

T.C
YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF PROSTHODONTICS

**EVALTUATION OF SHEAR BOND STRENGTH OF
TWO HIGHLY TRANSLUCENT MONOLITHIC
ZIRCONIA CAD/CAM MATERIALS TO SELF
ADHESIVE RESIN CEMENT AFTER DIFFERENT
SURFACE PRETREATMENT**

DOCTOR OF PHILOSOPHY THESIS

SIRAGEDDIN ALHMADI, DDS, MSc

ISTANBUL – 2022

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated and numbered

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.



13.01.2022

Sirageddin Alhmadi

DEDICATION

This thesis and my study over the past five years of graduate training are dedicated to my family. My most sincere gratitude and appreciation go to my father **MOHAMED** and mother **FOUZIA** for their patience, continuous encouragement, and instilled the drive to keep learning and rising above every challenge over the past difficult years.

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LIST OF ABBREVIATION AND SYMBOLS

μm	Micrometer
%	Percent
$^{\circ}\text{C}$	Celsius
3D	Three-dimensional
ANOVA	Analysis of variance
AFM	Atomic force microscopy
Al_2O_3	Aluminium oxide
$\text{Al}_2\text{O}_3/\text{SiO}_2$	Silica coated alumina
ATZ	Alumina-toughened zirconia
BIS-EMA	Bisphenol a diglycidyl methacrylate
BIS-GMA	Bisphenol a glycidyl methacrylate
C	Cubic phase
CAD/CAM	Computer-aided design/computer-aided-manufacturing
CAO	Calcium oxide
$\text{Ca}_5(\text{PO}_4)_3\text{F}$	Fluorapatite
CO_2	Carbon dioxide
E	Standard Error
Er: YAG	Erbium-doped yttrium aluminum garnet laser
HfO_2	Hafnium oxide
H_2O_2	Hydrogen peroxide
CEREC	Computer-assisted ceramic reconstruction
CCD	Couple charged device
FSZ	Fully stabilized zirconia
g	Gram
GPA	Gigapascal
HF	Hydrofluoric acid
HCL	Hydrochloric
HTZ	High translucent zirconia

ISO	International organization for standardization
K1C	Fracture toughness
K ₂ O	Potassium oxide
K ₂ O-AL ₂ O ₃ -4SiO ₂	Leucite
K ₂ AL ₂ Si ₆ O ₁₆	Potassium feldspar
LDS	Lithium disilicate glass ceramic
LSP	Lithium silicate/phosphate
LTD	Low temperature degradation
M	Monoclinic phase
$\bar{x}$	Mean
mm	Millimeter
MDP	10-methacryloxydecyl dihydrogen phosphate
Mol%	Mole percentage, it is unite of atoms measurement
min.	Minute
MSBS	Micro shear bond strength
MTBS	Micro tensile bond strength
Mg-PSZ	Magnesium partially stabilized zirconia
MPa	PICN Polymer-infiltrated ceramic network
N	Newton
n	Number of specimens
Nd: YAG	Neodymium-doped yttrium aluminum garnet
OCT	Optical coherence tomography
PSZ	Partially stabilized zirconia Megapascal
PTT	Phase transformation toughness
RP	Rapid prototyping
RMC _s	Resin matrix ceramic
PICN	Polymer infiltrated ceramic network
SACs	Self adhesive resin cement
SBS	Shear bond strength
SEM	Scanning electron microscopy

SIE	Selective infiltration etching
Si ⁴⁺	Silicone atom
SiO ₂	Silica
SiO ₄ ⁴⁻	Silicate ion (Si-tetrahedron)
SiO ₂ -Li ₂ O	Lithium disilicate
Skew	Skewness
Std.	Standard deviation
SLS	Selective laser sintering
t	Tetragonal phase
TBC	Tribochemical coating
TEGDMA	Triethylene glycol dimethacrylate
TC	Thermocycling
TZP	Tetragonal zirconia polycrystals
UDMA	Urethane dimethacrylate
Y-TZP	Ytria-stabilized tetragonal zirconia polycrystals
Wt%	Weight percentage
ZLs	Zirconia-reinforced lithium silicate
ZrO ₂	Zirconium dioxide
ZTA	Zirconia-toughened alumina
YbPL	Ytterbium-doped fiber laser

ABSTRACT

Sirageddin Alhmadi (2022). Evaluation of shear bond strength of two highly translucent monolithic zirconia CAD/CAM materials to self-adhesive resin cement after different surface pretreatment. Yeditepe University, Institute of Health Science, Department of Prosthodontics, PhD Thesis, Istanbul.

In-vitro study aimed to assess the effect of different surface treatments on the shear bond strength of self-adhesive resin cement to highly translucent monolithic zirconia-based CAD/CAM materials. 2 brands of highly translucent monolithic CAD/CAM zirconia were evaluated: Zenostar Zr translucent (Wieland Dental; Pforzheim, Germany) and Ceramill zolid fx preshade (Amann Girrbach AG, Koblach, Austria). 152 disc shaped monolithic zirconia sample of two brands were used and prepared from pre-sintered blocks using 5 axis CAD/CAM system (VHF K5 Germany) and then sintered to the final required dimension (10 mm in diameter and 3 mm in height) in a special high-temperature furnace. After those 140 discs were divided into seven groups according to the surface treatment received: no treatment (control), 9.5% HF acid etching, airblasting with 50 μm Al_2O_3 , airblasting with 50 μm Al_2O_3 + Z Prime Plus, Cojet, Siljet, fiber laser. Composite resin cylinders were bonded to zirconia disc with RelyX U200 self-adhesive resin cement according to manufacturers instructions. All specimens were thermocycled (5000 cycles at 5°C/55°C). 12 samples were used for surface roughness evaluation using SEM. A shear bond test was performed using the universal testing machine. Failure modes were examined using stereomicroscope and SEM. Data were analyzed statistically by using two-way ANOVA and post hoc Tukey's multiple comparison test. The bond strength was not statistically significantly different between two highly translucent zirconia CAD/CAM materials ($p:0.055$; $p>0.05$). The bond strength was significantly affected by the surface treatment ($p:0.000$; $p<0.05$). The highest shear bond strength for Zenostar was reported as fiber laser ($17,81\pm2$ MPa). The highest shear bond strength for Ceramill was reported as fiber laser ($21,7\pm3,55$ MPa). There was no statistically significant difference between bond strength of Tribochemical silica coating (Cojet, Siljet) and air blasting plus Z Prime Plus for both monolithic zirconia groups. The predominant failure mode was cohesive failure for fiber laser groups and mixed failure for

