ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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Fracture Strength of Surface Treated Zirconia Based Multilayer CAD/CAM Ceramic Crowns

Yüzey İşlemi Yapılan Zirkonya Kaideli Çok Tabakalı CAD/CAM Seramik Kronların Kırılma Dayanıklılığı

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ABSTRACT Objective: The purpose of this study was to evaluate the effect of different surface treatments on the fracture strength of veneered zirconia crowns designed by multilayer technique. **Material and Methods:** Thirty zirconia cores (Sirona inCoris ZI) were constructed (inLab 4.4) on metal dies. Zirconia cores were divided into three groups: sandblasting with 30 µm silica-coated aluminum oxide particles (Group C), sandblasting with 50 µm aluminum oxide particles (Group K) and sandblasting with 50 µm aluminum oxide particles then silica coating with Silano-Pen (Group KS). Thirty feldsphatic ceramic (VITABLOCS Mark II) veneers were fabricated (inLab 4.4). Veneers were cemented to the cores. Crowns were cemented to the metal dies. A universal test machine was used for the fracture strength test at a crosshead speed of 1 mm/min. The data were analyzed with one-way ANOVA ($\alpha=0.05$). **Results**: Surface pre-treatment methods affected the fracture strength ($p<0.05$). Higher fracture strengths were obtained in Group KS ($p<0.05$). No significant differences were found between Group K and Group C ($p>0.05$). **Conclusion**: Although Group K and C showed lower flexural strength, it was higher than the maximum loads which may occur clinically (Fmax=600N on one tooth). Also, Silano-Pen application is advisable for increasing the fracture strength. Clinical Relevance: The multilayer zirconia crowns can be applied successfully, especially in single-crown restorations.

Keywords: Air abrasion, dental; fractures, stress

ÖZET Amaç: Bu çalışmanın amacı, farklı yüzey işlemlerinin, çok tabakalı teknik ile hazırlanmış zirkonya kronlarının kırılma dayanıklılığına olan etkisini değerlendirmektir. **Gereç ve Yöntemler:** Metal daylar üzerinde otuz adet zirkonyum kor (Sirona inCoris ZI) hazırlandı (inLab 4.4). Zirkonyum korlar yüzey işlemlerine göre 3 gruba ayrıldı; 30 mikron silika kaplı alüminyum oksit parçacıklarıyla (Grup C) kumlama, 50 mikron alüminyum oksit parçacıklarıyla kumlama (Grup K) ve 50 mikron alüminyum oksit partikülleri ile kumlama sonrası Silano-Pen ile silika kaplama (Grup KS). Zirkonya korlar üzerine otuz adet feldspatik seramik (VITABLOCS Mark II) veneerler üretildi (inLab 4.4). Veneerler, kor altyapılar üzerine simante edildi. Daha sonra, kronlar metal daylar üzerine simante edildi. Kırılma dayanıklılığı testi için kafa hızı 1 mm/dakika olan evrensel bir test makinesi kullanıldı. Veriler tek yönlü ANOVA ile analiz edildi (alfa=0,05). **Bulgular:** Yüzey hazırlama işlemleri kırılma direncini etkiledi ($p<0,05$). Grup KS'de daha yüksek kırılma direnci ($p<0,05$) elde edildi. Grup K ve Grup C arasında anlamlı fark bulunmadı ($p>0,05$). **Sonuç:** Grup K ve C daha düşük bükülme dayanıklılığı elde edilmesine rağmen, bu değerler klinik olarak oluşabilen maksimum yüklerden (bir dişte Fmax=600N) daha yüksektir. Ayrıca, kırılma direncini arttırmak için Silano-Pen uygulaması da önerilir. Klinik Uygunluk: Çok katlı zirkonya kronları, özellikle tek kron restorasyonlarda başarıyla uygulanabilir.

