Bond strength of glass fiber reinforced composite and base metal frameworks used in resin-bonded fixed partial dentures

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ABSTRACT

Background & Aim: Glass fiber reinforced composite (GFRC) for the fabrication of esthetic fixed partial dentures (FPDs) have been recently developed. The aim of this invitro study was to measure and to compare the bond strength of GFRC and base metal as framework used in maxillary anterior resin-bonded FPDs.

Materials & Methods: Twenty resin-bonded FPDs were made with GFRC and base metal. The specimens were stored for 2 weeks at 37°±1°C in distilled water, thermo cycled (5°-55°C, x 2500) and statically loaded to fracture. The instron universal testing machine measured bond strength of the specimens. A metal cone with 1.0mm tip cut vertically to the center of labial surface of pontic with 1.0mm/min speed to debond of prosthesis from abutment teeth. The debonding force was recorded in Newtons.

Results: The mean and standard deviation for bond strength of GFRC RBFPDs were 113±45 and for base metal RBFPDs were 43±32 Newtons. ANOVA showed that bond strength between the two groups were statistically significant (P ≤ 0.0009).

Conclusion: Although more clinical experience is needed it is possible to use, fiber reinforced composite materials for metal-free prostheses to obtain excellent esthetic qualities.

Keywords: Bond strength, Fiber reinforcement, Resin-bonded, Composite, Fixed partial denture.

INTRODUCTION

A resin-bonded anterior fixed partial denture (RBFPD) is a well established option for the replacement of missing teeth and the success rate is reported to be 76% after 5 years and 60% after 10 year. However, it has been reported that the metal framework of the RBFPD frequently debonds from the composite luting cement, despite improvements in metal bonding agents. Considerably less debonding of the composite luting cement occurs from the etched enamel.¹,²,³

Reasons for the debonding of the cast metal framework from the luting cement relates to the surface treatment and rigidity of the cast metal alloy. Repeated stresses predispose sometime to the fatigue of the adhesive joint. In order to improve the bonding of RBFPD, the materials of the RBFPD should allow sufficiently bonding strength and the bonding surface area should be as large as possible. Furthermore, a metal shadow and the dark color of cast metal framework appear through labial surface of abutment teeth and might cause aesthetic problems in the anterior teeth.¹,³,⁴,⁵

By selecting a material with a lower modulus of elasticity than cast metal alloy, stresses at the interface can be diminished. From this perspective, a framework material with a lower elastic modulus would be beneficial in reducing the stress level at the
interface of the luting cement and tooth.\cite{3,6,7}

Glass fiber reinforced composite (GFRC) system comprising and prefabricated glass fiber reinforced elements, processing and curing equipment was introduced in 1996.\cite{8,9,10} Flexural modulus of GFRC is approximately 18GPa, which is considerably lower than the cast metal alloy, such as cobalt-chromium alloy (180Gpa).\cite{5}

Recently, it was shown that by selecting the form of the reinforcing fibers, the physical properties of the FRC could be tailored to specific needs.\cite{11} The use of GFRC framework can potentially overcome the problem of debonding of composite luting cement to the frame of RBFPD and the aesthetic liability of cast metal framework. A new type of fiber composite material has been recently introduced for dental use.\cite{7}

One of the advantages of this new material is the ability to form good bonding with the polymeric composite framework.\cite{5,11}

By using continuous unidirectional fibers in the FRC, the strength and rigidity of the material can be considerably enhanced, or by using continuous fibers in woven form the fracture strain of the FRC can be increased. The color of the FRC made from glass fibers and dimethacrylate polymer matrix is translucent. Bonding of the FRC material to the composite luting cement is based on the free radical polymerization of the unreacted functional groups of the polymer matrix of the FRC, or alternatively, to the formation of an interpenetrating polymer network (IPN).\cite{4}

By designing the RBFPD construction with different fiber orientations, the frame can be extended into the undercut regions of the crown. If the translucent FRC material is employed, the bonding surface area can be extended to the buccal and labial surface of the tooth. Finally the FRC material will improve the bond strength of composite luting cement to the frame of the RBFPD.\cite{3,4}

The purpose of this invitro study was to compare the bond strengths of RBFPDs made of GFRC with base metal frameworks.