Cojet, Siljet, and blasting+ Z Prime Plus groups. HF acid surface treatment for one hour is not effective for bond of monolithic zirconia. Cojet, Siljet, and alumina blasting with Z Prime Plus is the best available cementation protocol for highly translucent monolithic zirconia. Fiber laser enhanced shear bond strength of two highly translucent monolithic zirconia CAD/CAM blocks, however it led to discoloration of zirconia. Fiber laser as surface treatment needs more research for optimization their effect to increase bond strength without damage to highly translucent monolithic zirconia.

Key Words: Shear bond strength, CAD/CAM, monolithic zirconia, self-adhesive resin cement, surface treatment, fiber laser.

ÖZET

Sirageddin Alhmadi (2022). Farklı yüzey işlemlerinin iki yüksek translüsent monolitik zirkonya CAD/CAM malzemesinin self adeziv simanlarla bağlanma mukavemetine olan etkisinin değerlendirilmesi. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Protetik Diş Tedavisi, Doktora Tezi, İstanbul.

Bu in vitro çalışmanın amacı; farklı yüzey işlemlerinin, self adeziv rezin simanın iki yüksek translüsent monolitik zirkonya CAD/CAM malzemesinin kesme mukavemeti üzerindeki etkisini değerlendirmektir. İki yüksek translüsent monolitik CAD/CAM zirkonya markası değerlendirilmiştir: Zenostar Zr translüsent (Wieland Dental; Pforzheim, Almanya) ve Ceramill zolid fx pre-shade (Amann Girrbach AG, Koblach, Avusturya). 152 adet disk şeklinde iki markanın monolitik zirkonya örnekleri, 5 eksenli CAD/CAM sistemi (VHF K5 Almanya) kullanılarak ön sinterlenmiş bloklarla hazırlanmıştır, daha sonra özel fırında gerekli nihai boyuta (10 mm çapında ve 3 mm yüksekliğinde) gelecek şekilde sinterlenmiştir. 140 örnek Yüzey işlemlerine göre yedi gruba ayrılmıştır: yüzey işlemi yok (kontrol), %9.5 HF asit ile aşındırma, 50 µm Al₂O₃ ile kumlama, 50 µm Al₂O₃ ile kumlama + Z Prime Plus, Cojet, Siljet ve fiber lazer. Üreticilerin önerilerine göre, kompozit rezin silindirleri, RelyX U200 self adeziv rezin siman ile zirkonya disklerle yapıştırılmıştır. Bütün örnekler termosiklusa (5C/55C'de 5000 siklus) maruz bırakılmıştır. 12 örneğin yüzey pürüzlülüğü SEM kullanılarak değerlendirilmiştir. Üniversal test makinesi kullanılarak kesme bağlanma mukavemeti test edilmiştir. Bağlanmadaki kopma tipleri SEM ve Steromikroskop kullanılarak incelenmiştir. Veriler, iki yönlü ANOVA ve post hoc Tukey çoklu karşılaştırma testi kullanılarak istatistiksel olarak analiz edilmiştir. Bağlanma dayanımı, iki farklı yüksek translüsent zirkonya CAD/CAM materyali arasında istatistiksel olarak anlamlı bir farklılık göstermemiştir (p:0.055; p>0.05). Bağlanma dayanımı, yüzey işleminden önemli ölçüde etkilenmiştir (p:0.000; p<0.05). Zenostar için en yüksek kesme bağlanma kuvveti fiber lazerde bildirilmiştir (17,81±2MPa). Ceramill için en yüksek kesme bağlanma kuvveti fiber lazerde bildirilmiştir (21,7±3,55 MPa). Her iki monolitik zirkonya grubu için tribokimyasal silika kaplamanın (Cojet, Siljet) ve 50 µm Al₂O₃ ile kumlama + Z Prime Plus uygulamasının bağlanma gücüne etkisinde istatistiksel olarak anlamlı bir fark bulunmamıştır. En baskın

kopma tipi, fiber lazer gruplarında kohezivdi ve Cojet, Siljet ve kumlama+Z Prime Plus gruplarında ise karışık (adeziv ve koheziv) tip oldu. HF asit yüzey işlemi 1 saat uygulandığında monolitik zirkonyanın bağlanması için etkili bir yüzey işlemi olmamıştır. Kumlama+Z Prime Plus, Cojet ve Siljet monolitik zirkonya için mevcut en iyi simantasyon protokolüdür. İki monolitik zirkonya CAD/CAM bloğu için fiber lazerle yapılan yüzey işlemi bağlanma dayanımını artırmıştır ancak zirkonyanın renk değiştirmesine neden olmuştur. Fiber lazerin yüksek taranlulent monolilik zirkonyada zarar vermeden bağlanmayı artırmak için daha fazla araştırmaya ihtiyaç vardır.