Anahtar Kelimeler: Hava abrazyonu, dental; kırıklar, stres

When esthetic and strength are indispensable at the same time, zirconia based ceramic restorations are used as an alternative to porcelain-fused-to-metal restorations. Ceramic restorations with yittria-stabilized tetragonal zirconia polycrystalline (Y-TZP) core have greater flexural and fracture strength than other ceramic cores, including lithium disilicate, glass infiltrated alumina and glass infiltrated alumina strengthened with zirconia.[1-6] To produce zirconia core, fabricated pre-sintered Y-TZP blocks are used. Using computer-aided design/computer-aided manufacturing (CAD/CAM) technology homogenous zirconia cores with no imperfections and/or porosities are obtained. Despite the superior flexural strength of Y-TZP, chipping of the veneering ceramic is still one of the most common clinical failure for zirconia-based ceramic restorations.[1,5,7,8] Also, previous in-vivo studies focused on the chipping for zirconia-based ceramic restorations which was one of the most common clinical failure type (13-25%) while using conventional veneering techniques.[2,9]

Many factors can cause the chipping of the veneering layer including the mechanical properties, design and thickness of zirconia core, surface treatment of the zirconia core, quality and homogeneity of the veneering ceramic, the type of veneering layer ceramic, wettability of the core by the veneering ceramic, residual stresses at the interface as well as the physical properties such as the coefficient of thermal expansion and elastic modulus of veneering ceramic and zirconia core.[1,5,7,8,10] Veneering techniques also have a potential effect on the chipping of ceramic due to the processing methods of ceramic.

To veneer zirconia core with glassy matrix ceramic, various methods have been developed. Traditional layering technique and overpressing are commonly used techniques. In the traditional layering technique, the mixed ceramic powder and its liquid are built on the sintered zirconia core larger than the final dimensions to compensate for the shrinkage of the veneering ceramic. In the overpressing method, a wax-up model with the final contour of the veneer is modeled on the sintered zirconia core then it is invested under heat-pressed vacuum with pressable ceramics.[5,7,8]

Additionally, to these common veneering techniques, "CAD-on" and "multilayer" techniques have been introduced with the improvements of CAD/CAM systems. By these techniques, zirconia core and its supra-structure are designed together with the CAD software, and after milling with the CAM unit, the two parts are cemented using a fusion glass-ceramic (CAD-on) or resin cement (multilayer) which depends on manufacturer instruc- tions. These manufacturing techniques not only decrease the number of laboratory procedures, but also provides the opportunity to use homogenous ceramic blocks with relatively high strength.[1,7]

First study about using milled veneering ceramic (Lithium disilicate) over a Y-TZP core (CAD-on technique) was studied by Beuer et al. as an experimental study.[7,11] This study showed that higher fracture strength and mechanical stability were obtained with the CAD/CAM fabricated bilayered restorations (CAD-on) in which used lithium disilicate ceramic fused to zirconia core (6262.67 (2257.42) N) than traditional layering (3700.39 (1238.72) N) and press-on (3523.73 (1181.11) N) techniques. Other studies showed that higher flexural fracture (1900 (254) N), and shear bond strength values were obtained with file-splitting technique and also the specimens fabricated by CAD-on technique not only survived aging but displayed fracture failure loads up to 1600N, as well.[8,12]

Reliable adhesion principally requires surface treatment of ceramics, with either mechanical surface treatment, chemical conditioning or a combination of the two.[6] Surface treatments effect the shear bond strength of veneer ceramic and resin cement to zirconia core.[13-16] To increase shear bond strength many surface treatment methods were evaluated (sandblasting, acid etching, silica coating, primer applications). Because of the zirconia is an acid-resistant material, chemical roughening procedures do not work on the zirconia surface and other methods are required, such as sandblasting, to produce a rough surface for micromechanical bonding.[6,15-17] To improve the adhesion between the cement and zirconia core through creation of a higher surface area, sandblasting is performed. Sandblasting densely sintered zirconia creates sharp depressions and protrusions on the surface and promotes a phase transformation (from tetragonal to monoclinic). In the multilayer technique before the connecting of zirconia core and feldspathic veneer, zirconia core surfaces are sandblasted with Al_2O_3 particles.

