Journal of Applied Dental and Medical Sciences
NLM ID: 101671413 ISSN:2454-2288
Volume 4 Issue2 April-June 2018

Original Article

Evaluation of shear bond strength of ceramic on commercially pure titanium (CpTi) after Tungsten Inert Gas (TIG) welding - An in vitro study

Gopisetty Harshini[1], S. Venkat Aditya[2], K. Mahendranadh Reddy[3], Y. Mahadev Shastry[4], G. V. Krishna Mohan Reddy[5], Jayakrishna Babu[6]

[1] *PG student, Department of Prosthodontics, Sri Sai College Of Dental Surgery, Telangana, India*
[2] *Professor, Department of Prosthodontics, Sri Sai College Of Dental Surgery, Telangana, India*
[3] *Professor and HOD, Department of Prosthodontics, Sri Sai College Of Dental Surgery, Telangana, India*
[4] *Professor, Department of Prosthodontics, Sri Sai College Of Dental Surgery, Telangana, India*
[5] *Reader, Department of Prosthodontics, Sri Sai College Of Dental Surgery, Telangana, India*
[6] *Reader, Department of Prosthodontics, Sri Sai College Of Dental Surgery, Telangana, India*

ARTICLE INFO

Keywords:
TIG welding, Bond strength, Titanium, Universal testing machine

ABSTRACT

PURPOSE: The aim of the study was to evaluate the shear bond strength of ceramic layered to commercially pure Titanium after Tungsten inert gas (TIG) welding.
MATERIALS AND METHODOLOGY: 60 pre fabricated titanium blocks were taken and were equally and randomly allocated in to two groups i.e., TIG welding and control group. The TIG welded group samples were ditched on one end in an area of 5mm x 5mm to a depth of 0.5mm for layering the compatible welding material using TIG welding technique. Ceramic was veneered onto both the group samples using putty mould which was with inner dimensions of 5 x 5x 2mm in area. Universal testing machine was used to measure the shear bond strength and the results were statistically analysed.
RESULTS: The average shear bond strength of ceramic veneered to titanium was 25.3N/mm^2. Whereas for the ceramic veneered to TIG welded group samples was 53.64N/mm^2. Significant difference was found in the bond strength between the TIG welded and control group.
CONCLUSION: Within the limitation of this study, it was concluded that TIG welding gives a better metal-ceramic bond strength.

INTRODUCTION

The phase which most individuals face is missing teeth. The standard of care worldwide for replacement of missing teeth is fixed crown and bridges, removable partial or complete denture, cast partial denture and dental implants.[1] Titanium is the most commonly used base metal alloy for the implant prosthesis. Titanium is called as a "miracle material" because of its properties of corrosion resistance, shape memory, high strength, rigidity, low density and biocompatibility.[2] Recently, ADA has placed titanium alloy between high-noble and noble alloys in the revised classification because of its excellent biocompatibility.

The passive fit of a cast metal framework and supporting prosthesis is very much necessary for long-term success of any implant prosthesis, even a slight misfit of the prosthesis will lead to a remake of the entire prosthesis. In such situations, sectioning of the metal framework after casting can be done and re-assembled by soldering or welding to achieve a passive fit and avoid the remake of the prosthesis.[3,4] Welding is a process carried out by heating the broken parts to their melting point and fusing them together by application of pressure in cold or heated state. Tungsten inert gas welding has gained popularity, as it provides a concentrated heating of the workplace, is independent of filler material, can be welded in areas of difficult access and no slag or spatter is produced after the welding.[5] It can be used in situations as in correction of porosities, defective frameworks, defective margins of crowns, connector area in crown and bridge prosthesis and ill-fitting prosthesis without the need for remakes.[6]

The success of these restorations depends on the presence of strong bond between the porcelain and metal substructure. The purpose of this In- Vitro study

* Corresponding author: ***Gopisetty Harshini, PG student, Department of Prosthodontics, Sri Sai College Of Dental Surgery, Telangana, India***

was to investigate the effect of TIG welding on the bond strength between welded titanium metal and veneering ceramic.

