Original Research

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A COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF ZIRCONIA CORE AND VENEERING CERAMICS OF TWO CAD/CAM SYSTEMS, CEREC AND LAVA- AN INVITRO STUDY

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ABSTRACT

Background: All- ceramic restorations are most frequently used restorations in replacement of missing teeth. Combination of strong core with an esthetic ceramic veneer is used in recent times for fixed partial dentures. The bond strength between the zirconia core and ceramic veneer is the weakest component in the layered structure. The purpose of this study is to evaluate and compare the shear bond strength of zirconia core with their veneered ceramics milled by two different CAD/CAM systems i.e., CEREC and LAVA. **Materials & Methods:** A study was carried out using 40 samples of zirconia veneered with their respective ceramics of two CAD/CAM systems, 20 samples from each CAD/CAD systems CEREC and LAVA were collected. Zirconia blocks of dimension 5x5x4mm, length, breadth and width respectively were milled from two CAD/CAM systems; later blocks were veneered with their respective ceramics. After ceramic build up the samples were subjected to shear bond strength using the Instron universal testing machine at the interface of zirconia and ceramic at speed of 0.5mm/min. The amount of force at which delamination occurred was recorded in Newtons. Shear strengths were calculated by dividing the force at which the failure occurred by the bonding area. **Results:** Higher mean shear bond strength (Mpa) is recorded in LAVA compared to CEREC system and the difference in strength between them is found to be statistically significant. **Conclusion:** Within the limitations of this study, higher mean shear bond strength was recorded in LAVA system compared to CEREC system. However, the precise bonding mechanism between zirconia and veneered ceramic has not yet been identified. The final product is probably influenced by variables like chemical structure, difference in coefficient of thermal expansion, their fabrication technique, milling procedure and sintering temperature difference.

KEYWORDS: Shear strength; zirconia; CAD/CAM; ceramic

INTRODUCTION

The increasing demand for esthetic restorations can be met with ceramic restoration systems that are currently available. All-ceramic restorations are preferred in clinical dental practice mainly because of their superior aesthetics, inertness and biocompatibility when compared to their metal–ceramic counterparts.[1] The introduction of tetragonal zirconia polycrystals as a restorative core material has expanded the use of ceramic restorations. As a restorative core material it opened up the design limits of all-ceramic restorations to extensive multiunit restorations with high confidence and success rates. The unique chemical stability, the superior mechanical properties, and esthetics, combined with CAD/CAM technology all make zirconia the core material of choice.[2-4] Zirconia frameworks can be fabricated mainly with the help of CAD/CAM or copy-milling techniques by means of grinding zirconia block.[5,6] Currently, several CAD/CAM system use zirconia based ceramics for frameworks like CEREC, LAVA, CERCON, PROCERA, etc. Shear strength is the maximum stress that a material can withstand before failure in a shear mode of loading i.e., a twisting motion or sliding of the body over another. The bond strength between veneer ceramic and the zirconia framework is the weakest component in the layered structure.[4] To ensure structural integrity of restorations under functional loads and to

Fig. 1: A customized jig with sample placed in PVC pipe using cold cure acrylic

Fig. 2: Sample mounted in jig, subjected to force by universal testing machine

Fig. 3: Sample after subjecting to shear load in universal testing machine

prevent chipping and delamination of the veneer ceramic, the core veneer bond must be of a certain minimal strength.[9] Many variables may affect the core-veneer bond strength such as the surface finish of the core, which affects mechanical retention, residual stresses generated by mismatch in thermal expansion coefficient , development of flaws and structure defects at core-veneer interface and wetting properties and volumetric shrinkage of the veneer.[3] The purpose of this study is to evaluate the shear bond strength of zirconia core with their veneering ceramics milled by two CAD/CAM systems i.e., CEREC and LAVA.

MATERIALS AND METHOD

Specimen Collection

A total of 40 zirconia blocks measuring 5x5x4mm length breadth and width were collected. 20 zirconia blocks were milled using CEREC CAD/CAM system and 20 zirconia blocks milled using LAVA CAD/CAM system. To mill zirconia blocks, dies were fabricated using die stone dimension of 5x5x4mm length breadth and width respectively. CEREC zirconia samples were fabricated in the following stages:

Scanning: The prepared die is sprayed with contrasting powder before scanning in order to adjust the optical properties of die stone and to enable accurate scan. The CEREC acquisition unit is mobile and houses a computer. It uses non-contact optical scan system. For optical measurement of sample, a laser light source of wave length 650nm present with in the unit records the digital impression of the die.