Anahtar Kelimeler: kesme bağlanma dayanımı, CAD/CAM, monolitik zirkonya, self adeziv rezin siman, yüzey işlemi

1 INTRODUCTION and PURPOSE

The progression in modern dentistry to restorations that copy natural teeth is unquestionable. The explore for strong, lasting esthetic restorations that match the long-lasting functional predictability of gold restorations has begun since the starting of the dental practice. Established on real patient require about the esthetic and health concerns, material options have changed to metal-free restorations because of their biocompatibility and esthetic advantages¹.

In the beginning, zirconia crowns were fabricated with a zirconia substructure layered or pressed with distinct kinds of porcelain. Esthetic, strong, biocompatible, durable, conservative tooth preparation and good price are a couple of the characters that push a lot of laboratories to move toward full-contour monolithic restorations ². Moreover, modern digital technology changed the laboratory and dentists to shape and control such completely dense zirconia to fabricated crowns in little time. Curiously, it gives to the patients the convenience of same-day restoration ³. Monolithic zirconia restorations start as chalky white blocks with little translucency that are milled to their predesigned shape and soaked in a dyeing liquid ⁴. To fix this trouble, a further translucent monolithic zirconia was created for anatomic-contour restorations. One approach for making translucent monolithic zirconia has been to elevate the tetragonal grain size. In a structure with bigger grains, little grain boundaries exist, which leads to less light refraction^{5,6}.

The larger tetragonal grains are more tender to hydrothermal degradation⁵. Another approach has been to reduce the grain size to less than 100 nm,⁶ which is smaller than the visible light wavelength (400-700 nm). Thus, light can move through the material with only a little scattering incomparable to the bigger grains. Another approach has been to employ zirconia with cubic grains, which are isotropic and better the light transmittance ⁶. This kind of material which called fully stabilized zirconia (FSZ) and cubic grains are created by elevating the yttria content ⁶. However, an effective eran of translucency and a stable cubic phase is created when a higher concentration of yttria (approximately 9.3 wt%/5 mol%) is present, cubic zirconia does not demonstrate the t/m transformation toughening phenomenon.

High translucent zirconia (HTZ) materials have markedly inferior flexural strength (550–800 MPa instead of 900–1400 MPa), and even poorer adhesive act with resin-based cement incomparable to traditional zirconia⁷. The push to accomplish millable monolithic materials has recommended the innovation of higher translucent zirconia millable materials in shaded gradations and various opacities to better the esthetics of the final product. After adjusting some compositional items and powder physical characteristics, zirconia accomplished higher translucency⁴. The zirconia-producing company's goal is to be able to achieve zirconia powders that match all the shades in the VITA shade guide and to make high-density milling blocks that are more translucent and without loss in strength⁴.

There is little scientific information concerning the bonding strength of HTZ subjected to various surface modifications. Like other types of zirconia, HTZ owns a dense polycrystalline structure with no vitreous phase, which makes its surface roughness very difficult. Methods for example sandblasting with alumina particles⁸, tribochemical silica coating⁹, deposition of low fusing porcelain¹⁰, plasma coating with hexamethyldisiloxane¹¹, laser surface treatment¹², selective infiltration etching method¹³, and zirconia alloy primers¹⁴ and many others have been suggested for traditional zirconia.

Presently, the most dependable bonding method for zirconia is the combination of sandblasting with alumina (Al_2O_3) or silica-coated alumina ($\text{Al}_2\text{O}_3/\text{SiO}_2$) particles and promote surface conditioning with a primer containing MDP¹⁵. Abrasive alumina particles of different sizes are employed to remove impurities and elevate their surface roughness, thereby allowing for mechanical interlocking with cement. Primer containing MDP can chemically bond to the zirconia surface through zirconium phosphate formation. Salem et al.¹⁶ described promising outcomes for translucent zirconia bond strength when using alumina air-particle abrasion with an MDP-containing alloy. Other techniques like air abrasion with silica-coated alumina particles, called tribochemical silica coating, allow for coating the zirconia surface with a thin silica layer that is capable to react with silane. In this respect, Ruales-Carrera et al⁷, proved that tribochemical treatment with $\text{Al}_2\text{O}_3/\text{SiO}_2$ particles was effective at elevating the bond strength of both highly translucent and conventional zirconia. Conventional silica-based ceramics, for example, feldspathic porcelain, are best

treated with hydrofluoric acid (HF) for bonding uses¹⁷. Nevertheless, the HF etching process is less effective at zirconia. Recently, various studies proved that to be effective HF etching of zirconia demands a longer etching time, a higher concentration of HF and/or a higher temperature, such as 9.5% HF at 80 °C for 1 min or at 25 °C for 1 h, or 48% HF at 25 °C for 30 min⁴, 20% or 30% HF for 30 min, or 48% HF at 100 °C for 25 min¹⁷.

Different Laser kinds applied for surface treatment are Er: YAG laser, Nd: YAG laser, CO₂ laser, an ytterbium-doped fiber laser (YbPL)^{18,19,20}. Transforming light energy into heat energy is the principle of laser uses. The process of the laser energy absorbed by the substrate is the most significant interaction between the laser light and the substrate²¹. Erbium and ytterbium lasers are widely utilized in biomedical applications. While the Yb³⁺-ion transitions give prominent high pumping efficiency because of small quantum defect, ytterbium lasers work near 1 μ m and provide small nonradiative losses, low heating, almost 80% conversion efficiency, and 25% wall-plug efficiency²². One recent study proved that a YbPL was the best surface treatment for shear bond strength between YTZP and resin cement²³.