**MATERIALS & METHODS**

Forty freshly extracted maxillary central and lateral incisors were collected and disinfected in a solution of chlorohydrin 2% for 24 hours. The teeth were intact without caries; crack or restoration, and then were cleaned, polished and stored in distilled water. Each sample included a central and a lateral incisor, which were positioned in 5×3×2cm polymethylmethacrylate (PMMA) resin and 1.0mm up to CEJ. The distance between the abutments was similar to a maxillary central incisor (about 8.5 mm). 20 samples were randomly separated into two groups. The teeth were prepared to provide adequate space for the RBFPD substructure.

In group A, the tooth preparation included reduction of lingual surface by approximately 0.2mm. Tooth preparation terminated 1.0mm cervical to incisal edge, 1.0mm incisal to CEJ and 2.0mm to distal marginal ridge with beveling margins. The bonding surfaces of the teeth were cleaned by water spray, dried with oil-free compressed air, acid-etched with 37% phosphoric acid (Total Etch, Ivoclar Vivadent Ets, Schaan, Liechtenstein) for 20 seconds, rinsed with water for 30 seconds and then blown dry.

With a dental floss the right length of fiber bundle was measured (EverStick, Stick Tech Ltd, Turku, Finland). The adhesive (Stick Resin) was brushed on the etched surfaces, air thinned and light cured for 20 seconds for each surface. Before placing the fiber bundle, a thin layer of a flow composite (Stick Flow) was applied on bonding surfaces of the teeth. The flow composite was not light cured at this point. The fiber bundle was placed with a hand instrument and then light cured for 5-10 seconds per tooth, then they were covered with a thin layer of flow composite and then light cured for 10 seconds per tooth. So a glass fiber framework was made on the abutment teeth that contained continuous unidirectional glass fiber reinforcement.

Now the pontic could be built up, layer by layer with hybrid composite (Tetric Ceram, Ivoclar Vivadent, Amherst, NY). Each layer was light cured for about 10 seconds. Finally, after polishing, the bridge was light cured for...
40 seconds per tooth.

In group B, the tooth preparation included reduction of lingual and proximal surfaces by approximately 0.3mm and a V-shaped cingulum rest and grooves were prepared with a 169L carbide bur and were limited in depth by the diameter of the bur. Tooth preparation terminated 1.0mm incisal to the CEJ and 1.0mm cervical to the incisal edge. Impressions were made of the prepared teeth, 10 wax patterns were prepared, replicated cast in nickel-chromium alloy (base metal) and porcelain contoured. After adjustments the bridges were made, they were returned to the laboratory for corrections, final glazing, polishing and sandblasting of the metal frameworks. The retainers were cemented to the abutment teeth with dual cement (Duo Cement, Coltene AG, Switzerland), according to the manufacturer's instructions.

The samples were stored in distilled water at 37°±1°C for two weeks, then thermocycled 2500 cycles in 2 water baths at 5-55°C. An instron universal testing machine (model 1011, Instron, Buckinghamshire, U.K.) was selected to measure bond strength. A metal cone with 1.0mm tip cut vertically to the center of labial surface of pontic with speed of 1mm/min. The force in Newtons was recorded at debonding of bridge from abutment teeth.

One-way analysis of variance (ANOVA) and t-test were used to compare the mean values of bond strength.

