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Analysis of the effects of implant cements between different abutments and CAD/CAM materials on connection strength

İmplant simanlarının farklı abutment ve CAD/CAM materyalleri arasındaki bağlantı dayanımı üzerine etkilerinin incelenmesi

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ABSTRACT

Objective: The aim of this study is to evaluate the effects of cementation of zirconium and titanium abutments and different Computer Aided Design/ Computer Aided Manufacturing (CAD/CAM) materials with 2 different implant cements on shear bond strength.

Methods: For this study, a total of 120 rectangular prism specimens of monolithic zirconia and titanium blocks have been prepared and 40 specimens have been prepared from 3 different CAD/CAM blocks. 9% hydrofluoric acid was applied to zirconia-supported lithium disilicate. Resin nano ceramic and zirconium oxide ceramic stabilized with yttrium were sandblasted with Al_2O_3 particles. CAD/CAM specimens produced were cemented on abutments using permanent and temporary implant cement. Upon the cementation, the specimens were stored in distilled water at 37°C for 24 hours, and after that, a microshear test was applied at a speed of 0.5 mm/min in a universal test device. The values obtained were evaluated statistically by Student's *t*-test, Mann–Whitney *U* test, Kruskal–Wallis, and all pairwise tests ($P < .05$).

Results: The bond strength of all permanent implant cements (17.15± 5.75) was found to be significantly higher than the bond strength of temporary implant cements (10.66 ± 3.85). No significant difference in the bond strength was determined between titanium (13.77 ± 4.64) and zirconia (14.04 ± 6.91) abutment materials. There was a significant difference between the superstructure ceramics in terms of bond strength ($P = .001$).

Conclusion: According to the results of this study, it was seen that the abutment material had no effect on the bond strength, but the bond strength of the selected cement and restoration was significantly affected.

Keywords: Adhesion, CAD/CAM, microshear

ÖZ

Amaç: Bu çalışmanın amacı, zirkonyum ve titanyum abutmentlar ile farklı CAD/CAM materyallerinin 2 farklı implant simanı ile simantasyonunun, makaslama bağlanma dayanımı üzerindeki etkilerinin değerlendirilmesi.

Yöntemler: Toplamda 120 adet dikdörtgen prizma şeklinde monolotik zirkonya ve titanyum örnekler hazırlandı. Zirkonya ile güçlendirilmiş lityum disilikat cam seramik, rezin nano seramik ve itrium ile stabilitize zirkonyum oksit seramik oluşan 3 farklı tip CAD/CAM bloğundan 40'ar adet örnek üretildi. Rezin nanoseramik ve yitrium ile stabilitize zirkonyum oksit seramik blokların simantasyon yüzeyi Al_2O_3 partikülleri ile kumlandı. Üretilen CAD/CAM örnekler, daimi ve geçici implant simanı kullanılarak simante edildi. Simantasyonu takiben örnekler 24 saat boyunca 37°C de damıtılmış su içinde saklandı ve sonra universal test cihazında 0,5 mm/dk hızla makaslama testi uygulandı. Elde edilen değerleri Student t-testi, Mann Whitney U, Kruskal Wallis ve All Pairwise testleri kullanılarak istatistiksel olarak değerlendirildi ($P < ,05$).

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Bulgular: Tüm daimi implant simanların bağlanma dayanımları [17,15 (±5,75)], geçici implant simanlarının bağlanma dayanımlarından [10,66 (±3,85)] anlamlı derecede yüksek bulundu. Titanyum [13,77(± 4,64)], ve zirkonya [14,04 (±6,91)] abutment materyalleri arasında bağlanma dayanımları bakımından anlamlı bir farklılık bulunmadı. Üst yapı seramikleri arasında bağlanma dayanımı bakımından anlamlı bir farklılık vardı (P = ,001).

Sonuç: Bu çalışmanın sonuçlarına göre abutment materyal tipinin bağlantı dayanımına etkisinin olmadığı ancak seçilen siman ve üst yapı restorasyonunun bağlantı dayanımında anlamlı derecede etkili olduğu görüldü.