MATERIALS AND METHODOLOGY

The study was undertaken in the Department of Prosthodontics. 60 Type II pre fabricated Commercially pure Titanium blocks of 15x5x3mm dimensions were used. An acrylic block was made with dimensions of 5x5x2mm using acrylic resin and a putty index was made of this acrylic block using addition silicone material (Dentsply, Aquasil). This putty index was used as a guide for layering uniform thickness of ceramic of constant dimensions on the titanium block.[7]

These blocks were randomly allocated into two groups to avoid bias. 30 blocks in each group. Group A and Group B

Group A - Test group (TIG group) and

Group B - Control group

TEST GROUP

A layer of titanium was removed at one side of the block in an area of 5x5mm to 0.5mm depth using carborundum disk.[8]This area of the test group blocks was treated with 250microns alumina followed by 110 microns through sandblasting under 30 pounds of air pressure.[9]On this area, 0.5mm of titanium alloy was built up using TUNGSTEN INERT GAS welder (Lampert PUK D2) so that the surface was leveled to get the original profile. [10,11,12,13]

TUNGSTEN INERT GAS WELDING

A cylinder which contains argon gas was attached to the Lampert welding control unit and was programmed for titanium material with power 45% for 7 milliseconds. This argon gas controlled the temperature for titanium welding. The electrodes were internally connected to the control unit and microscope. The microscope had a filament nib connected, through which the current passed and a clip that held on to the titanium block. When this filament nib and the clip that held the block came in contact, it completed a circuit.[14] Titanium alloy was held on to the titanium block and when the current passed through the filament nib, the alloy melted on to the 0.5mm area where previously a layer of titanium was removed. This completed TIG welding process followed by ceramic layering.[15]

CERAMIC LAYERING

The test group and control group surfaces were cleaned in an ultrasonic cleaner for 2 minutes to remove any remnant alumina particles left over on the surface and then treated with 250microns alumina followed by 110microns alumina through sandblasting under 30 pounds of air pressure.

Glass ceramic initial was applied as a thin layer in a single coat for adhering of ceramic on to titanium followed by firing cycle in the ceramic furnace for 15minutes at 810^0C.[16]For the TIG welded group, ceramic layering was done at the sandblasted area of the block where Tig welding was done initially.[17] 0.3-0.5mm of opaque paste was applied as a single coat using glass spatula until it masked the underneath metal followed by opaque firing cycle in the ceramic furnace for 15 minutes at 810^oC.[7] After the completion of the firing of the opaque layer, 2ml of liquid with 1.42 gms of dentin powder was dispensed and was applied using a putty index guide for uniform thickness followed by firing cycle for 15 minutes at 780^0C.[18]The glaze was applied as a thin coat using brush followed by firing in the ceramic furnace for 15 minutes at a 780^0C and then it was allowed to cool.

Group A and Group B samples veneered with the ceramic material were mounted on a Universal Testing Machine (UTM) with a crosshead speed of 1mm/min to test shear bond strength.[19] Results obtained were tabulated and subjected to statistical analysis using spss software.

RESULTS

All the analysis was done using SPSS version16. Comparison of mean shear load and strength between groups was done using independent sample t test. The maximum and minimum shear bond strength of ceramic veneered to titanium (CpTi) was found to be 38.049MPa and 21.09MPa[7] and the average of it was 25.53 MPa (Table 1).

The maximum and minimum shear bond strength of ceramic veneered to TIG welded titanium samples was 70.742MPa and 40.323MPa[11]and the average of it was 53.64MPa (Table2).

Chi square test(p) value showed less than 0.001 NS. Statistical analysis revealed significant difference between the two groups (Table 3). After shear testing, cohesive mode of failure in veneering materials was observed in both the groups. When the SEM images were evaluated, the cohesive failures were often observed as partially delaminated surfaces revealing no clear crack sites.[8,17]

Table 1 Shear Bond Strength of Ceramic Veneered To Titanium (CpTi) - Control Group

Specimen	C.S.A sq.mm	Shear load N	Shear strength MPa
1	24.00	580.0	24.558
2	24.00	700.0	28.458
3	24.00	900.0	37.488
4	24.00	520.0	21.094
5	24.00	540.0	22.833
6	24.00	840.0	33.268
7	24.00	640.0	24.904
8	24.00	550.0	21.707
9	24.00	930.0	38.049
10	24.00	760.0	31.405
11	24.00	620.0	24.731
12	24.00	570.0	22.426
13	24.00	660.0	28.385
14	24.00	780.0	35.643
15	24.00	800.0	33.398
16	24.00	580.0	22.142
17	24.00	700.0	26.458
18	24.00	900.0	35.286
19	24.00	520.0	23.706
20	24.00	540.0	25.523
21	24.00	840.0	30.312
22	24.00	640.0	27.944
23	24.00	550.0	23.652
24	24.00	930.0	36.213
25	24.00	760.0	33.696
26	24.00	620.0	26.136
27	24.00	570.0	25.501
28	24.00	660.0	26.336
29	24.00	780.0	34.874
30	24.00	800.0	31.900