Silane coupling is the one of the affective methods on the shear bond strength of resin cement to zirconia. Silane coupling can be made with various methods. Tribochemical silica coating (Rocatec, CoJet), Silicoater Classic, Silicoater MD, and Siloc are some of these methods. While tribochemical silica coating is a specially engineered grit-blasting system based on special chemically designed silica- coated alumina particles for extraoral conditioning of the substrate surface, Silicoater Classic, Silicoater MD, and Siloc are pyrochemical silica-coating technologies based on the use of elevated temperatures.[18-21] Silano-Pen is the chairside version of Silicoater technology (Silicoater MD, Heraeus Kulzer, Wehrheim, Germany), applied by a hand-held device (Silano-Pen or PyrosilPen); using a flame treatment approach, could deliver reliable adhesion.[20,21]

In previous studies, the performance of CAD-on technique was assessed, little information is available about the multilayer technique which used zirconia core and feldspathic ceramic and the effects of surface treatments such as silicoating with Silano-Pen or SiO_X on the fracture strength between two different parts of restorations.[1,7,8,11,12]

The purpose of this study was to evaluate the effect of different surface treatment on the fracture strength of veneering ceramic and zirconia core designed with CAD/CAM multilayer technique. The null hypothesis tested was the surface treatment methods would affect the fracture strength of zirconia based veneer crown designed with CAD/CAM multilayer technique.

MATERIAL AND METHODS

To evaluate chipping and/or delamination of the veneer, the performance of all-ceramic molar crowns fabricated with CAD/CAM technique was of interest. One trained researcher (I.K) produced all the specimens to avoid any operator effect. The brands, manufacturers, chemical compositions and batch numbers of the materials used in this study are listed in Table 1.

For crown-shaped specimens, industrially fabricated stainless steel dies (N=30) were designed with a 1 mm circumferential chamfer, and a groove on the axial side to avoid the rotation of the crowns during mechanical testing. Dies were coated with a contrast spray (Cerec Optispray®, Sirona, Bensheim, Germany) to eliminate light reflective surfaces. The restorations were designed for the maxillar first molar and multilayer option and material data were selected before the digital impressions using CAD/CAM (Cerec Omnicam, Sirona, Bensheim, Germany). Die spacer thickness of 30 µm was chosen for fit of zirconia core to metal die.[22] Thirty zirconia cores (Sirona inCoris ZI, mono L F1, 0.5 mm thickness) on these metal dies were constructed (inLab 4.4; Sirona Dental Systems GmbH, Bensheim, Germany) in an approximately 20% to 25% enlarged volume to compensate for the shrinkage of the sintering process. While designing the Zirconia cores, nonanatomical tubercle was preferred and groove in 1mm depth was created on one of the proximal

TABLE 1: Material used in the study.

Material	Type	Manufacturer
inCoris ZI	Presintered yittria stabilized zirconia	Sirona, Bensheim, Germany
VITABLOCS Mark II	Feldspathic ceramic block	Vita Zahnfabric, Bad Sackingen, Germany
Korox 50	99.6% 50 µm Al2O3	BEGO, Bremen, Germany
CoJet Sand	30 mm silica-coated Al2O3 particles	3M ESPE, Seefeld, Germany
Silan coupling agent	Alcoholic solution of 3-methacrylyoyloxypropyltrimethoxy silane (MPS), ethanol	Bredent GmbH, Senden, Germany
Panavia F 2.0	Dual-polymerized adhesive resin cement	Kuraray, Okayama, Japan

side to prevent the rotation of the superstructure. Circumferential margin and insertion path of the dies were controlled by a groove which was positioned on the buccal surface. Zirconia cores were sintered (InFire HTC speed; Sirona Dental Systems) according to manufacturer instructions and the adaptations of the zirconia cores to metal dies were controlled.