**RESULTS**

The mean and standard deviations for forces of dislodgement were recorded in Newtons for two groups. The mean load required for debonding the RBFPDs with GFRC framework (group A) were 113N (SD±45) and for RBFPDs with metal framework (group B) were 43N (SD±32) (Table 1).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean ±SD</th>
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<tr>
<td>A</td>
<td>10</td>
<td>113±45</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>43±32</td>
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<td>P ≤ 0.0009</td>
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**DISCUSSION**

Replacement of missing teeth with RBFPD is a non-invasive restorative treatment. This concept has reduced the risk of critical loss of tooth structure and provides the maintenance of optimal strength, form and esthetic. The RBFPD with GFRC framework consist of an external particular composite combined with an internal GFRC substructure, which is placed over and bonded to abutment teeth. Freilich et al. described in a clinical study that GFRC materials can be used to make metal-free RBFPD.

Conventional materials, namely metal alloy and ceramics, are used in prosthetic dentistry because of their rigidity. The rigidity of the material makes it impossible to use enamel surfaces with undercuts as a bonding surface. For this reason, the conventional type of RBFPD is made with relatively small bonding surface area. In order to improve the mechanical interlocking of a RBFPD with a cast metal framework, preparation of tooth substance is needed. However, this makes the treatment technically more complicated and the risk of misfit and thereafter debonding of the construction is likely to occur. Paradoxically, tooth preparation for a RBFPD or for a full coverage crown retained FPD destroys the best bonding surface in the oral cavity, i.e. the enamel of the tooth. It has been well established that resin-enamel bond strength is the highest obtainable in the oral cavity. Therefore, the use of FRC materials which reduce the need for tooth preparation by selecting tailor-made mechanical properties in the frame construction was fascinating and this was the principal reason proposed for
development of FRC RBFPDs with an increased bonding surface.\(^{(4)}\)

This invitro study measured and compared bond strengths of RBFPD with GFRC and metal framework for replacement of maxillary anterior missing tooth and showed that bond strength of GFRC is higher than metal framework (P<0.0009) and can be used in the fabrication of a maxillary anterior 3-unit RBFPD. Freilich et al. in a clinical performance of 39 light and heat polymerized fixed partial bridges showed that a unidirectional GFRC can be used in certain clinical situation in which a base metal substructure is not desired.\(^{(16)}\)

Vallittu PK et al. evaluated 31 GFRC RBFPD in a clinical study and exclaimed that survival probability was 93%. No framework fractures were observed so it may be an alternative for RBFPD with metal framework\(^{(3)}\) and in another study reported that bonding GFRC RBFPD is adequate for long span FPDs.\(^{(5)}\) Short-term clinical results suggest that the bonding of the GFRC RBFPD made from Stick and StickNet fiber reinforcement is adequate for long span RBFPDs.\(^{(12)}\)

Gohring TN et al. in a clinical study evaluated 20 FRC inlay FPDs for 15 patients. The results of this study showed that bonded GFRC inlay FPDs were considered clinically successful at the 1-year examination.\(^{(5)}\) However, multiyear clinical studies determine the value and efficacy of the GFRC as long-term tooth replacement.

The risks which relate to the GFRC RBFPD, as well as to all dental FRC constructions, are: insufficient wear resistance of the veneering composite on the occlusal surface, debonding of veneering composite from the FRC frame, debonding of composite luting cement from the FRC frame or from the etched enamel and weakening of the glass FRC frame in moist conditions by leaching of ions from the glass fiber surface over a very long period of time. The prosthodontist should be able to control the risks which relate to any prosthetic treatment, especially the risks which relate to a new type of dental material.\(^{(4)}\)

With the data of this invitro study no generalizations can be made, and this study isn't a complete substitute for RBFPDs made from base metal alloy and ceramics. More invitro and invivo experience must be documented to create a sound basis for final assessment of this method. However, it is our impression that GFRC is a new option to treat patients with a less invasive and has the potential to satisfy requirement for durable and conservative FPDs.

**CONCLUSIONS**

GFRC RBFPD made from ever stick fiber bundle is adequate for 3-unit maxillary anterior FPDs also has potential for long-term provisional prosthesis.

**REFERENCES**

7. Vallittu PK: Flexural properties of acrylic...