Designing: The computer and CEREC software converts the optical measurement of sample to a virtual model. Then it is designed of the screen using software according to the desired shape. Once it is designed the design is transfered onto CEREC milling unit.

Milling: The milling process is started by clicking the “mill” icon. The diamond coated burs present in the milling unit will carve the zirconia blank to desired size and shape. The time taken to mill the samples is around 20 minutes.

Sintering: Rapid 90-minute sintering of zirconia blocks is done at a temperature 1500^{o}C.

LAVA zirconia samples were fabricated in the following stages:

Scanning: The non-contact optical scan system includes a computer with monitor and the Lava CAD software, which displays the model as a three-dimensional object. The scanner automatically records and digitizes the dies.

Designing: The design of the die appears on the screen. Any additional design or modelling required is done with the software support. The data is then transfered on to milling unit.

Milling: The blocks were milled from a zirconium oxide blank using hard metal tools. The average milling time is 18-20 minutes.

Sintering: The fully-automated, monitored sintering process is done with no manual intervention in a special furnace, the Lava Therm. Once the Start button is pressed, the sintering program starts up automatically and heats the furnace to 1,500°C. The sintering time is approx. 8 hours.

PORCELAIN BUILD UP

Porcelain build up was started according to the manufacturing instructions. Each zirconia sample was veneered with its own ceramic material. CEREC zirconia samples were veneered with Noritake. The irregularities and excess material were removed using micromotor hand piece. The blocks were cleaned in ultrasonic bath. Ceramic is layered onto the zirconia blocks with no additional surface treatment. Appropriate amount of ceramic powder and liquid is mixed to get a creamy consistency mix. Using a damp brush the mix is layered onto the surface of the zirconia blank. Ceramic build up was done upto 2mm. The ceramic is dried for 5 minutes then placed in a ceramic firing unit. Firing is done from temperature 600^0C to 930^0C under vaccum. Hold time under vaccum is1 minute. Lava zirconia samples were veneered with LAVA ceram. Similarly the LAVA blocks were checked for irregularities and cleaned in ultrasonic bath. Appropriate amount of ceramic powder and liquid is mixed to get a creamy consistency. Using damp brush the mix is layered onto the surface of zirconia sample. Thickness of ceramic build up was 2mm. The sample is then placed in a ceramic firing unit after dying it for 5 minutes. Firing is done from temperature 450^0C to 800^0C under vaccum. Hold time under vaccum is 1 minute. The fabricated zirconia block samples were mounted onto the Poly Vinyl Chloride (PVC) pipe and placed on to the jig to apply shear force. Poly vinyl chloride pipe was taken and cut into 40 pieces of uniform dimension measuring 2cms in length. Self cure acrylic resin is mixed according to manufacturer's instructions and poured in fluid stage into the pipe (Fig. 1). The samples were later embedded along their vertical alignment so that ceramic build up is above the top of the standard PVC mounting cylinders. This is done to ensure the application of force is at the zirconia and ceramic interface (Fig. 2). The prepared samples were loaded on to UTM-INSTRON UNIVERSAL TESTING MACHINE. Samples were mounted on customised jig. The jig used has two components, one is attach to universal testing machine to apply force, the other component with the provision to place the poly vinyl chloride mounting cylinders in it and is attached to the universal testing machine to hold the specimen at the time of testing. Force was applied by a stainless steel jig until fracture occurred. Universal testing machine cross head speed was maintained at 0.5mm/min. the fracture load was measured and recorded by a digital monitor in Newton for all samples.

