

Int Poster J Dent Oral Med 2011, Vol 13 No 3, Poster 541

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

Language: English

Authors:

Dr. Shaymaa Elsaka, BDS (Hons), MSc, PhD, Prof. Ibrahim M. Hamouda, BDS, MSc, PhD, Mansoura University, Faculty of Dentistry, Department of Dental Biomaterials, Mansoura, Egypt
Prof. Yehia A. Elewady, BSc, MSc, PhD, Mansoura University, Faculty of Science, Department of Chemistry, Mansoura, Egypt
Assoc. Prof. Ossama B. Abouelatta, BSc, MSc, PhD, Mansoura University, Faculty of Engineering, Department of Production Engineering, Mansoura, Egypt
Prof. Michael V. Swain, The University of Sydney, Faculty of Dentistry, Biomaterials Science Research Unit, NSW, Australia

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

$$G = \frac{\eta \left[P^2 l^2 (1 - \nu_m^2) \right]}{E_m b^2 h^3}$$

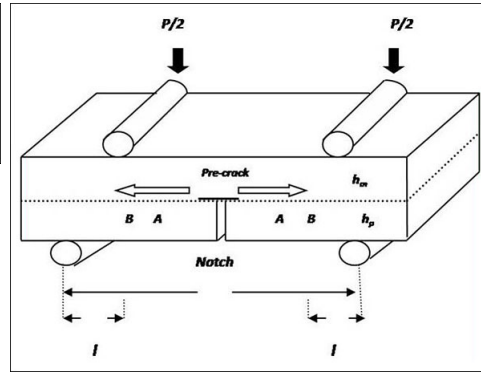


Fig. 1a: G equation in Materials and Methods Fig. 1b: Interface fracture-testing section configuration

Results

Table 1: Mean (standard deviation) of the shear bond strength values (MPa) and the strain energy release rate (G-values) (J/m²) of CP Ti-porcelain combinations with different electroplating treatments, and Tukey's analysis with Cr film thickness (μm).

Electroplating treatment	CP Ti/Vita Titankeramik		CP Ti/Triceram		Cr film thickness (μm)
	SBS (MPa)	G (J/m ²)	SBS (MPa)	G (J/m ²)	
Control	15.96 (5.54) aAB	21.09 (5.03) aA	14.38 (3.24) aB	14.99 (1.50) aA	0
1/2 h 5% w/v	21.4 (4.23) abAB	36.94 (3.25) bcB	25.48 (4.14) bAB	26.72 (4.36) bcAC	0.57 (0.08)
1 h 5% w/v	23.68 (6.42) abAB	38.87 (7.91) bB	18.48 (4.06) abAB	24.30 (3.81) acAC	0.85 (0.12)
2 h 5% w/v	20.36 (5.72) abAB	23.95 (5.66) aA	18.08 (3.29) abAB	20.18 (3.94) acAC	1.03 (0.08)
1/2 h 10% w/v	26.72 (5.78) bA	37.22 (5.76) bcB	20.68 (4.53) abAB	26.94 (3.52) bcAC	0.65 (0.11)
1 h 10% w/v	21.34 (4.31) abAB	27.33 (3.78) acC	21.54 (4.21) abAB	17.78 (2.24) acAC	0.93 (0.21)
2 h 10% w/v	18.44 (3.55) abAB	21.51 (4.29) aA	16.58 (3.06) abAB	21.01 (3.78) acAC	1.23 (0.15)

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)

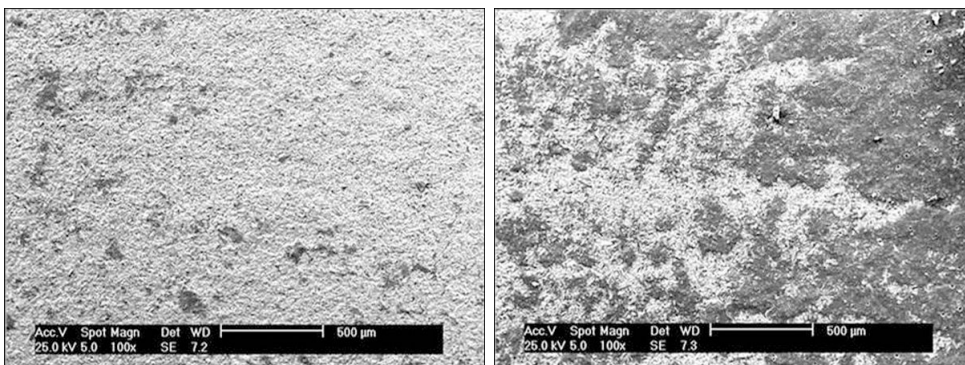


Fig. 2: Representative SEM images (x100) of the peeled surface of the cp Ti/Vita Titankeramik (a) Control (adhesive bond failure) and (b) 1 h 5% w/v (mixed bond failure) groups. Dark area represents retained porcelain and light area represents titanium.

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.

Literature


- Charalambides PG, Lund J, Evans AG, McMeeking RM. A test specimen for determining the fracture resistance of bimaterial interfaces. *J Appl Mech* 1989; 56:77-82.
- Elsaka SE, Hamouda IM, Elewady YA, Abouelatta OB, Swain MV. Effect of chromium interlayer on the shear bond strength between porcelain and pure titanium. *Dent Mater* 2010;26:793-798.
- Elsaka SE, Hamouda IM, Elewady YA, Abouelatta OB, Swain MV. Influence of chromium interlayer on the adhesion of porcelain to machined titanium as determined by the strain energy release rate. *J Dent* 2010;38:648-654.