Sintered zirconia cores were divided into three groups according to the following surface treatments: sandblasting with 30 µm silica-coated aluminum oxide particles (CoJet Sand) (Group C), sandblasting with 50 µm aluminum oxide particles (Korox 50) (Group K) and sandblasting with 50 µm aluminum oxide particles then flamed with Silano-Pen (Group KS).

The air abrasion procedure was performed using an intraoral air abrasion device (Microetcher; Danville Engineering Inc, San Ramon, CA) at an air pressure of 2.5 bar for 15 secs at a distance of 10 mm.

In group KS, after air abrasion with 50 µm aluminum oxide particles zirconia surfaces flamed with the Silano-Pen device for 5 s/cm^2. After cooling down to room temperature a silane coupling agent Silano-Pen bonding agent was brushed on and air-dried for 3 minutes.

Thirty feldspathic ceramic veneers (VITA Mark II) as veneer were designed (1 mm axial wall thickness, 1.5 mm occlusal thickness) and fabricated with the same system (inLab 4.4; Sirona Dental Systems). A hole in 0.5 mm diameter and depth was designed on the mesiopalatal tubercule for fitting the tip of the fracture strength test machine. An internal gap between superstructure and zirconia core was created as 60 µm according to the manufacturer's instructions and then data were transferred to the milling unit (CEREC MC XL®) (Figure 1).

After controlling the adaptation to sintered zirconia cores, veneers were glazed according to manufacturer's instructions (Vita Akzent; Vita Zahnfabric). Inner surface of veneers was etched with 9.5 % hydrofluoric acid (Porcelain Etchant Gel, Bisco, Schaumburg, USA) for 30 secs, then washed with water for 20 secs and air dried for 5

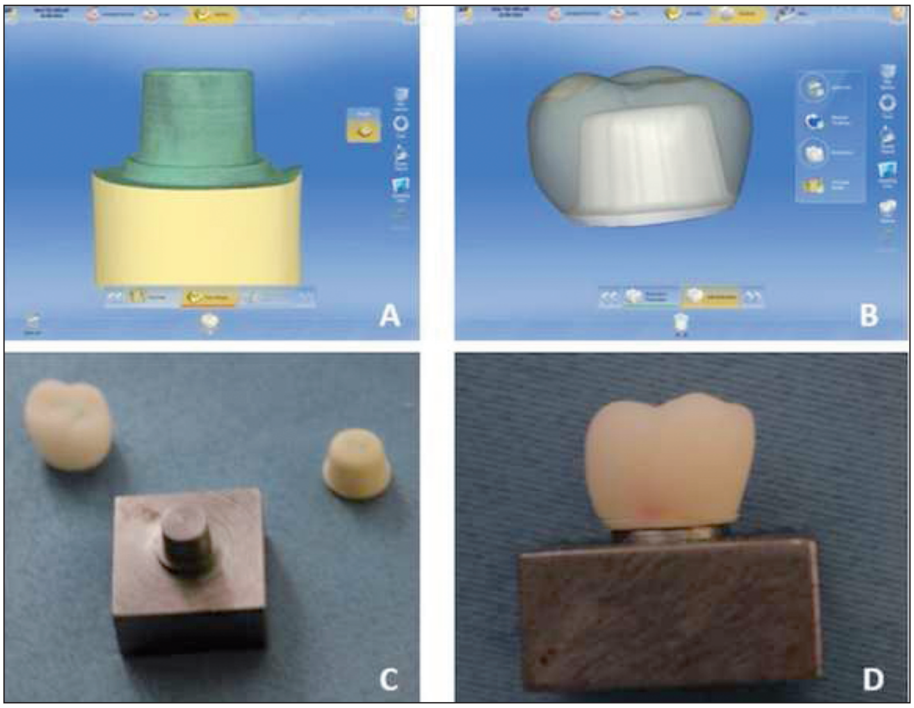

FIGURE 1A-D: Preparation of specimens.