The null hypothesis of this study that

- 1-There would not be a significant difference in the shear bond strength of the self-adhesive resin cement to both types of highly translucent monolithic zirconia CAD/CAM material.
- 2- Pre-stained highly translucent monolithic zirconia CAD/CAM material would be a significant difference in the shear bond strength in term of surface treatment.
- 3- HF acid surface treatment for 1 hour would be improve bond strength shear bond strength of self-adhesive cement for both types of CAD/CAM highly translucent monolithic zirconia.
- 4- That fiber-optic laser surface treatment would improve the bond strength of self-adhesive resin cement for both types of CAD/CAM highly translucent monolithic zirconia.

2 LITERATURE REVIEW

2.1 Digitalization in dentistry (CAD/CAM)

In the 1950s and 1960s, when the first versions of computer-aided design (CAD) and computer-aided manufacturing (CAM) were introduced in industrial settings²⁴, the level was changed to reflect exciting breakthroughs in dentistry. Novel manufacturing processes and intervention concepts will be expected as a result of a further increase in computer hardware and software, allowing for more cost savings²⁵. With the introduction of CAD/CAM, dentists and laboratories can now use computers to plan and construct beautiful and long-lasting restorations²⁶.

2.1.1 Evolution of CAD/CAM systems

Dr. Francois Duret was the first of those who design CAD/CAM equipment, produce crown constructed on an optical impression of the prepared tooth, and employed a numerically operated milling machine in 1971^{27,28}. He produced the first CAD/CAM dental restoration in 1983²⁷. Dr. Andersson developed out the Procera Method of manufacturing high-precision dental crowns in 1983. Dr. Duret later created the Sopha system in 1984^{27,28}. Dr. Andersson was the first person to apply CAD/CAM to construct composite veneered restorations^{27,29}. In 1987, Mörmann and Brandestini utilized the CEREC system, which was the first dental system to link the digital scanning component with the milling unit^{27,30,31}. The E4D Dentist system, launched in 2008, enables same-day in-office restorations through the use of the CEREC system²⁷.

2.1.2 CAD/CAM components

2.1.2.1 Digitalization tool/ scanner

There are two distinct scanning techniques the first one is optical scanning and the second is mechanical scanning.

2.1.2.1.1 Optical scanners

This model of the scanner is based on a 'triangulation method' that gathers 3D structures. In this case, the laser and the receptor unit are connected at a specific angle. The computer is able to calculate a three-dimensional data set from the image on the receptor unit by using this angle. Examples: Lava Scan ST (3M ESPE, white light projections) and es1 (etkon, the laser beam) ³².

2.1.2.1.2 Mechanical scanner

A ruby ball is used to inspect the master cast mechanically line-by-line, and the 3D structure is assessed. This sort of scanner is known for its high level of precision since the diameter of the ruby ball is set to the smallest grinder in the milling system, resulting in the milling of all data gathered by the system for example is the Procera Scanner. The mechanical scanner is quite complex, the equipment is expensive, and the processing time is significantly longer than that of optical systems ³².

2.1.2.2 Design software

Three-axis, four-axis, and five-axis processing systems are identified by the number of milling axes they have ³².

2.1.2.2.1 Axis milling devices

This type of milling machine may travel in any of the three directions. The X, Y, and Z values are used to identify the milling route points. All 3-axis dental appliances can rotate the component 180° in the path of processing the outside and inside. Milling times are reduced, control is simplified, and costs are lower when using a 3-axis milling machine. InLab (Sirona), Lava (3M ESPE), and Cercon brain (Degu Dent) ³².

2.1.2.2.2 4-axis milling devices

The tension bridge for the component can be turned infinitely in any direction with this device's three spatial axes. Thus, it is possible to regulate bridge construction with a great vertical height displacement into the standard mold parameters, resulting in reduced material consumption and milling time. For instance Zeno (Wieland-Imes) ³².

2.1.2.2.3 5-axis milling devices

It has three dimensions and a moveable tension bridge (4th axis) in addition to the milling spindle's ability to be rotated (5th axis). Complex geometries with subsections can be milled using this method. For instance, Kavo, the Everest Engine ³³.

2.1.3 Different CAD/CAM systems

2.1.3.1 Everest

The scan, engine, and therm constituents are all part of this system. On the turntable, the scanning unit is mounted, and a CCD camera scans it in a 1:1 ratio with a measurement precision of 20 microns. The 5-axis movement of its machining unit allows it to generate extremely exact features and shapes, as well as correct margins, for a variety of materials. Several examples include leucite reinforced glass ceramics, zirconia, and titanium ²⁸.

2.1.3.2 Lava

When compared to typical ceramics, (Y-TZP) is more resistant to fracture. Laser optics are used to digitize data in the lava system. Software in the Lava CAD detects the restoration margin and recommends a pontic. Sintering shrinkage will necessitate a 20% increase in the size of the framework ^{24,25}.

2.1.3.3 Procera

Electrical discharge (also known as spark eroding) machining has been combined with pantographic reproduction in this technology. New ideas are employed in the production of its alumina and zirconium components. The scanning stylus first creates a 3D image of the

master dies, which is subsequently transmitted to the processing center by modem. Because of the shrinking of the ceramic material, the processing center makes larger dies²⁸. With the help of a high-purity, 99.9 percent alumina powder, Copings are made. The desired thickness is then machined out of these tightly packed copings. Procera restorations are known for their long-term clinical viability and high strength²⁸.

2.1.3.4 Cicero system

In the Netherlands, CICERO Dental Technology B.V. was developing this system (Hoorn, The Netherlands). For the manufacturing of ceramic restorations, the CICERO approach employs official scanning, ceramic sintering, and computer-assisted milling technologies to generate restorations with the most stable and dynamic occlusal contact relationships possible³¹.

2.1.3.5 Cerec system

In the CEREC (computer-aided ceramic reconstruction) technology, restorations are designed and milled using a computer-controlled milling machine.