This Poster was submitted by *Dr. Shaymaa Elsaka*.

Correspondence address:

Dr. Shaymaa Elsaka
Mansoura University
Faculty of Dentistry, Department of Dental Biomaterials
Al gomhoria street
Mansoura P C 35516
Egypt

Poster Faksimile:



17th AIDC 2010

Authors

^aDepartment of Dental Biomaterials, Faculty of Dentistry, Mansoura University, Egypt.
^bDepartment of Chemistry, Faculty of Science, Mansoura University, Egypt.
^cDepartment of Production Engineering, Faculty of Engineering, Mansoura University, Egypt.
^dBiomaterials Science Research Unit, Faculty of Dentistry, The University of Sydney, Australia.


Correspondence

Dr. Shaymaa E. Elsaka
Lecturer, Department of Dental Biomaterials, Faculty of Dentistry, Mansoura University, Egypt.
E-mail: shaymaanaghy@mans.edu.eg
Phone: +2 0104101558

17th AIDC 2010
Dentistry Art & Science
Alexandria International Dental
Congress
2-5 November

Comparison of Shear Bond Strength and Interfacial Fracture Testing Methodologies for Quantifying Adhesion of Porcelain to Titanium

Shaymaa E. Elsaka ^{a,*}, Ibrahim M. Hamouda ^a, Yehia A. Elewady ^b, Ossama B. Abouelatta ^c, Michael V. Swain ^d



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/m²]) or interfacial toughness) testing methodologies on the adhesion between porcelain and commercially pure titanium (cp Ti) using chromium interlayer.

MATERIALS AND METHODS

Seventy square (10 mm × 10 mm × 1 mm) and seventy rectangular (8 mm × 30 mm × 3.5 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 Zahnfabrik, Bad Säckingen, Germany) and Triceram (Dentaurum, Espringen, 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-8, 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.² The strain energy release rate, G, is given by¹

$$G = \frac{7 \sqrt{P^2 J^2 (1 - \nu^2)}}{E D^2 J^2}$$

The testing configuration shown in Fig. 1 illustrates the relationship between the specimen and the rollers of the four-point bending jig.³

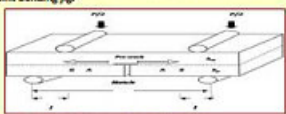


Fig. 1. Interface fracture-testing configuration.

RESULTS

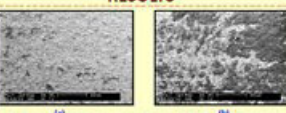


Fig. 2. Representative SEM images (x1000) of the peeled surface of the cp Ti/Titankeramik (a) Control (adhesive bond failure) and (b) 1 h 5% w/v (mixed bond failure) groups. Dark area represents retained porcelain and light area represents titanium.

RESULTS

Table 1. Mean (standard deviation) of the shear bond strength values (MPa) and the strain energy release rate (G-values) [J/m²] of cp Ti/porcelain combinations with different electroplating treatments, and Tukey's analysis with Cr film thickness (µm)

Electroplating treatment	cp Ti/Vita Titankeramik SBS (MPa)	G (J/m ²)	cp Ti/Triceram SBS (MPa)	G (J/m ²)	Cr film thickness (µm)
Control	15.96 (5.54) ^{***}	21.09 (5.03) ^{**}	14.38 (3.24) ^{**}	14.99 (1.50) ^{**}	0
1/2 h 5% w/v	21.4 (4.23) ^{***}	36.94 (3.25) ^{***}	25.48 (4.14) ^{***}	26.72 (4.36) ^{***}	0.37 (0.40)
1 h 5% w/v	23.68 (6.42) ^{***}	38.87 (7.81) ^{***}	18.48 (4.06) ^{**}	24.30 (3.81) ^{**}	0.85 (0.52)
2 h 5% w/v	20.36 (5.72) ^{***}	23.95 (5.66) ^{**}	18.08 (3.23) ^{**}	20.18 (3.94) ^{**}	1.01 (0.49)
1/2 h 10% w/v	26.72 (5.78) ^{***}	37.22 (5.78) ^{***}	20.68 (4.53) ^{**}	26.94 (3.52) ^{**}	0.45 (0.51)
1 h 10% w/v	21.34 (4.32) ^{***}	27.83 (5.78) ^{***}	21.54 (4.11) ^{**}	17.78 (3.24) ^{**}	0.85 (0.51)
2 h 10% w/v	18.46 (3.55) ^{***}	21.51 (4.29) ^{**}	16.58 (3.04) ^{**}	21.01 (3.78) ^{**}	1.23 (0.51)

Three values are reported (mean, standard deviation and range) (columns) for control (rows) for each test are not significantly different according to Tukey test (P<0.05).

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.

REFERENCES

- Charalambides PG, Lund J, Evans AG, McMeeking RM. A test specimen for determining the fracture resistance of bimaterial interfaces. *J Appl Mech* 1989; 56:77-82.
- Elsaka SE, Hamouda IM, Elewady YA, Abouelatta OB, Swain MV. Effect of chromium interlayer on the shear bond strength between porcelain and pure titanium. *Dent Mater* 2010;26:793-798.
- Elsaka SE, Hamouda IM, Elewady YA, Abouelatta OB, Swain MV. Influence of chromium interlayer on the adhesion of porcelain to machined titanium as determined by the strain energy release rate. *J Dent* 2010;38:648-654.

ACKNOWLEDGEMENTS

Dr Shaymaa E. Elsaka wishes to thank the Egyptian Government for the opportunity to be a visiting fellow at the University of Sydney, Faculty of Dentistry, Dental Biomaterials Laboratory.