymer segments and reactive free radicals formed during polymerisation. This allowed a greater degree of conversion and increased cross linking of polymer units. Exposure to elevated temperature accelerated the process of polymerisation. A study by Tanoë and Matsumura has shown that the metal halide unit exhibited the greatest depth of cure which led to improved mechanical properties of the composite material [7]. The ATL system (Group C) used the metal halide unit for curing the composite as compared to fluorescent light used by groups A and B.

Certain studies have shown that 80psi pressure is optimum to eliminate porosity [8]. Pressure of 85–100 psi is used for the polymerisation of Group C. The improved post curing methods and the light source intensity used for curing could explain the superior flexural bond strength of Group C specimens as compared to Groups A and B.

Group A specimens were supplemented with micromechanical retention in the form of retention beads. The retentive bead method is sensitive at all stages of investing and casting [9]. The decrease in bond strength in specimens with retention beads could be attributed to opaque pools in the spaces among the beads. This explains the improved flexural strength of Group A over Group B.

The Group B specimens were polymerised using heat and light. The heat applied was less in intensity as compared to other groups and pressure was not used for polymerisation. These could be the reasons that contributed

towards low flexural strength of Group B in comparison with Groups A and C.

Tanoue et al. [10] pointed out that the best mechanical and physical properties are achieved by using a combination of composite material and curing unit from the same manufacturer. Borba et al. [11] observed that the hardness and flexural strength of direct resin composites were better than that of the IRCs. This was attributed to the high filler content. Neves et al. [12] also concluded that the filler content directly affects the hardness values. Other studies also investigated the association between the mechanical properties of composites and the filler volume. The authors reported that materials with higher filler volumes showed better mechanical properties [13, 14]. Miranda et al. [15] observed that Targis had the highest microhardness among the IRCs even though its filler content was less than in the others. This may be because there is a correlation between the method of polymerization and the microhardness. Some IRC's presents inferior mechanical properties, even though it is polymerized with light and vacuum. This suggests that the composition of the material influences the degree of conversion during polymerization resulting into lower resistance to indentation [16].

The metal to resin bonding system is highly technique sensitive and depends upon whether the commercial laboratory uses a standardised method as recommended by the manufacturer [10].

When compared to porcelain and porcelain-fused-to-metal restorations, the transfer of masticatory forces is considerably less. Composite materials have shown a greater capacity to absorb compressive loading forces and reduce the impact forces by 57 % more than porcelain. Tsitrou et al. [17] found that resin composites have a lower tendency for marginal chipping than ceramics. Due to the similar composition of the luting cement and composites, the marginal adaptation of composites is better than that of ceramics.

One of the problems associated with composite materials is the unpredictable color stability (Optical property). The mode of curing and the remaining double bonds may influence the color stability of the material. Papadopoulos et al. [18] observed that there was an increase in lightness and a green-yellow or green-blue shift in color in IRCs on curing as well as after aging in various environments, but the changes were found to be within the clinically acceptable range.

Aggarwal et al. [19] observed that marginal adaptation and bond strength of an indirect resin system after thermocycling was better than that after direct restoration. Other studies shows IRCs has better marginal adaptation than ceramics because of lower polymerization contraction. The refractory die is fractured to remove the ceramic inlays and this may result in marginal microfracture, thus increasing the marginal gap [20].

One of the main failures of IRC restoration is the formation of secondary caries due to plaque accumulation, which is aggravated by the surface roughness of the material. The biofilm accumulation is based on the filler size and matrix monomer. Smaller filler size with more weight % produces a smooth surface and, consequently, less biofilm adhesion. The surface roughness ranges from 6 to 8 μ . Polishing with diamond pastes also renders a smooth surface. Another possible factor for bacterial adherence is the presence of remaining uncured monomers [21].

The treatment of the intaglio surface of indirect restorations determines the bonding of the restoration to the tooth. The use of hydrofluoric acid for surface treatment causes microstructural alteration of the composite because of the dissolution of the inorganic particles. The best alternative method to raise the surface energy is by sand-blasting with aluminium oxide particles for 10 s. This causes a nonselective degradation of the resin and promotes better adhesion. According to Soares, application of silane after sand-blasting resulted in higher bond strength. Since the compositions of the IRCs are similar, the surface treatment for all materials can be the same [22, 23].

Wear of composite resin materials has been evaluated in terms of two main clinical components: occlusal contact/attrition wear and contact free/abrasive wear. Filler size, volume, shape, and bonding to matrix affects wear. The substantial increase in wear resistance of the indirect material can be attributed in part to the incorporation of multifunctional monomers, which permits better control over the positions along the carbon chain where the cross-linking does occur. Consequently, this can aid in improving the wear resistance and the other physical and mechanical properties of the resin matrix [24].

Clinical Advantages and Disadvantages of Irc's

A properly fabricated indirect restoration is wear resistant, esthetic, and relatively less prone to postoperative sensitivity. Since, the only polymerization that occurs is that associated with a thin liner of luting agent, the potential for tensile stresses on the odontoblastic processes is considerably less, which translates into less potential for postoperative sensitivity. Indirect laboratory-processed composite resin systems provide an esthetic alternative for intracoronal posterior restorations and may also reinforce tooth structure. IRC restorations offer some benefits as compared to direct restorations, such as better mechanical performance and a significant reduction in polymerization shrinkage (i.e., limited to the dual-cured luting cement). Additional clinical benefits include precise marginal integrity, ideal proximal contacts, excellent anatomic morphology, and optimal esthetics [25, 26].

Though the mechanical properties of the IRCs are much inferior to that of ceramics, in some clinical situations, IRCs can supplement and complement (rather than replace) ceramic restorations: for example, in coronal restoration of dental implants. As ceramics exhibit a high modulus of elasticity and absorb little of the masticatory energy, considerable amount of the masticatory force is transmitted to the implant and the periosseous structure, reducing the longevity of the restoration. Polymers become the materials of choice in this situation because they absorb relatively more of the occlusal stress. For patients with poor periodontal structures who require occlusal coverage, stress-absorbing materials like IRCs are indicated [27].

Conclusion

1. Tescera with curing temperature of 130 °C and pressure of 80 psi, cured with metal halide unit exhibited the highest flexural bond strength as compared to Adoro and Targis.
2. Adoro with curing temperature of 104 °C without pressure and with incorporation of retention beads exhibited lesser flexural bond strength as compared to Tescera, but higher bond strength as compared to Targis.
3. Targis with curing temperature of 95 °C exhibited the least flexural bond strength, compared to the Adoro and Tescera groups.

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