2.1.3.5.1 Cerec 1

The ceramic block is rotated on the block carried by the spindle and fed against the grinding wheel, which grinds the ceramic block to a new contour with a variable distance from the axis at each feed step³².

2.1.3.5.2 Cerec 2

The installation of a cylinder diamond allows for the grinding of partial and whole crowns. It offered three methods for designing the occlusion: extrapolation, correlation, and function. However, the design was still presented in two dimensions³⁰. With CEREC 1 and CEREC 2, an optical scan of the prepared tooth is performed using a pair-charged device camera, and a three-dimensional digital image of the prepared tooth is displayed on the monitor. Following that, the restoration is developed and milled²⁸.

2.1.3.5.3 Cerec 3

This system introduced the dual bur-system. The "step bur" reduced the diameter of the cylindrical bur's top one-third to a small-diameter tip, allowing for excellent precision while maintaining an acceptable bur life ³⁰. The most significant aspect of three-dimensional scanning with the Cerec 3 intraoral camera is that tooth preparations for crowns and inlays have a unique feature: all locations of interest can be viewed from a single viewing line, which represents the preparation and insertion axis separately ³⁴.

2.1.3.5.4 CEREC in lab

The working dies are scanned with a laser and a digital image of the virtual model is displayed on a screen in this system. After designing the coping or framework, the technician inserts the appropriate VITA In-Ceram block into the CEREC in Lab milling machine. The technician then inspects the milled coping or framework for fit ²⁸.

2.1.3.6 E4D dentist system

At the moment, it is the only CEREC technology that enables same-day in-office dental restorations. This system consists of a laser-assisted intraoral digitizer, a design center, and a milling machine. The intraoral scanner is placed near the prepared tooth and is equipped with two rubber feet that secure it to a specific measurement distance from the area being scanned. While the photograph is being shot, the software gradually creates a 3D image ³². The design system finds and marks the finish lines automatically. Once the restoration is approved, the data is sent to the in-house milling machine or to a dental laboratory. The office milling machine will next fabricate the restoration from the ceramic or composite blocks that have been selected ²⁷.

2.1.4 Stages in the fabrication of prosthesis with CAD/CAM technology

2.1.4.1 Computer surface digitization

After the tooth has been prepared, it is scanned using LED or laser-based scanners.

2.1.4.1.1 Led based scanner

This kind was utilized. After completing tooth preparation, a small portable video camera with a 1cm wide lens (scanner) is positioned over the occlusal surface. The camera emits infrared light that passes through an internal grid consisting of a series of parallel lines³². The pattern of light and dark stripes that falls on the prepared tooth surface is reflected in the scanning head and then to the photoreceptor, where its intensity is shown as a voltage measurement and communicated to the CAD unit as digital data³².

2.1.4.1.2 Laser based scanner

A high-speed laser is used to collect digital scans of the prepped and proximal teeth in order to create an interactive 3D representation. Rapid scan enables the automatic capture of digital images at the operator-selected pace for intra- or extra-oral scanning of traditional impressions or models, all without the use of powder³². Using optical coherence tomography (OCT), more unique laser-based scanners can scan at subgingival levels. To produce the image, a minimum of nine scans is required³². Stabilizers are included with the scanning apparatus. If a scanned image is correct, it appears green; if it is nearly correct, it appears yellow; but if the scanned image does not meet the requirements, the software skips the image and displays it in red³⁵.

2.1.5 Computer aided designing (CAD)

Over the screen, a three-dimensional image of the die is generated and may be rotated to allow for inspection from any angle³⁶. After capturing the three-dimensional image with one of the computer surface digitization techniques, the three-dimensional image is processed and the digitized data is entered into the computer. Finally, data reduction and curve smoothing can be performed at this step, as well as blocking of undercuts. The restoration is designed using CAD software, which then sends fabrication directions to the CAM unit³⁶.

2.1.6 Computer aided manufacturing (CAM)

The third and concluding step is (CAM). According to the technique utilized, CAM technologies can be classified into three categories.

2.1.6.1 Subtractive technique from a Solid Block

Milling is carried out at this stage using computerized electrically powered diamond disks or burs to remove the restoration from the ingots³⁶. The CAM technique is most frequently used to fabricate frameworks for single crowns. The size of the FPDs is limited by the size of the material blocks available for the milling units³⁷.

2.1.6.2 The additive technique (by applying Material on Die)

Alumina or Zirconia is dry pressed on the die and the temperature is increased to a pre-sintering temperature in this procedure. The expanded and porous coping is stable at this time. It is milled to the proper form and coping, removed from the die, and sintered into the furnace for full sintering³².

2.1.6.3 Solid freeform fabrication

In this category are innovative technologies that have emerged from the field of Rapid Prototyping and have been tailored to the requirements of the dental technology industry.

2.1.7 Rapid prototyping techniques

One form is stereolithography, another is selective laser sintering (SLS), and a third is 3-D printing (three-dimensional printing)³⁷.

2.1.7.1 Stereolithography (Perfactory, Delta Med, Frieberg, Germany)

It is a method of fabricating three-dimensional structures in which a moving laser beam controlled by a computer is used to build the required structure layer by layer²⁶. This

technique can be used to create occlusal splints and diagnostic templates that are used in oral implantology³⁷.

2.1.7.2 Selective laser sintering

The process starts with the transformation of the CAD data into a sequence of layers. They are transferred to the additive SLS machine, which begins laying the first layer of powder on top of the previous layers. While the laser is scanning the surface, the material is heated and fuses together²⁶. As soon as the single-layer formation is complete, the powder bed is lowered, and the next layer of powder is rolled out smooth and submitted to the laser for cutting. As a result, the object is established layer by layer throughout the process²⁶.