Anahtar Kelimeler: Adezyon, CAD/CAM, mikroshear

INTRODUCTION

Dental ceramics were first used in the 18th century. The properties of the ceramics were developed, and different types of ceramics were produced. Currently, ceramics and ceramic-like restorative materials are classified into 3 main ceramic groups according to their structural content: glass-matrix, polycrystalline, and resin-matrix based on the classifications by Gracis et al.[1] To eliminate the dimensional problems that occur with homogeneity, microporosity, and high temperature firing processes, CAD/CAM systems are used.[2]

Dental implants serve as a reliable treatment option for partially or fully edentulous patients. The retention of implant-supported restorations with proven reliability is provided by cement or implant abutment screws.[3] More aesthetic materials are used in clinical applications with reinforced ceramic abutments that have a durability similar to titanium abutments.[4] However, considerations should be made when choosing between permanent and temporary cements. Temporary cements provide some advantages such as easy cleaning of residual cement, adequate retention under appropriate conditions, and easy removal of the restoration without damaging the abutment or implant.[5,6] However, they have some disadvantages compared to permanent cements including greater solubility and less retention. The main advantage of permanent cements is their degree of durability.[7]

Different methods have been used to analyze the mechanical properties of dental materials. Long-term in vivo studies are the most valuable but are also the most difficult when attempting to identify the specific behavior of the materials. Therefore, in vitro studies are typically conducted.[8] The micro-shear test is used to measure shear bond strength of a surface area of 1 mm² or less. In this test (given that the bonding surface is very small), the dispersed stress distribution caused by the forces applied to the interfaces in conventional shear tests decreases due to the reduction of the bonding surface.[8,9] Furthermore, the concentration of forces at the bonding interface, without the material bending, increases the accuracy of the test.[10]

The aim of this study was to evaluate the effects of 2 different implant cements used between zirconium and titanium abutments and 3 different CAD/CAM materials on shear bond strength.

Our null hypotheses were given as follows:

1. the use of temporary and permanent resin-based implant cements would not cause a significant difference in the bond strength between the abutments and the restorations.
2. there would be no significant differences between titanium and zirconia abutment materials in terms of bond strength.
3. evaluations of the bond strengths between the groups of specimens cemented with the same cement would show no differences between the different restorations.

MATERIAL AND METHODS

In this study, the CAD/CAM materials, zirconia reinforced lithium disilicate glass-ceramic (ZLS) (Vita Suprinity; Vita Zahnfabrik, Bad Sackingen, Germany), resin nano ceramic Lava Ultimate (3M ESPE, Seefeld, Germany), and a zirconium oxide ceramic stabilized with yttrium (Katana; Kuraray Nortake Dental Inc., Tokyo, Japan), were cemented on zirconia and titanium abutment materials using 2 different implant cements and their shear bond strengths were tested. The resin cement multilink speed (Ivoclar Vivadent AG, Schaan, Liechtenstein) was used for the permanent cementation of the implants, and the resin cement premier implant (Premier Dental Products Company, Plymouth Meeting, Pa, USA) was used for temporary implant cementation.

Sixty pieces of 16 × 9 × 2 mm titanium specimens in the form of rectangular prisms were produced using a Scheftner Starbond Ti5 Milling Disc (size: 18 × 98.3 mm) (Scheftner Dental Alloys, Mainz, Germany). The 16 × 9 mm surfaces of the specimens were polished to imitate the cementation surface of implant abutments. The final size of the zirconia specimens was 16 × 9 × 2 mm and was prepared from a zirconia disc with a precision specimen cutter (Metkon™ Micracut 151; Metkon, Bursa, Turkey) that was operated under cooling water at 250 rpm, considering the thickness of the cutting disc (0.43 mm) and the loss in size after sintering.

The prepared titanium and zirconia specimens were embedded in acrylic resin in a form suitable for the holder plate of a universal test device with a diameter of 28 mm and a height of 18 mm. The cementation surfaces were not covered. The samples were first gridded with 600 grid and then 800, 1000, and finally, 1200 grid silicon carbide abrasives.[11,12] Afterward, all samples were cleaned on an ultrasonic machine (UT 206; Sharp, Osaka, Japan) for 5 minutes with distilled water.

A total of 40 0.97 × 0.97 × 3 mm resin nano ceramic specimens were produced, 40 ZLS specimens were produced with final dimensions of 0.97 × 0.97 × 3 mm, and 40 specimens of monolithic zirconia were produced with final measurements of 0.95 × 0.95 × 3 mm.