RESULTS

This study consisted of total 40 samples, 20 samples belonging to group A (CEREC) and 20 samples belonging to group B (LAVA). The ultimate load at which the delamination of ceramic occurred was recorded in Newtons and the shear bond strengths were calculated in Megapascals (MPa) by dividing the load (N) at which failure occurred by the bonding area (mm^2). Shear stress (MPa) = Load (N)/ Area (mm^2) Where bonding area is calculated by formula length x breadth i.e,. Area = 5mm x 4mm = $20mm^2$. Table I and II illustrates the amount of force applied and stress of displacement of group A and group B respectively. In group A the maximum shear strength recorded was 7.78 MPa and the amount of load required to delaminate the ceramic is 155.6N. In group B the maximum shear strength recorded was 18.45 MPa, and the amount of load required to delaminate the ceramic is 370.9N. In group A the minimum shear strength recorded was 4.05MPa, the amount of load required to delaminate the ceramic was 81.18N. In group B the minimum shear strength recorded was 1.80MPa, the amount of load required to delaminate the ceramic was 36.14N. Statistical test used for analysis is un-paired t- test. According to Null Hypothesis there was no significant difference in the mean shear bond strength between two systems, however in Alternate Hypothesis significant difference was found in the mean shear bond strength between the two systems. Higher mean shear bond strength is recorded in group B when compared to group A.

Table I: The amount of force applied and stress of displacement of group A samples

Sample	N	MPa
1	122.1	6.10
2	91.21	4.56
3	85.82	4.29
4	106.2	5.31
5	81.18	4.05
6	106.0	5.31
7	131.2	6.56
8	155.6	7.78
9	84.33	4.21
10	92.61	4.63
11	93.42	4.53
12	106.2	5.31
13	91.21	4.56
14	131.2	6.56
15	84.33	4.21
16	81.18	4.05
17	91.21	4.56
18	131.2	6.56
19	84.33	4.21
20	106.0	5.3

DISCUSSION

The continuing search for ultimate strength, esthetics and biocompatibility has always encouraged the development of new improved restorative materials, especially in the field of dental ceramics. Despite the success of porcelain fused to metal restorations, the need for better esthetics and biocompatibility remains and is the driving force for the development of all-ceramic core materials. The introduction of zirconia as a dental material has generated considerable interest in the dental community. Zirconia is widely used to build restorations because of its good chemical properties, dimensional stability, high mechanical strength, toughness, and Young's modulus similar to that of stainless steel alloy. The sintering behavior of zirconia does not allow the fabrication of fixed partial denture frameworks by direct sintering on customized dies. Therefore, fixed partial dentures made from commercially available zirconium oxide ceramic can be fabricated only by machining techniques that require conventional copy milling or computer-aided design/computer-assisted manufacturing (CAD/CAM) procedures.[7]

Table II: The amount of force applied and stress of displacement of group B samples

Sample	N	MPa
1	36.14	1.8
2	241.4	12.07
3	201.9	10.09
4	113.2	5.66
5	287.7	14.38
6	295.3	14.76
7	370.9	18.45
8	277.0	13.85
9	238.2	11.91
10	269.4	13.47
11	113.2	5.66
12	241.4	12.07
13	370.9	18.45
14	287.7	14.38
15	113.2	5.66
16	269.4	13.47
17	241.4	12.07
18	113.2	5.66
19	201.9	10.09
20	295.3	14.76

Complications that are commonly associated with zirconia based fixed partial dentures include framework fracture, minor veneer chipping, secondary carries, loss of retention, abutment tooth extraction, endodontic problems and gingival bleeding. The most frequent problem in all studies of zirconia reconstructions is chipping or cracking of the veneer ceramics.[8] The cause of fracture of veneering ceramics on zirconia all-ceramic cores was reported to be multifactorial in clinical applications. Restoration geometry such as lack of proper veneering ceramic support, inadequate framework design and thickness of the ceramic layers seem to play a decisive role. Moreover direction, magnitude and frequency of the applied load as well as size and location of occlusal contact areas can contribute to failures of the veneering ceramic.[10] The core–veneer bond strength was previously investigated using mean tensile bond strength, and the results indicate that the bond strength was sensitive to the surface finish of the framework material and to the type of the veneer ceramic and its method of application.[20] The main aim of this study was to compare the shear bond strength of the two

Table III: mean value of group A and B, standard deviation and p value

Un-paired t test					
Groups	Mean	Std. Deviation	t value	p value	Significance
CEREC	5.1320	1.06086	6.108	0.000	HS
LAVA	11.4355	4.49140			

