Comparison of shear bond strength and interfacial fracture testing methodologies for quantifying adhesion of porcelain to titanium

Language: English

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Date/Event/Venue:
2-5 November 2010
The 17th Alexandria International Dental Congress (17th AIDC 2010)
Hilton Alexandria Green Plaza Hotel, Alexandria, Egypt

Introduction
A variety of tests have been designed and used to evaluate the metal-porcelain bond strengths. An alternative fracture mechanics approach for determining the adhesion at a bimaterial interfaces has been described by Charalambides et al.\(^1\) It has been suggested that the bimaterial bond test geometry combined with interfacial fracture toughness measurement is an appropriate alternative method for studying the bonding characteristics of a porcelain-fused-to-metal systems.

Objectives
To compare the shear bond strength (SBS) and strain energy release rate (G-value (J/m\(^2\)) or interfacial toughness) testing methodologies on the adhesion between porcelain and commercially pure titanium (cp Ti) using chromium interlayer.

Material and Methods
Seventy square (10 mm × 10 mm × 1 mm) and seventy rectangular (8 mm × 30 mm × 1.5 mm) specimens of cp Ti plates (ASTM, Grade II, Modern Techniques and Materials Engineering Center, Egypt) were prepared for shear bond strength testing and strain energy release rate testing. Two types of titanium-ceramic were used: Vita Titankeramik (Vita Zahnfabrick, Bad Säckingen, Germany) and Triceram (Dentaurum, Esprident, Germany).

Electroplating Process
All of the titanium specimens were electroplated except the control group. The electroplating solution consisted of chromium (III) nitrate (Sigma-Aldrich) in distilled water. Electroplating was performed using a 12 V DC source and 0.5 amp.\(^2,3\)

Grouping of specimens
The specimens in each test were divided into seven groups according to the electroplating treatment; Gr 1 (control without electroplating, n = 10); Gr 2 (5% w/v chromium nitrate solution for 30 minutes, n = 10); Gr 3 (5% w/v chromium nitrate solution for 60 minutes, n = 10); Gr 4 (5% w/v chromium nitrate solution for 120 minutes, n = 10); Gr 5 (10% w/v chromium nitrate solution for 30 minutes, n = 10); Gr 6 (10% w/v chromium nitrate solution for 60 minutes, n = 10) and Gr 7 (10% w/v chromium nitrate solution for 120 minutes, n = 10). Each group was further equally divided into two subgroups according to the type of porcelain used (n = 5).

Shear bond strength
The shear bond specimens were tested using a universal testing machine (Lloyd Model TT-B, Instron Corp., Canton, MA, USA).\(^2\)

Strain energy release rate (G)
The specimens' preparation, testing procedures and the details of the equation were described before.\(^3\) The strain energy release rate, G, is given by \(^1\). The testing configuration shown in Fig. 1 illustrates the relationship between the specimen and the rollers of the four-point bending jig.\(^3\)
Fig. 1a: G equation in Materials and Methods section
Fig. 1b: Interface fracture-testing configuration

Results

Table 1: Mean (standard deviation) of the shear bond strength values (MPa) and the strain energy release rate (G-values) (J/m$^2$) of CP Ti-porcelain combinations with different electroplating treatments, and Tukey’s analysis with Cr film thickness (µm).

<table>
<thead>
<tr>
<th>Electroplating treatment</th>
<th>CP Ti/Vita Titankeramik</th>
<th>CP Ti/Triceram</th>
<th>Cr film thickness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBS (MPa)</td>
<td>G (J/m$^2$)</td>
<td>SBS (MPa)</td>
<td>G (J/m$^2$)</td>
</tr>
<tr>
<td>Control</td>
<td>15.96 (5.54)</td>
<td>21.09 (5.03)</td>
<td>14.38 (3.24)</td>
</tr>
<tr>
<td>1/2 h 5% w/v</td>
<td>21.4 (4.23)</td>
<td>36.94 (3.25)</td>
<td>25.48 (4.14)</td>
</tr>
<tr>
<td>abAB</td>
<td>bcb</td>
<td>bAB</td>
<td>bAb</td>
</tr>
<tr>
<td>1 h 5% w/v</td>
<td>23.68 (6.42)</td>
<td>38.87 (7.91)</td>
<td>18.48 (4.06)</td>
</tr>
<tr>
<td>abAB</td>
<td>bB</td>
<td>bAb</td>
<td>baB</td>
</tr>
<tr>
<td>2 h 5% w/v</td>
<td>20.36 (5.72)</td>
<td>23.95 (5.66)</td>
<td>18.08 (3.29)</td>
</tr>
<tr>
<td>abAB</td>
<td>aA</td>
<td>aAb</td>
<td>aAb</td>
</tr>
<tr>
<td>1/2 h 10% w/v</td>
<td>26.72 (5.78)</td>
<td>37.22 (5.76)</td>
<td>20.68 (4.53)</td>
</tr>
<tr>
<td>baA</td>
<td>bcB</td>
<td>abAB</td>
<td>abAB</td>
</tr>
<tr>
<td>1 h 10% w/v</td>
<td>21.34 (4.31)</td>
<td>27.33 (3.78)</td>
<td>21.54 (4.21)</td>
</tr>
<tr>
<td>abAB</td>
<td>bCc</td>
<td>abAB</td>
<td>abAB</td>
</tr>
<tr>
<td>2 h 10% w/v</td>
<td>18.44 (3.55)</td>
<td>21.51 (4.29)</td>
<td>16.58 (3.06)</td>
</tr>
<tr>
<td>abAB</td>
<td>aA</td>
<td>aAb</td>
<td>aAb</td>
</tr>
</tbody>
</table>

Tab. 1: Mean values represented with common or same small letters (column) or capital letters (row) for each test are not significantly different according to Tukey test (P>0.05)

Fig. 2: Representative SEM images (x100) of the peeled surface of the cp Ti/Vita Titankeramik (a) Control (adhesive bond failure) and (b) 1 h 5% w/v (mixed bond failure) groups. Dark area represents retained porcelain and light area represents titanium.

Conclusions

The interfacial four-point flexure test provided a simple and reproducible method to quantify the influence of an electroplated chromium interlayer on the adhesion of porcelain to titanium than shear bond strength test.


This Poster was submitted by Dr. Shaymaa Elsaka.

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