The resin nano ceramic and monolithic zirconian specimens were sandblasted with Al_2O_3 particles with a particle size of 110 µm at a pressure of 4 megapascals bars (MPa) from a 10 mm distance for 10 seconds. The ZLS samples were roughened with 9% hydrofluoric acid for 20 seconds. All specimens were air dried for 60 seconds after the application of a universal primer containing Methacryloyloxydecyl dihydrogen phosphate (MDP) (Monobond

N; Ivoclar Vivadent AG, Schaan, Liechtenstein). All specimens were divided into 2 groups. Permanent implant cement was applied to one group, while in the other group the temporary implant cement was applied to the abutments and ceramic surfaces in accordance with the manufacturer's instructions. Ceramic specimens were placed on the surfaces of the titanium and zirconia with pliers, and polymerization was achieved just above and in the center of the ceramics with an Light Emitting Diode (LED) light device, under finger pressure, for 20 seconds. Excess cement was carefully removed with a scalpel. The prepared samples were then placed in distilled water for 24 hours.

Bond strength tests were carried out using a universal test device (Shear Bond Tester; Bisco, Vaterstetten, Germany). After the specimens were fixed on the specimen holder, a force was applied at a speed of 1 mm/min parallel to the bonding interface. The strongest forces that caused failure were recorded in Newtons (N). The shear force was calculated by dividing the resultant force by the 0.94 mm^2 bonding area. Failure types were evaluated by examining the fractured surfaces of the specimens at 30× magnification using a stereo microscope (ZEISS, Baden-Vürtemberg, Germany).

The Statistical Package for the Social Sciences version 22.0 program (International Business Machines Corp., Armonk, NY, USA) was used for all statistical analyses with $P < .05$ considered significant. The Shapiro–Wilk test was used to test for normality; the Student's *t*-test was applied to compare normally distributed numerical variables in 2 groups; the Mann–Whitney *U* test was used to compare non-normally distributed variables in 2 groups; analysis of variance and Least Significant Difference (LSD) tests were used to compare normally distributed variables in 3 groups; and the Kruskal–Wallis and all pairwise tests were used for the comparison of non-normally distributed variables in 3 groups.

RESULTS

In the shear bond strength test, the bond strength between titanium and zirconium surfaces and the 2 different resin cements, and 3 different all-ceramic materials were examined using MPa values (Table 1). The shear bond strength of 60 titanium and zirconia samples each were determined as 13.77 ± 4.64 and 14.04 ± 6.9 MPa, respectively. Regardless of the variety of cements and ceramics used, there were no significant differences in bond strength between all titanium and zirconia abutments ($P = .806$). Among the groups for which the bond strength of the abutment materials was evaluated, only the bond strength of the titanium abutment, temporary implant cement, and the resin nanomer ceramic [titanium abutment-premier implant cement-Lava Ultimate ceramic (TPL)] group samples was found to be significantly higher than those in the zirconia abutment, temporary implant cement, and resin nanomer ceramic [zirconia abutment-premier implant cement-Lava Ultimate ceramic (ZPL)] group. The mean was 17.15 ± 5.75 MPa in the samples bonded with permanent implant cement and 10.66 ± 3.85 MPa in samples bonded with temporary implant cement. The bond strengths of all permanent implant cements were significantly higher than those of temporary implant cements. ($P = .001$) (Table 2).