2.1.7.3 3-D printing

Following the completion of the computer-aided design, the equipment is used to create (print) a wax pattern of the restoration. Following that, the wax pattern is cast in the same manner as with the classic lost-wax technique. Patterns are now being created using resin-type material instead of wax, which represents a significant advancement in the field of pattern making^{26, 36}.

2.2 CAD/CAM ceramic restorative materials

The patient's preferences, as well as the optimal marginal and internal fit of fixed prosthodontic restorations^{38,39}, are the most significant advantages of the digital workflow when compared to the old impression technique. Because of the use of homogeneous industrial blanks and blocks, it is likely that fewer material failures will occur during the course of production and clinical application⁴⁰. The existence of defects and porosity is minimized in CAD/CAM blocks when compared to hand-built materials, resulting in increased durability⁴¹.

2.2.1 Glass ceramics

2.2.1.1 Silica

Conventional ceramics, such as VITA Mark II (VITA-Zahnfabrik), were used to build the first CAD/CAM fine-structure feldspathic ceramics (VITA-Zahnfabrik). There are two crystallization patterns in this feldspathic CAD/CAM ceramic: one is a sodium-potassium aluminum silicate peak ($\text{Al}_8\text{K}_2\text{Na}_6\text{O}_{34}\text{Si}_9$), the other is a potassium sodium aluminum silicate peak ($\text{AlK}_{0.29}\text{Na}_{0.71}\text{O}_3\text{Si}_3$)⁴². This material demonstrated low characteristic strength⁴³.

2.2.1.2 Leucite reinforced glass ceramics

Leucite crystals equaling 40% of Empress CAD (Ivoclar-Vivadent) are implanted in the glass-ceramic Empress (Ivoclar-Vivadent), which has been around for a long time. ProCAD (Ivoclar-Vivadent) is a replacement for the monolithic CAD/CAM block⁴⁴. (ProCAD) that uses a glass system including a mixture of silicate oxides, aluminum oxides, and potassium oxides (K_2O and Na_2O). Using TiO_2 and CeO_2 as nucleating agents, massive crystallizations of monolithic glasses in powdered glass demonstrate a dendritic development of glass particles in powdered glass⁴⁵. With the use of "dispersion strengthening" approach and the addition of fillers like uniformly dispersed leucite, he was able to achieve a somewhat elevated strength⁴⁵.

2.2.1.3 Lithium disilicate ceramics

Using a glass-ceramic, a significant increase in strength was achieved by precipitating lithium disilicate crystals⁴⁵. Empress 2 (Ivoclar-Vivadent) and Ivoclar-IPS Vivadent's e.max Press (Ivoclar-Vivadent) have been used to develop a lithium disilicate glass-ceramic for CAD/CAM processing technologies. Solid state reaction⁴⁵, is the process by which the SiO_2 - $\text{Li}_2\text{OK}_2\text{O}$ - ZnO - P_2O_5 - Al_2O_3 - ZrO_2 system is formed. Particles of lithium disilicate (LDS) ceramic (0.5 to 4 μm in diameter) show different orientations⁴⁶. A two-stage crystallization method is applied to the machined LDS CAD/CAM. According to the manufacturer, the LDS CAD/final CAM's flexural strength is 530 MPa after sintering. The Weibull modulus

(13.4) and characteristic strength (0, 609.80MPa) were described in a recent study. Since LDS is the strongest glass-ceramic, it is approximately three to four times stronger than other glass-rich ceramics. For monolithic dental restorations, the material can be employed as a core material coated with apatite-containing veneering ceramics⁴⁷. because of its translucent and color variation. A wide range of single-tooth and implant restorations, as well as three-unit fixed dental prostheses limited to premolars⁴¹.

2.2.1.4 Lithium silicate phosphate glass ceramics

An entirely new lithium silicate/phosphate (LSP) CAD/CAM material known as zirconia-reinforced lithium silicate glass-ceramics was introduced to the market in 2013. When the final crystallization firing is completed, the monolithic Suprinity blocks are delivered in a metal sintered stage, making the grinding process easier. A precrystallized (Celtra CAD) or fully sintered (Celtra Duo) stage is available for the Celtra blocks. Inlays, Onlays, veneers, and crowns⁴⁰ are the best candidates for LSP. To crystallize metasilicate in lithium silicate glass, the diphosphorous pentoxide P_2O_5 serves as a nucleation agent⁴⁰.

2.2.2 Resin matrix ceramics

New CAD/CAM ceramic restorative materials known as resin-matrix-ceramics (RMCs) were developed to combine the advantages of polymers, which are not brittle, with ceramics to provide high-quality cosmetic restorations. The proper classification of this new CAD/CAM ceramic restorative material group is still up for debate in the literature. Hybrid ceramic or "nanoceramics" are also known as RMCs because of the selling reasons or insurance reimbursement policies in North America⁴⁹. However, this commercial phrase does not accurately reflect the chemical composition of the item it refers to. In terms of structure and industrial polymerization method, RMCs can be sub-grouped into 1-high-temperature polymerized resin-based composites (CAD/CAM) with dispersed fillers and a predominantly organic phase, as well as 2-high-temperature PICN materials with a mostly inorganic phase^{48,49}.

2.2.3 Resin based composites (CAD/CAM)

2.2.3.1 Lava ultimate (LU)

The 3M-ESPE CAD/CAM machining block was released in 2011. It is built on Filtek Supreme Ultra (3M), a polymerizable resin composite, and contains dispersed nanometric colloidal silica and ZrO₂ spherical particles in agglomerated and non-agglomerated forms (80% wt, 65%) planted in dimethacrylate resin ⁴⁰.