secs. Silane coupling agent (Monobond Plus) was applied to inner surfaces and allowed to evaporate for 60 secs. Dual-cured resin cement (Panavia F 2.0) were used according to manufacturer's instructions. Veneers were inserted onto zirconia cores with finger pressure, then a manual dynometer was used to ensure that the crown was loaded centrally at a force of 50 N for 10 minutes (Figure 2). The remnants of resin cement were removed with a cotton pellet. Samples were light polymerized for 20 secs (ELIPAR, S10, 3M ESPE, Germany) on each surface, and the borders were then polished. All restorations were stored in distilled water at a temperature of 37 °C for 24 hours until they were loaded for the fracture test.

To positioned the specimens on the universal testing machine (Lloyd LRX, Lloyd Instruments PIC, Fareham, Hampshire, UK), a special apparatus at a 10º inclination relative to the long axis was used and the specimens were loaded until fracture occurred (Figure 3). The load was applied with a 6 mm diameter stainless steel ball placed on the occlusal surface of the crowns and the crosshead speed of 1 mm/min. The fracture load for each specimen was recorded in Newton (N). A homogeneity of variance test was done using Levene's test (F =2.500, P>0.05). The Kolmogorov–Simirnov test showed that the data followed a normal distribution (P>0.05).

The failure mode of fractured specimen was assessed under a stereomicroscopy (Stemi 2000-C; Carl Zeiss, Gottingen, Germany) at 10 magnifications and it was performed by the same investigator. The nature of the failure was designed as follows: adhesive in zirconia core if the resin cement was totally separated from the core; adhesive in veneer ceramic if the resin cement was totally separated from veneer ceramic; cohesive if the fracture occurred only on veneer ceramic, zirconia

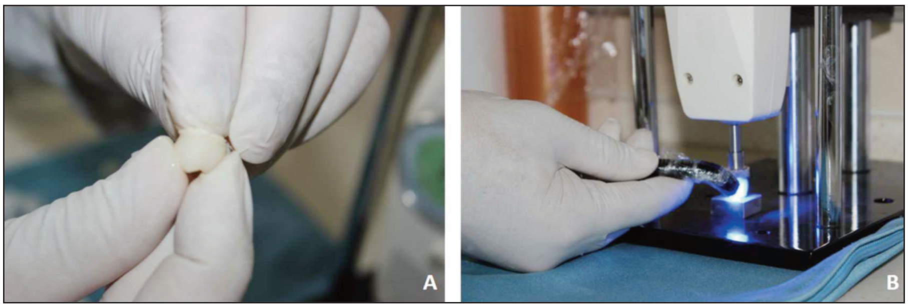

FIGURE 2: Cementation of zirconia core and veneer under dynometer and light polimerization.

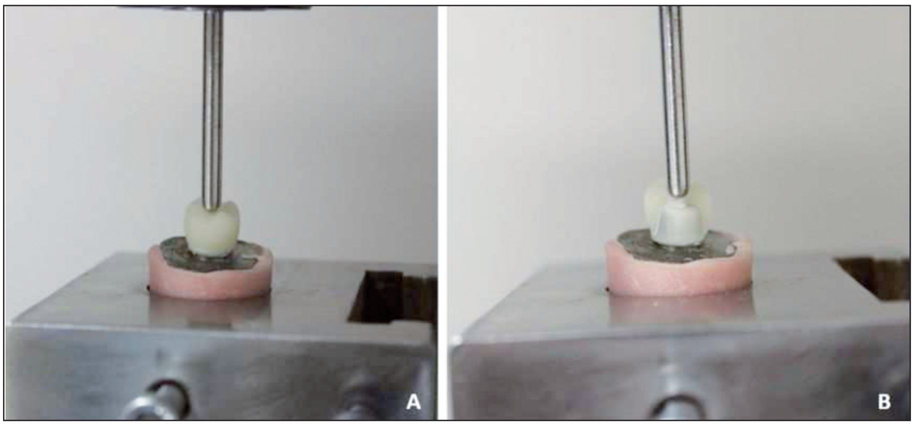

FIGURE 3: Fracture strength test.