The bond strength of samples in the group of titanium abutment, permanent implant cement, and zirconia ceramic [titanium abutment-multilink speed cement-Katana ceramic (TMK)] was significantly higher than the titanium abutment-premier implant cement-Katana ceramic (TPK) group ($P = .015$). The bond strength of samples in the group of titanium abutment, permanent implant cement, and resin nanomer ceramic [titanium abutment-multilink speed cement-Lava Ultimate ceramic (TML)] was significantly higher than the TPL group ($P = .001$). The bond strength of samples in the group of titanium abutment, permanent implant cement, and zirconia-reinforced lithium disilicate glass-ceramic [titanium abutment-multilink speed cement-Vita Suprinity ceramic (TMS)] was significantly higher than the titanium abutment, temporary implant cement, and zirconia reinforced lithium disilicate, which was also significantly higher than the glass ceramic [titanium abutment-premier implant cement-Vita Suprinity ceramic (TPS)] group ($P = .039$). The bond strength of the samples in the zirconia abutment, permanent implant cement, and zirconia ceramic [zirconia abutment- multilink speed cement- Katana ceramic (ZMK)] group was significantly higher than the zirconia abutment, temporary implant cement, and zirconia ceramic [zirconia abutment-premier implant cement-Katana ceramic (ZPK)] group ($P = .028$). The bond strength of the zirconia abutment, permanent implant cement, and resin nanomer ceramic [zirconia abutment-multilink speed cement-Lava Ultimate ceramic (ZML)] group was significantly higher than the zirconia abutment, temporary implant cement, and zirconia reinforced lithium disilicate glass ceramic [zirconia abutment-premier implant cement-Vita Suprinity ceramic (ZPS)] group ($P = .001$). The bond strength of the samples in the zirconia abutment, permanent implant cement, and zirconia reinforced lithium disilicate glass-ceramic [zirconia abutment-multilink speed cement-Vita Suprinity ceramic (ZMS)] group was significantly higher than that of the ZPS group ($P = .033$) (Table 3).

There was a significant difference between the restorations in terms of bond strength ($P = .001$). The average shear bond strength value of 16.26 MPa obtained from the samples using zirconia ceramics was found to be significantly higher than the materials (Table 4). The difference between the bond strength values of different restorations with temporary implant cement materials was significant ($P = .001$) In contrast, when permanent implant cements were used, there were no significant differences

Table 1. Micro-shear bonds in megapascals (MPa)

	N	Maximum (MPa)	Minimum (MPa)	Mean (MPa)	Standard. Deviation (MPa)
Group 1 (TML)	10	18.2	9.3	13.92	3.24
Group 2 (TPL)	10	11.2	6.3	8.49	1.56
Group 3 (TMS)	10	23.2	10.2	16.36	4.65
Group 4 (TPS)	10	15.9	8.7	12.55	2.48
Group 5 (TMK)	10	24.8	13.3	18.74	4.92
Group 6 (TPK)	10	15.9	8.00	12.56	2.66
Group 7 (ZML)	10	23.1	11.4	16.00	4.03
Group 8 (ZPL)	10	8.9	3.4	5.24	1.82
Group 9 (ZMS)	10	30.6	5.8	18.0	8.39
Group 10 (ZPS)	10	14.3	8.0	11.24	2.21
Group 11 (ZMK)	10	27.9	3.5	19.88	6.94
Group 12 (ZPK)	10	23.5	9.2	13.85	3.95

T, titanium; Z, zirconia; M, multilink speed cement; P, premier implant cement; K, Katana; S, Vita Suprinity; L, lava ultimate; TML, titanium abutment-multilink speed cement-Lava Ultimate ceramic; TPL, titanium abutment-premier implant cement-Lava Ultimate ceramic; TMS, titanium abutment-multilink speed cement-Vita Suprinity ceramic; TPS, titanium abutment-premier implant cement-Vita Suprinity ceramic; TMK, titanium abutment-multilink speed cement-Katana ceramic; TPK, titanium abutment-premier implant cement-Katana ceramic; ZML, zirconia abutment-multilink speed cement-Lava Ultimate ceramic; ZPL, zirconia abutment-premier implant cement-Lava Ultimate ceramic; ZMS, zirconia abutment-multilink speed cement-Vita Suprinity ceramic; ZPS, zirconia abutment-premier implant cement-Vita Suprinity ceramic; ZMK, zirconia abutment- multilink speed cement-Katana ceramic; ZPK, zirconia abutment-premier implant cement-Katana ceramic.

Table 2. Multilink speed and premier implant cement microshear bonds in megapascals (MPa)

Group	N	Mean	Standard Deviation	*P*
Multilink speed	60	17.15	5.75	.001*
Premier implant	60	10.66	3.85	

*$P < .05$.