2.2.3.2 Cerasmart (GC-Corp), Shofu block hc (Shofu-Inc.), and brilliant crios (Coltene)

Are brand-new RBCs with a uniform ceramic network. In one study, the researchers found a flexural strength of 230 MPa ⁵⁰. For veneers, inlays, onlays, single crowns (SCs), and implant crowns, RBCs restoration is indicated (except LU). RBCs should be prepared with air-particle abrasion and a universal bonding agent before resin bonding ⁵¹.

2.2.3.3 Polymer infiltrated ceramic network material

This material (VITA Enamic; VITA-Zahnfabrik) is constructed of a PICN of urethane dimethacrylate and triethylene glycoldimethacrylate cross-linked polymers with a fine open porous feldspathic ceramic structure network (86 percent wt, 75 percent vol) ⁴⁸.

2.2.4 Oxide ceramics

2.2.4.1 Zirconia ceramics CAD/CAM blocks

Dental zirconia became available in the 1990s thanks to CAD/CAM technology. Because of this, the material's features are well-known and stated in a concise manner. Thermal conductivity, corrosion potential, and radio-opacity are all reduced by the material's dense monocrystalline homogeneity. Zirconia's flexural strength (900 to 1,200 MPa) and fracture toughness (9 to 10 MPa) have been elevated due to a phenomenon called

transformation toughening. Research has shown that it has an increased Weibull modulus (12.30; 43.) and higher characteristic strength (0:1,303.21 MPa) ⁵². Infrastructure materials like yttria stabilized zirconia polycrystal (Y-TZP) have been established to prevent bulk fracture of restorations from happening. This has allowed for a widening of the range of applications, from single crown and short span FDP to long-span and full-arch zirconia frameworks to support the fixed and removable prostheses ⁵³. Before densification, form blocks of zirconia are commonly used in CAD/CAM systems. Following this, a 25 percent shrinking is achieved in order to get the desired dimensions.⁴⁰. Press and hand-layer veneering processes are utilized to apply the suitable ceramic veneer. High-load-bearing areas are the most common application for recently developed functionally graded glass/zirconia/glass constructions ^{53,54}.

2.2.4.2 Monolithic zirconia CAD/CAM blocks

Refined with superficial glazing are progressively utilized ^{55,56}. Numerous in vitro investigations have proved the mechanical strength of monolithic zirconia for use in single crowns and bridges⁵³. The zirconia sintering process takes a long period, in order to save time and money at the chairside CAD/CAM restorations can be completed in one visit, super-fast and high-speed sintering techniques (Speedfire; Dentsply-Sirona) have been sophisticated. The flexural strength of monolithic Y-TZP was tested and no substantial change was seen as a result of speed sintering ⁵⁷.

2.2.4.3 Translucent zirconia CAD/CAM blocks

To defeat the difficulty of veneer chipping, there has been some progress made in bettering the translucency of Y-TZP by diminishing zirconia porosity, reducing grain particle size, and eliminating the alumina addition. Many brands brought in somewhat better translucent CAD/CAM zirconia blocks utilized for fabrication crowns and fixed bridge ⁵³. Besides that, cubic zirconia materials were developed for monolithic applications according to the claims. An optically isotropic cubic zirconia phase brought in an ordinarily tetragonal material (e.g., DD CubeX2, Dental-Direkt; ZpexSmile, TosoCorp). In comparison to typical dental tetragonal zirconia, these translucent ceramic materials are noticeably weaker and

more brittle, and they cannot be considered a replacement for the opaquer Y-TZP ceramic material. The described ceramic has a flexural strength of between 600 and 700 MPa, which is approximately half that of Y-TZP ⁵³.

2.3 Basic knowledge about zirconia

2.3.1 Zirconia phases (monoclinic, tetragonal, and cubic)

Polymorphism refers to the fact that the atoms of zirconia are arranged in various crystallographic forms that are distinct from one another. Monoclinic, tetragonal, and cubic crystal formations are the three phases or crystal structures that support this material ⁵². Pure zirconia has a monoclinic structure at normal temperature, which is constant at 1170°C. Tetragonal zirconia is formed between this temperature and 2370°C, while cubic zirconia is created above 2370°C. When cooled, the tetragonal phase turns monoclinic at around 970°C after treatment. Polymorphism prevents the use of pure zirconia at high temperatures because cooling to the monoclinic phase results in a considerable volume change (3-5 percent) ⁵².

2.3.1.1 Monoclinic zirconia

Identified as baddelyite, includes about 2% HfO₂ (hafnium oxide), In terms of structure and chemical properties, it is similar to zirconia. Because oxygen ions occupied tetrahedral interstices, Zr⁴⁺ ions have a coordination number of seven. With an average distance of 2.07 between the zirconia ion and three of the seven oxygen ions ⁵⁸. As a result, the average distance between the zirconium ion and the four oxygen ions is 2.21 Å, structure, one of the angles in the structure (134.3°) differs significantly from the tetrahedral value (109.5°). Therefore, the oxygen ion's structure is not planar, and there is a curve in the plane of four oxygens, whereas the plane of three oxygens is irregular ⁵⁸.

2.3.1.2 Tetragonal zirconia

Zirconia's tetragonal phase resembles a straight prism with a rectangular side. Zr⁴⁺ ions have an eight-coordination number, The coordination number of Zr⁴⁺ ions is eight, and

the form seems twisted once more because four oxygen ions are at a distance of 2.065 from a tetrahedron plan, in a tetrahedron that has been extended and rotated 90 degrees, four others are at a distance of 2.455 ⁵⁹.

2.3.1.3 Cubic zirconia

A basic cubic lattice with eight oxygen ions can be used to describe the structure of cubic zirconia, which are encapsulated in a cubic arrangement of cations and are referred to as fluorite, ie The oxygens fill the tetrahedral interstices of a cation-filled cubic lattice (CFC) ⁵⁹.