TABLE 2: Descriptive analysis.

					95% Confidence Interval for Mean			
Groups	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Min.**	**Max.**
K	10	8,2108E2	83,22349	26,31758	761,5415	880,6105	755,51	967,89
KS	10	9,2808E2	21,49143	6,79619	912,7060	943,4540	900,80	960,10
C	10	8,4805E2	19,89994	6,29291	833,8104	862,2816	823,20	881,41
Total	30	8,6573E2	67,46611	12,31757	840,5417	890,9263	755,51	967,89

core or resin cement; or mixed when a combination of adhesive in veneer ceramic, zirconia core and resin cement failure occurred. The percentage of each type of failure within each group was then calculated.

RESULTS

The data were analyzed with one-way analysis of variance (ANOVA) followed by a Post Hoc Tukey's test ($\alpha = 0.05$).

Mean and standard deviations of the data are shown in Table 2 and the results of one-way ANOVA are shown in Table 3. Significant differences were found between the surface treatments (*P*<0.05). The fracture strength of veneering ceramic to zirconia core depended on the surface treatment method.

The mean fracture strength values and standard deviations for each group are presented in Table 4. The lowest fracture strength values were obtained with the Group K and C (821,73±83,22; 848,78 ±19,89), respectively and no significant difference was found between group K and C (*P*>0.05).

The highest values were obtained with groups KS (928,21 ±21,49) and significant difference was found between other groups (*P*<0.05). Failure types were seen in Table 5. Mixed (30%) adhesive in zirconia core failures (50%) and adhesive in veneer failures (20%) were observed in Group KS. Adhesive in zirconia core failures (70%) and adhesive in veneer failures (30%) were observed in Group C and adhesive in veneer failures (20%) and adhesive in zirconia core failures (80%) were observed in Group K.

TABLE 3: One-way ANOVA.

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	61942,260	2	30971,130	11,936	,000
Within Groups	70056,346	27	2594,679		
Total	131998,607	29			

TABLE 4: Post Hoc Tukey test.

Group	**N (±SD) ***
K	821,73 (83,22)^{a}
C	848,78 (19,89)^{a}
KS	928,21 (21,49)^{b}

*Values indicated with the same letter did not differ significantly in the Post Hoc Tukey test (P> 0.05).

TABLE 5: Failure types.

Groups		**Failure Types Adhesive (veneer and cement)**	**Adhesive (Cement and core) Mix**	**Cohesive**
K	2	8	-	-
C	3	7	-	-
KS	2	5	-	3

DISCUSSION

In this in-vitro study the surface treatments on the fracture performance on the zirconia based restoration designed by CAD/CAM multilayer technique was investigated and the results showed that surface treatment methods affected fracture strength of restorations (*P*<0.05). Therefore, the null hypothesis was accepted.

Zirconia cores are generally veneered with lithium disilicate ceramic or feldspathic ceramic. Although esthetic aspects of feldspathic veneer might be slightly superior to those of lithium disilicate veneer or mechanical properties of lithium disilicate veneer better than the feldspathic veneer, both materials are suitable for production of appealing dental restorations. In the CAD/CAM multilayer technique, sintered zirconia core and veneering ceramic (feldspathic or lithium disilicate) is cemented with resin cement. With this technique, time-consuming and operator-sensitive laboratory procedures such as impression making, model obtaining, investing and finishing can be eliminated.[7,8,10,11,23] Also choosing feldspathic ceramic as a veneer has economical advantage.[23] But the indication range is strongly limited to single crowns and small FPDs.[23]

Although production of zirconia based ceramic crown with traditional layering technique was preferred because of esthetic and economic reasons, after chipping, restoration must be repaired or renewed. Repair of zirconia based all ceramic restoration can be made with direct or indirect methods.[7,24] When restoration is designed with CAD/CAM multilayer technique, repair of restoration is easier with milling of veneering ceramic superstructure with the help of previously recorded data.