Table 3. Cement type micro-shear test results in megapascals (MPa)

Group	n	Mean	Standard Deviation	*P*
TMK†	10	18.74	4.92	.015*
TPK	10	12.56	2.66	
TML**	10	13.92	3.24	.001*
TPL	10	8.49	1.56	
TMS**	10	16.36	4.65	.039*
TPS	10	12.55	2.48	
ZMK**	10	19.88	6.94	.028*
ZPK	10	13.85	3.95	
ZML†	10	16.00	4.03	.001*
ZPL	10	5.24	1.82	
ZMS**	10	18.00	8.39	.033*
ZPS	10	11.24	2.21	

T, titanium; Z, zirconia; M, multilink speed cement; P, premier implant cement; K, Katana; S, Vita Suprinity; L, Lava Ultimate; TML, titanium abutment-multilink speed cement-Lava Ultimate ceramic; TPL, titanium abutment-premier implant cement-Lava Ultimate ceramic; TMS, titanium abutment-multilink speed cement-Vita Suprinity ceramic; TPS, titanium abutment-premier implant cement-Vita Suprinity ceramic; TMK, titanium abutment-multilink speed cement-Katana ceramic; TPK, titanium abutment-premier implant cement-Katana ceramic; ZML, zirconia abutment-multilink speed cement-Lava Ultimate ceramic; ZPL, zirconia abutment-premier implant cement-Lava Ultimate ceramic; ZMS, zirconia abutment-multilink speed cement-Vita Suprinity ceramic; ZPS, zirconia abutment-premier implant cement-Vita Suprinity ceramic; ZMK, zirconia abutment- multilink speed cement-Katana ceramic; ZPK, zirconia abutment-premier implant cement-Katana ceramic.
**Student's *t* test; †Mann–Whitney *U* test; *$P < .05$.

Table 4. Restoration type microshear test results in megapascals (MPa)

Group	N	Mean	Standard Deviation	*P*
K	40	16.26	5.64	.001*
L	40	10.91	5.12	
S	40	14.54	5.61	

K, Katana; S, Vita Suprinity; L, Lava Ultimate; ANOVA, analysis of variance.
*$P < .05$ based on the ANOVA test.

in bonding ($P = .101$ and $P = .443$). The bond strength for the TPL group was found to be significantly lower than for the TPK and TPS groups ($P = .001$), while no significant difference was found between the TPK and TPS groups ($P = .992$). The bond strength of the ZPL group was significantly lower than the ZPK and ZPS groups ($P = .001$), and the bond strength of the ZPK group was significantly higher than in the ZPL and ZPS groups ($P = .001$). The bond strength of the ZPS group was significantly lower than in the ZPK group and significantly higher than in the ZPL group ($P = .001$) (Table 5).

No sample failed to the point of exclusion from a pre-test run. The types of failures were examined under 30× magnification with the aid of a stereomicroscope. Failure types were adhesive and mixed (adhesive and cohesive), and no cohesive failures were observed in our study (Figure 1). Where the total adhesive/mixed failure rate was 70%/30% in the permanent implant cement groups, all samples in the temporary implant cement groups demonstrated adhesive failure.

Table 5. Restoration type microshear test results in megapascals (MPa)

Group	N	Mean	Standard Deviation	*P*
TMK†	10	18.74	4.92	.101
TML	10	13.92	3.24	
TMS	10	16.36	4.65	
TPK**	10	12.56	2.66	.001*
TPL	10	8.49	1.56	
TPS	10	12.55	2.48	
ZMK**	10	19.88	6.94	.443
ZML	10	16.00	4.03	
ZMS	10	18.00	8.39	
ZPK†	10	13.85	3.95	.001*
ZPL	10	5.24	1.82	
ZPS	10	11.24	2.21	

T, titanium; Z, zirconia; M, multilink speed cement; P, premier implant cement; K, Katana; S, Vita Suprinity; L, Lava Ultimate; ANOVA, analysis of variance; TML, titanium abutment-multilink speed cement-Lava Ultimate ceramic; TPL, titanium abutment-premier implant cement-Lava Ultimate ceramic; TMS, titanium abutment-multilink speed cement-Vita Suprinity ceramic; TPS, titanium abutment-premier implant cement-Vita Suprinity ceramic; TMK, titanium abutment-multilink speed cement-Katana ceramic; TPK, titanium abutment-premier implant cement-Katana ceramic; ZPL, zirconia abutment-premier implant cement-Lava Ultimate ceramic; ZMS, zirconia abutment-multilink speed cement-Vita Suprinity ceramic; ZPS, zirconia abutment-premier implant cement-Vita Suprinity ceramic; ZMK, zirconia abutment- multilink speed cement-Katana ceramic; ZPK, zirconia abutment-premier implant cement-Katana ceramic.
**ANOVA test; †Kruskal–Wallis test; *$P < .05$.