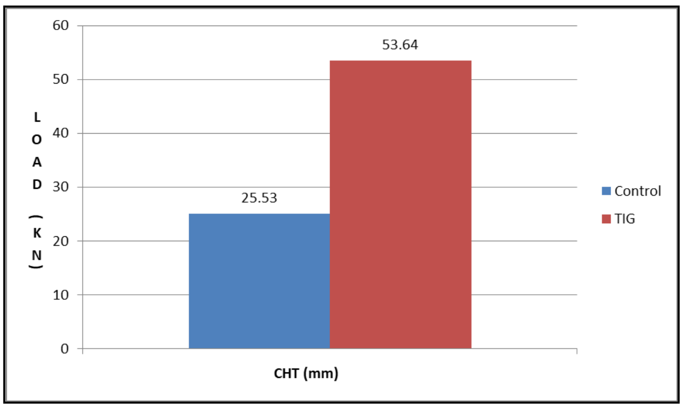
Table 2 : Shear Bond Strength of Ceramic Veneered to Tig Welded Titanium (CpTi) - Test Group

Specimen	C.S.A sq.mm	Shear load N	Shear strength MPa
1	24.00	160.1	46.871
2	24.00	210.1	48.518
3	24.00	400.1	54.807
4	24.00	180.1	47.071
5	24.00	310.1	55.009
6	24.00	580.1	65.046
7	24.00	240.1	53.825
8	24.00	330.1	54.803
9	24.00	200.1	48.108
10	24.00	560.1	64.747
11	24.00	190.1	51.655
12	24.00	260.1	50.807
13	24.00	210.1	51.127
14	24.00	360.1	40.323
15	24.00	630.1	70.742
16	24.00	160.1	43.476
17	24.00	210.1	46.911
18	24.00	400.1	56.387
19	24.00	180.1	49.201
20	24.00	310.1	52.244
21	24.00	580.1	64.476
22	24.00	240.1	55.716
23	24.00	330.1	58.501
24	24.00	200.1	49.562
25	24.00	560.1	62.462
26	24.00	190.1	47.191
27	24.00	260.1	52.800
28	24.00	210.1	55.616
29	24.00	360.1	45.725
30	24.00	630.1	66.429

Table 3: Mean and Standard Deviation of Shear Bond Strength of Two Groups

Control		TIG		p-value
Mean	SD	Mean	SD	
25.53	5.23	53.64	7.38	0.001 NS

Chart 1: Mean Shear Bond Strength of Control and Tig Welded Samples.



DISCUSSION

The clinical performance of metal–ceramic FPDs is usually estimated by the bond strength tests where the adhesion of the specific ceramic to the metal substrate is tested. The longevity of any metal ceramic restorations depends on reliable bonding between metal and ceramic, primarily produced by an oxide layer.

Certain metals like Ti oxidize and easily formvery thin, stable passive layer that is self-limiting and protects the surface of the metal from further oxidation. The evaluation of bond strength between the alloy and the ceramic can be done using the shear bond test. Shear bond strength test method was used to evaluate the ceramic bond strength to titanium because of its simplicity, ease of specimen preparation, simple test protocol and ability to rank different products according to bond strength values.

The shear bond strength of control group showed less bond strength when compared to TIG welded group probably due to the oxidation that occurs at the interface of metal and porcelain. When working with temperatures between 700°C and 800°C, it is possible to obtain an unacceptable bond. Values that are close to or exceed 900°C promote the formation of a thick layer of oxide (TiO2) between the porcelain and the metal, making the union unfeasible and decrease the strength of the bond.[9] This study has followed a process of TIG welding followed by trimming the surface and then sandblasting was performed in order to remove the oxide layer formed. Thus reducing the influence of the oxide layer formed during welding on the bond strength.

The bond strength and fracture resistance are strictly related to the difference of thermal expansion between the metal substrate and the porcelain. In order for them to be compatible, the difference in the thermal expansion coefficient between the materials should be equal to or less than $1\times 10^{-6}/^{0}C$. Titanium has a thermal expansion coefficient of $9.41 \times 10\times {}^{-6}/^{0}C$, in the interval of 25–400°C.[9] The thermal expansion coefficient of the porcelain Vita Titanium ceramic used in this study according to its manufacturer is 8.2–8.9 × 10^{-6}/°C which is within the range of compatibility and is compatible with the bond strength.