In previous studies, higher fracture strength values were obtained with CAD-on technique when compared multilayer, press-on or layering techniques.[11,23] In this technique lithium disilicate ceramic is used. Fracture strength of lithium disilicate ceramic (350-400 MPa) is higher than feldspathic ceramic (100-150 MPa). Repair of CAD-on restoration can be made also with direct or indirect methods. Indirect repair of restoration can result more esthetic and higher strength results but restoration must be removed. This is the limitation of this technique.

When compared with previous studies which used lithium disilicate ceramic as a veneer ceramic, in this study lower fracture strength values were obtained but fracture strength values were higher than the maximum loads which may occur clinically (Fmax=600N on one tooth in the molar region in vivo).

Al-Wahadni et al., evaluated the veneering technique (overpressing, layering and digital veneering) on the fracture strength of zirconia-based crowns.[5] Layering veneering group showed higher fracture resistance (1200±306 N) when compared with overpressing (857±188 N) and digital veneering (638 ± 194 N) group which used resin cement to attachment of the veneering ceramic and zirconia. Previous studies demonstrated higher failure load values for digital veneered specimens compared with layering veneer specimens; in these studies a-low fusing feldspathic ceramic with a flexural strength around 160 MPa was used for attachment of the veneering ceramic veneer and zirconia core. Presence of a relatively weak intermediate layer (Panavia F 2.0 resin cement, with a flexural strength of around 60 MPa) between zirconia and the veneering layer in multilayer technique can cause high tensile stress at the inner surface of the veneering layer under loading.

In this study metal dies were used. Scherrer and Rijk indicated that, increasing elastic modulus of the supporting material results in increased fracture strength.[25] The elastic modulus of the supporting metal die (200 GPa) was higher than the dentin (12-14 GPa). If natural teeth were used as a supporting model, the fracture strength of crowns might have been lower. However natural teeth would have been destroyed during the testing at the high fracture loads. The fracture strength values of this study were lower than other studies which used multilayer technique.[7] It might be because of the die spacer layer. In this study die spacer layer was chosen as 30 μm but in the other studies it was chosen as 10 μm to obtain close fit with restoration and dies.[7,8,23] The mean marginal discrepancy for all ceramic restorations reported in former studies was between 3.7 μm to 174 μm; and the majority of the reported values were less than or equal to 120 μm. In CAD/CAM restorations, it is claimed that due to the reduction in human errors and material imperfections, minimal acceptable marginal gap was less than 100 μm.[22] Increase of cement thickness might be a result for lower fracture strength. The elastic modulus of the zirconia core (210 GPa) and veneering ceramics (63 GPa) were above the elastic modulus of the resin cement (18,6 GPa), which was used as an interfacial bonding agent between the zirconia core and the prefabricated feldspathic veneers.[23] Thus, the weaker intermediary cement layer at the zirconia/metal die might have decreased the supportive effect of rigid zirconia on the metal die. The stereomicroscope and visual analyses demonstrated that there were no cracks or fractures in the zirconia cores.

Shimitter et al. evaluated that the chipping behavior of feldspathic ceramic designed with multilayer or layering technique with the fracture strength test and reported that zirconia cores veneered with CAD/CAM-produced feldspathic ceramic are less sensitive to ageing than zirconia crowns with layered feldspathic veneer.