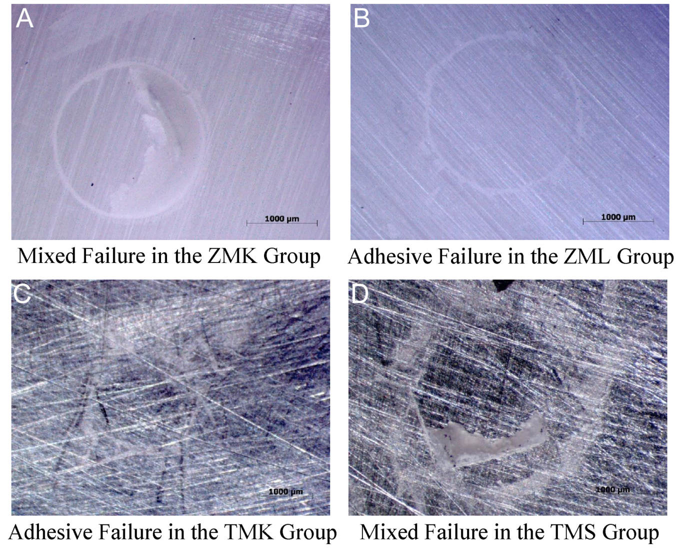

Figure 1. Failure type A-D

DISCUSSION

The first hypothesis was accepted due to significant differences in bond strength between permanent and temporary resin implant cements. Likewise, the second hypothesis was accepted as the bond strengths of the zirconium and titanium abutment materials demonstrated similar values. However, the third hypothesis was rejected as the bond strength values of resin nanoceramics, ZLS, and zirconia ceramics significantly differed.

There are studies that have compared different mechanical properties such as bonding and fracture between different abutment materials, cements, and restorations.[8,9] Implant restorations are cemented with temporary and permanent cements depending on the clinical situation.[5,6] In our study, we used titanium and zirconia abutments to compare their bond strength with different cements, ZLS ceramics, resin nanoceramics, and monolithic zirconia as restorations.

To provide reliable adhesion to dental ceramics, micro-mechanical retention is produced by creating micro-retentive surfaces through increasing surface roughness.[13] However, due to zirconia being structurally hydrophobic and free of hydroxyl groups, it is quite challenging to adhere zirconia with other substrates due to the difficulty in forming chemical bonds.[14-17] In our study, ZLS were roughened with 9% hydrofluoric acid for 20 seconds, while the zirconia and resin nanoceramic samples were sandblasted with Al_2O_3 with a particle size of 110 µm.

The chemical bonding of all ceramic materials with a glass matrix, or those containing glass ceramic in their structure, and exposing the bonding surfaces to silanization after roughening has been reported to strengthen the bonding.[5,18] This is achieved by binding the functional trihydroxylane group of the methacrylate monomer to the silicate surface of the glass ceramic as a result of the condensation reaction.[19] Zirconia has a high affinity for phosphoric acid, according to the manufacturer, and hence a universal primer containing MDP can also be used with indirect restorations formed through strong chemical bonds, which is resistant to water solubility, and the methacrylate monomer with a functional phosphoric acid group.[20] Therefore, in our study, a universal primer containing MDP was applied to the cementation surfaces of all the restorations.

There are studies that investigated the cementation process executed with finger pressure, whereas results have also been obtained using different weights ranging between 750 g and 10 kg.[21-23] In our study, the samples were cemented under finger pressure due to their very small cross-sections.

Shear and tension tests are recommended for analyzing the bonding between materials.[24,25] Micro-test methods have been developed to observe bonding in a smaller area, as the bonding values increase logarithmically.[10,26] As the forces applied during the micro-shear tests are concentrated at the bonding interface without causing the material to bend, the accuracy of the test is increased compared to the macro-shear test.[27] The macro and micro versions of tests measuring bond strength were compared, and the micro-test methods were determined to be significantly better than the macro-tests.[28] Given the limitations of the micro-test, we compared our results with macro-shear tests, and hence, our results were better.