The highest shear bond strength seen with ceramic veneered to TIG welded titanium group was 70.7N/mm^2. TIG welded group showed higher bond strength which may be due to the use of a powerful heat source (TIG) which increased the size of the welded site without reducing the diameter of the welded transverse area.[11] Use of argon gas with filler wire of the same parent metal produced strongest and fracture resistant joint.[10]

In the present study, Pearson Chi-Square test (P) was done using the bond strength values. The minimum P value count is 0.05 and the present study P value showed less than 0.001. This determines that there is significant difference between the expected frequencies and the observed frequencies.

Type of ceramic failure was determined by using quantitative scanning electron microscope(SEM) and failure modes were examined at 150 x magnification. Categorization of the failure modes in this study demonstrated cohesive failure in ceramic which was difficult to quantify visually the presence or absence of opaque porcelain due to combined microscopic fractures within the opaque layer and porcelain.

CONCLUSION

According to the results of the study, the metal ceramic bond strength of dental porcelain to the titanium was influenced by TIG welding since significant difference was found between the welded and control group. So TIG welding would be a better viable option for repairs in implant prosthesis.

Fig 1: TUNGSTEN INERT GAS WELDING (TIG GROUP)

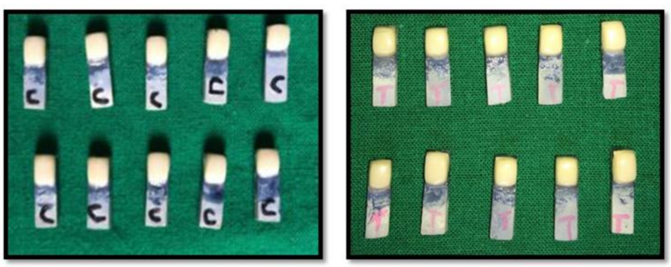


Fig 2: CERAMIC LAYERING ON CONTROL AND TEST GROUPS

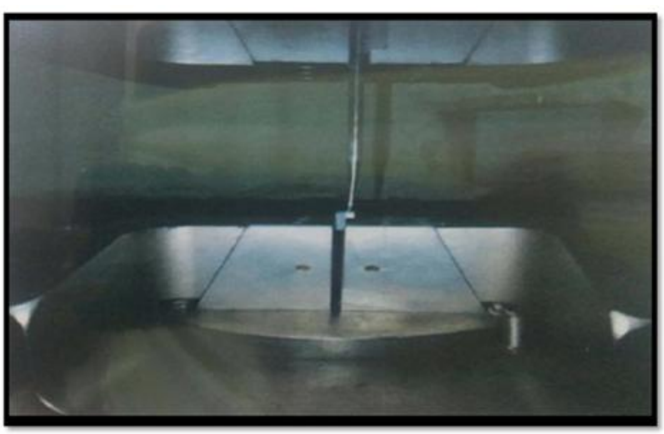


Fig 3: TITANIUM BLOCK MOUNTED ON UNIVERSAL TESTING MACHINE

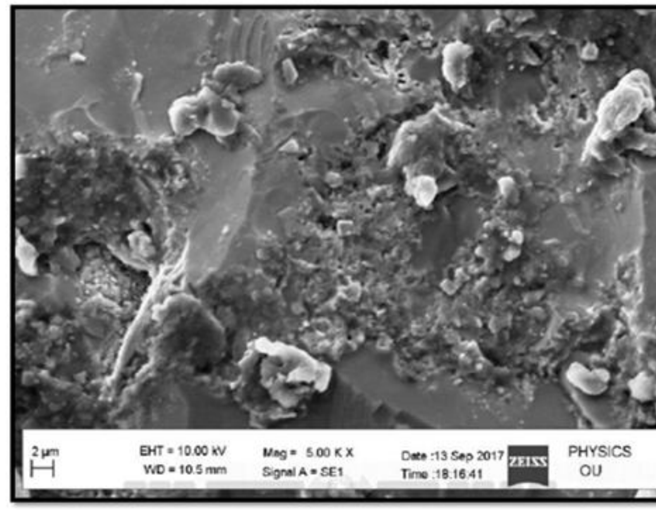


Fig 4 : SEM IMAGE OF CONTROL GROUP

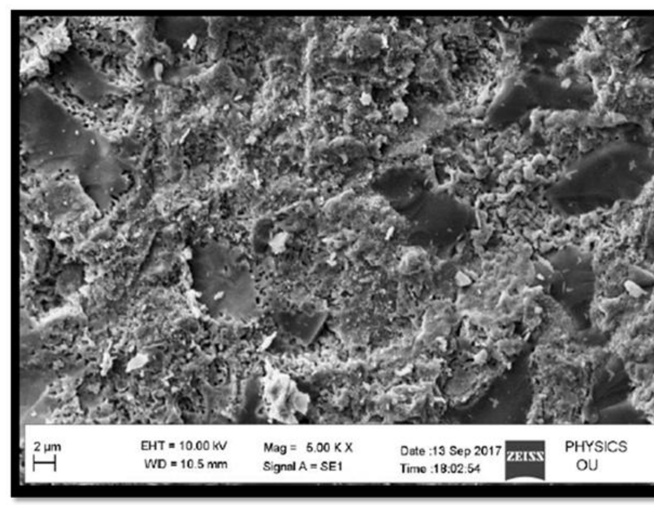


Fig 5 : SEM IMAGE OF TEST GROUP (TIG)