CAD-on technique contains more sensitive, expensive and time consuming procedures when compared to multilayer technique. Special devices and second sinterization procedure is recommended by the manufacturer.[7,8,10,26] Although fusion is recommended by the manufacturer, it might be relevant to determine the effect of attachment technique on fracture resistance, because, e.g., in the dental laboratory or even chair-side luting is often preferred because of rapid and easy handling.[26] To improve fracture strength of zirconia based all-ceramic crowns, changeover from feldspathic ceramic to lithium disilicate ceramic for production of veneer has been suggested. Fracture strength of lithium disilicate ceramic is higher than the feldspathic ceramic

Surface treatment with 30 µm silica-modified alumina particles (SiO_X) is one of the effective surface treatments used to increase shear bond strength of resin cement to zirconia. In a study El-Korashy and El-Refai indicated that silica coating with 30 µm SiO_X revealed the highest mean fracture toughness, biaxial flexural strength and bond strength value when compared with other surface treatments (air abrasion with110µm Al_2O_3, hot etching solution composed of methanol, 37% HCL and ferric chloride, and combination of these) and silica coating showed the highest tetragonal to monoclinic transformation percentage (22%).[17]

Silica coating with Silano-Pen technology is fast and trouble-free and is an effective surface treatment method for achieving very good bond strength between resin cements and restorative materials (metals and ceramics). Silano-Pen creates a very thin silicon dioxide-type layer and increases surface hydroxyl on the alloy's surface by decomposing silanes during flaming.[18,21] There was no study about effect of Silano-Pen application on the fracture strength of zirconia. It was thought that Silano-Pen application after sandblasting with 50 µm Al_2O_3 might have affected the phase transformation (T-M), so increased the fracture strength of zirconia core based veneer ceramic restoration. It was stated that an additional heat treatment decreases the monoclinic phase transformation.[27] Moon et al. claimed that, heat treatment after sandblasting did not affect the shear bond strength of resin cement to zirconia but increased the flexural strength of zirconia.[27] In this study, higher fracture strength values were obtained with Silano-Pen treated group and significant differences were found between other groups which were sandblasted alone and silica coated.

During sandblasting, transformation from the tetragonal to monoclinic structure may occur. In general, sandblasting is performed as a pre-cementation surface treatment after sintering zirconia which is believed to increase monoclinic phase fraction in the zirconia structure. Tetragonal to monoclinic phase transformation increases flexural strength of zirconia but the bigger particles are, the higher monoclinic content, furthermore, the deeper the transformation zone, the lower flexural strength.[6,17] Sandblasting with 30 µm SiO_X and 50 µm Al_2O_3 allow lower phase transformation.[6] Sandblasting with 50 µm Al_2O_3 and 30 µm SiO_x were found as effective surface treatment methods to improve the mechanical properties of the zirconia. In the present study, there were no significant difference between sandblasting with Al_2O_3 and silica coating with SiO_x.

In this study aging was not evaluated and oral environment conditions were not reproduced. There is no research about effect of Silano-Pen treatment on the fracture strength of zirconia core. Also, there were limited researches about other surface treatment (sandblasting, chemical etching, priming) on the fracture strength of zirconia core. Further investigations are needed to evaluate effect of different surface treatments and veneering technique on the mechanical properties and clinical performance of the CAD/CAM multilayer technique.

CONCLUSION

Within the limitations of this study, the following conclusions were drawn;

Zirconia surface treatment had a significant effect on the fracture strength.

Silano-Pen application could be an alternative to increase the fracture strength of veneered zirconia based crowns designed by multilayer technique.

Conflict of Interest

Authors declared no conflict of interest or financial support.

Authorship Contributions

To create the hypothesis or idea of the research and/or the article: *Şafak Külünk;* **To design a method to achieve the results:** *Şafak Külünk;* **Organize the execution of the study/study, take care of its progress and take responsibility:** *Şafak Külünk, Tolga Külünk, İdris Kavut;* **Take responsibility for evaluating the findings in a sensible way:** *Şafak Külünk, Tolga Külünk, İdris Kavut, Duygu Saraç, Göknil Ergün Kunt;* **Take responsibility for scanning the resources required for the work:** *Şafak Külünk, Tolga Külünk, İdris Kavut, Duygu Saraç, Göknil Ergün Kunt;* **Take responsibility for writing the complete work or important parts of the work:** *Şafak Külünk, Tolga Külünk, İdris Kavut, Duygu Saraç, Göknil Ergün Kunt.*

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