CAD/CAMsystems CEREC and LAVA and to evaluate the amount of load required to delaminate the veneered ceramic from zirconia core of two systems. In a previous study, the zirconia-veneer bond strength was inferior when compared to other all-ceramic systems, which suggests that the zirconia framework layered with ceramic are more susceptible to delamination and chipping under function.[4] In this study the type of zirconia frame work used was the white colour and no surface treatment was carried out on the zirconia surface before layering ceramic on to it. The shear bond strength of zirconia and its veneered ceramics of two CAD/CAM systems CEREC and LAVA were evaluated. This study consisted of total 40 samples, 20 samples belonging to group A (CEREC) and 20 samples belonging to group B (LAVA). The samples were later tested for the shear bond strength at the interface between zirconia and ceramics. Samples were loaded with shear stress using universal testing machine. The ultimate load at which the delamination of ceramic occurred was recorded in Newtons and the shear bond strengths were calculated in Megapascals (MPa) by dividing the load (N) at which failure occurred by the bonding area (mm^2). Shear stress (MPa) = Load (N)/ Area (mm^2) Where bonding area is calculated by formula length x breadth i.e,. Area = 5mm x 4mm = $20mm^2$. In group A the maximum shear strength recorded was 7.78 MPa and the amount of load required to delaminate the ceramic is 155.6N. In group B the maximum shear strength recorded was 18.45 MPa, and the amount of load required to delaminate the ceramic is 370.9N. The probable reasons behind the enhancement of overall strength of all ceramic restorations include the coefficient of thermal expansion of veneering porcelain and core material. It was proved that, for metal ceramic restorations, veneering porcelain with a slightly lower coefficient of thermal expansion compared to that of framework material is recommended. The concept behind this slight coefficient of thermal expansion mismatch is to generate compressive stresses in the weaker veneering porcelain, probably enhancing the overall strength of the restoration. However, only limited information is available on the influence of coefficient of thermal expansion on the bond behavior of veneering porcelain to zirconia framework.[29] Along with the coefficient of thermal expansion the glass transition temperature of the veneering porcelain also have an impact on the shear bond strength of veneering porcelain to zirconia.[29] In group A the minimum shear strength recorded was 4.05MPa, the amount of load required to delaminate the ceramic was 81.18N .In group B the minimum shear strength recorded was 1.80MPa, the amount of load required to delaminate the ceramic was 36.14N. In an invitro study the use of veneering porcelain with a coefficient of thermal expansion higher than that of zirconia framework resulted in delamination of the veneer and formation of massive microcracks.[3] Higher mean shear bond strength is recorded in group B when compared to group A and the difference in mean shear bond strength between them is found to be statistically significant. According to Null Hypothesis there was no significant difference in the mean shear bond strength between two systems, however in Alternate Hypothesis significant difference was found in the mean shear bond strength between the two systems. In the current study the complete delamination of the ceramic was not seen macroscopically in all samples. In few samples remnants of ceramic were seen on the zirconia. In few samples there was complete delamination of the veneered ceramic. The type of ceramic failure adhesive or cohesive was not evaluated in this study. According to studies the bond strength is determined by range of factors, including chemical bonds, mechanical interlocking, type and concentration of defects at the interface, wetting properties, and the degree of compressive stress in the veneering layer.[30] It is believed that core and veneer materials fuse together and some elements from each material diffuse across the interface. Either of these occurrences can cause a chemical alteration of the glass layer adjacent to the core, possibly by altering the physical properties, such as strength or coefficient of thermal expansion at the interface. However, the precise bonding mechanism between zirconia and veneering ceramic is yet to be identified and not well understood, since no documented evidence of the bonding between these materials is available.[3] It can be said that the final product might be influenced by the variables like, chemical structure, difference in coefficient of thermal expansion, their fabrication technique, milling procedure and sintering temperature difference. Limitations of this study and scope for further research: In the current study only two CAD/CAM systems are evaluated further research on different CAD/CAM systems can be carried out. Microscopic evaluation of the type of ceramic failure can be evaluated in future studies. Further study on different surface treatment on zirconia of different CAD/CAM system can be considered in future research. Long term survival rate studies on clinical restorations of different CAD/CAM systems is not available, this can be verified by further studies in future.

CONCLUSION

Within the limitations of this study, the following conclusion were made:

1. There is statistically significant difference in the mean shear bond strength between two tested groups.
2. Higher mean shear bond strength is recorded in group A compared to group B.

CONFLICT OF INTEREST & SOURCE OF FUNDING

The author declares that there is no source of funding and there is no conflict of interest among all authors.

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