REFERENCES

1. John A. Hobkirk, Roger M Watson, Lioyd J Searson. Introducing Dental Implants. 1st ed. Livingstone: Churchill Livingstone; 2003. p.3-18 .
2. Reham B. Osman, Michael V. Swain. A Critical Review of Dental Implant Materials with an Emphasis on Titanium versus Zirconia. Materials 2015; 8: 932-958.
3. Saime Sahin, Murat C. Çehreli. The Significance Of Passive Framework Fit. In Implant Prosthodontics: Current status. Implant Dentistry.2001; 10(2):85-92.
4. Titanium applications in dentistry. JADA 2003; 134:347-349.

5. John S. Shell, John P, Nielsen. Study of the Bond between Gold Alloys and Porcelain. J Dent Res.1962; 41(6):1424-1437.
6. Mutlu Ozcan, Christoph Hammerle. Titanium as a Reconstruction and Implant Material in Dentistry: Advantages and Pitfalls. Materials 2012; 5:1528-1545.
7. Khalid A. Al Wazzan, Ibrahim AL Hussaini, Ahmad A. AL NAzzawi. Bond compatibility of low-fusing porcelain to recast titanium. Pak Oral Dent J 2006; 26 (1):125-130.
8. Aladag A, Çomlekoglu E, Dundar M, Ali Gungor, Celal Artunç. Effects of soldering and laser welding on bond strength of ceramic to metal. J Prosthet Dent 2010; 105: 28-34.
9. Moldi AI, Bhandari KS, Nagral S, Deshpandey S, Kulkarni P. Effect of sandblasting on fracture load of titanium ceramic crowns. J Indian Prosthodont Soc 2017; 15(3): 224–228.
10. Youssef S. Al Jabbari, Theodoros Koutsoukis, Raymond A. Fournelle. Effect of Nd:YAG laser parameters on the penetration depth of a representative Ni-Cr dental casting alloy. Lasers Med Sci 2015; 4:26-40.
11. Rocha R, Pinheiro AL, Villaverde AB. Flexural strength of pure Ti, Ni-Cr and Co-Cr alloys submitted to Nd:YAG laser or TIG welding. Braz Dent J 2006; 17:20-23.
12. Tadayuki Otani. Titanium Welding Technology. Nippon steel technical 2007; 95:28-32.
13. Bock JJ, bailly J, Gernhardt CR, Werner RA. Fracture strength of different soldered and welded orthodontic joining configurations with and without filling material. J Appl Oral Sci. 2008; 16(5):328–335.
14. Yasuko Takayama, Rie Nomoto, Hiroyuki Nakajima and Chikahiro Ohkubo. Effects of argon gas flow rate on laser-welding. Dent Mater J 2012; 31(2): 316–326.
15. Masanobu Yoda, Tatsuhiko Konno, Yukyo Takada, Kazunori Iijima, Jason Griggs, Osamu Okuno et al. Bond strength of binary titanium alloys to porcelain. Biomaterials 2001; 11:1675-1681.
16. Takushi Fukuyama, Naho Hamano, Satoshi ino. Effects of silica-coating on surface topography and bond strength of porcelain fused to CAD/CAM pure titanium. Dent Mater J 2016; 35(2):325–332.
17. Garbelini WJ, Henriques GE, Troia Junior M, Mesquita MF, Dezan CC. Evaluation of low-fusing ceramic systems combined with titanium grades II and V by bending test and scanning electron microscopy. J Appl Oral Sci 2003; 11(4):354-60.
18. Akihiko Shirakura, Heeje Lee, Alessandro Geminiani, Carlo Ercoli, Feng C. The influence of veneering porcelain thickness of all ceramic and metal ceramic crowns on failure resistance after cyclic loading. J Prosthet Dent 2009; 101:119-127.
19. Haralambos Petridis, Hiroshi Hirayama, Gerard Kugel, Charles Habib, Pavlos Garefis. Shear bond strength of techniques for bonding esthetic veneers to metal. J Prosthet Dent 1999; 82:608-14.