In Valandro et al[29] study comparing the results of resin cements and ceramics bonding with micro-tension and micro-shear tests, no significant differences were found between the values; therefore, micro-tension tests were used to compare the results in our study. It had shown that the stress on the bonding depends not only on the testing method but also on the geometry of the sample and the loading tip.[10] The entire surface of the cutting tip must touch the sample's surface and the force must be transmitted to the area as close as possible.[30] As the cross-sections of the samples used in our study were squares, a straight and blunt-end cutting tip was used for this purpose.

Premier implant cement has provided better results than conventional temporary cements and worse results than conventional permanent cement in bond strength tests with titanium abutments.[31] In another study, they used titanium discs, and resin cements without surface treatments were compared with conventional cements. The untreated cements provided worse results than the polycarboxylate cements.[32] As a result of studies on the bond strength of implant abutments and cements, it has been observed that resin cements provided similar or better bonding values than conventional ones.[33] In our study, the bond strength results between the titanium and permanent implant cements were similar to studies.

Frankenberger et al[34] reviewed a study investigating the treatment of surfaces with 4 different CAD/CAM materials using a micro-tension and found that ZLS provided better results than the resin nanomers. We had a similar outcome, and the ZLS value was better than the resin nanoceramic. In Bellan et al[35] study, 10% hydrofluoric acid was applied to ZLS surfaces for 20 seconds and the resin nanoceramic was sandblasted with 50 µm aluminum. While the bond strength values observed for the ZLS are similar to our study, the values obtained by resin nano-ceramics are quite high compared to our results. We believe the results may differ due to the slight differences in blasting sensitivity and silane application precision.

Menon et al[36] have shown that the bond strength of zirconium abutments is higher than on titanium abutments. In our study, while the bond strength observed in the zirconium abutments was not statistically significant, it was higher than that in the titanium abutments. In 1 study where bond strength was measured on titanium and zirconium abutments, it was reported that resin and temporary implant cements' bond strength increased significantly.[9] Similarly, in our study, we observed no effect on bond strength among the abutment materials, but the selected cement type significantly affected the strength. In Sellers et al's[37] study, in which glass-infiltrated CAD/CAM ceramics was cemented to zirconium abutments and the bond strength was measured, the result of the thermal cycle was lowest in premier implant cement. In our study, a significant difference was determined between the temporary and permanent implant cement in terms of bond strength in zirconia.

In Dal Piva et al's[38] study which evaluated the bonding between resin cement and ZLS, as well as zirconia with high translucency, the zirconia was significantly higher than ZLS. Similarly, in our study, the bond strength of the zirconia was higher than ZLS but not significantly different.

In Secilmic et al's[39] study, the shear bond strength between 4 different CAD/CAM materials and 2 different resin cements was evaluated, with surface treatments performed. The highest bonding value was observed for Lava Ultimate connected with Panavia-F2.0 and the IPS e.max-CAD and Vita-Suprinity in the group where Monobond-N was applied. Similarly in our study, the bond strength values of ZLS were significantly higher in the group where MDP-containing permanent implant cement was applied in comparison to resin nanoceramics.

Cekic-Nagas et al[40] used 3 different resins and evaluated the bonding strength of surface-treated CAD/CAM materials via micro-shear tests. They divided specimens into 2 groups, where 1 group was put into a thermal cycle. There were no significant differences between specimens that were not treated with thermal cycle, whereas there was a significant decrease in the specimens in which the thermal cycle was applied. The micro-shear test bond strength values of the permanent resin cement group of the resin nanoceramics observed in our study provided similar results.

To test the continuity of the cement-ceramic bond, soaking in water for long periods and the application of thermal cycles are widely used methods, as these processes affect the integrity of the adhesive cement.[41] Hence, the samples in our study were kept in distilled water at room temperature (37°C) for 24 hours before the tests were performed. Limitation of our study was not using thermal cycle.

The results obtained in this study demonstrate that there is no significant difference between unprocessed zirconia and titanium surfaces as abutment material in terms of bond strength. However, the bond strength was significantly affected by the type of cement used. The highest bond strength was obtained by using permanent implant cement and ZLS ceramic samples on zirconia abutments.

Ethics Committee Approval: Since this study is a material study, ethics committee approval is not required.

Informed Consent: Informed consent is not required for this study, since no action was taken on animals or humans.

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