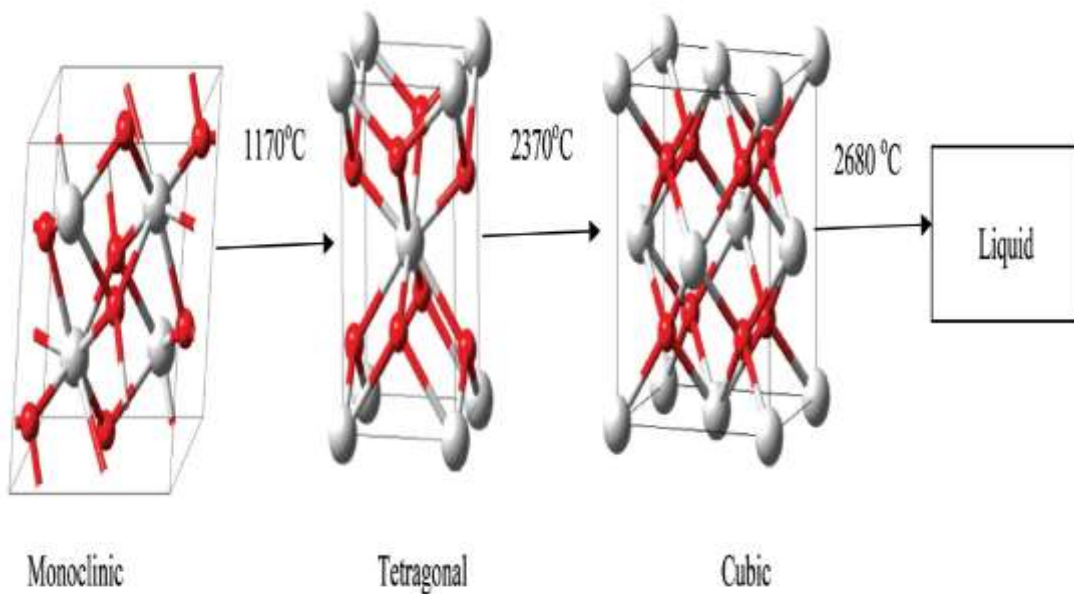


Figure 2.1. Crystal structure of monoclinic (a), tetragonal (b), and cubic zirconia(c) ⁵⁹

2.3.2 Available zirconia ceramics for dental applications

Three types of zirconia have been primarily used in the dental application, the first type is magnesium partly stabilized zirconia (Mg-PSZ), the second type zirconia-toughened alumina (ZTA), and the third type is the most often used 3Y-TZP ⁵².

2.3.2.1 Magnesium partially stabilized zirconia (Mg-PSZ)

Mg-PSZ is reportedly inappropriate for employment in dentistry due to its huge porosity and large grain size, which result in surface wear. The sintering temperature of this type of zirconia is too high between 1680°C and 1800°C. Moreover, Mg-PSZ has weak stability, which may somewhat decrease the energy for the T→M transformation ⁵².

2.3.2.2 Zirconia toughened alumina (ZTA)

ZTA is a combination of zirconia with an alumina matrix, which undergoes stress-induced transformation to achieve excellent mechanical properties ⁵². Among the dental ceramics, the only ceramic product available in the market which is toughened ceramic through dispersion is the In-Ceram Zirconia (Vita Zahnfabrik, Germany). This product can be processed via slip-casting or milling at a pre-sintering stage ⁵². However, ZTA has a large number of pores, between 8% and 11% ⁶⁰.

2.3.2.3 Zirconia 3Y-TZP

3Y-TZP zirconia has been employed in dentistry due to its mechanical qualities being comparable to those of metal and its color is comparable to that of natural teeth ⁵². Update, research into the possibility of 3Y-TZP zirconia in dental applications has accelerated. This assertion is substantiated by the increasing number of journal publications on 3Y-TZP zirconia in dental applications, which is increasing each year this statement. As a result, additional information and extensive investigations are required to ascertain these materials' capacities as biomaterials. The mechanical properties of 3Y-TZP are superior to those of other zirconia-based materials. 3Y-TZP, like polycrystal materials, has low porosity and a high density ⁶¹.

The essential grain size for the material is 1 micron; if the particle size surpasses 1micron, 3Y-TZP becomes susceptible to phase transformation toughening due to its decreased stability Conversely, this phenomenon does not happen when the grain particle size is less than 1 micron. Additionally, zirconia with a grain particle size of fewer than 0.2

micron does not experience this phase change toughening, as the fracture toughness of the material reduces ⁶². The grain particle size of zirconia 3Y-TZP has a substantial effect on its mechanical qualities, as higher temperatures and longer sintering times result in larger grain sizes, lowering the mechanical properties ⁶³. Increased sintering temperatures result in bigger grain sizes. As a result, the sintering process becomes critical, and process control must be focused throughout the dental restoration manufacturing process, as it affects grain size while also affecting the mechanical qualities and stability of the zirconia ⁶³.

2.3.2.4 Zirconia containing lithium silicate ceramics (ZIs)

The addition of 10% Zirconia oxide to lithium silicate resulted in a dual microstructure composed of lithium metasilicate (Li_2SiO_3) and lithium disilicate ($\text{Li}_2\text{SiO}_2\text{O}_5$) crystals embedded in a glassy matrix of ZrO_2 ⁴⁰.

2.3.2.5 Resin nano-ceramic materials

It is a restoration comprised of a cross-linked polymeric matrix including three distinct fillers like Lava Ultimate CAD/CAM. They consist of clusters of zirconia and silica nanoparticles, separately bonded silica nanoparticles, and separately bonded zirconia nanoparticles. These can be utilized in heavy-stress areas in the oral cavity like the second molar region ⁴⁰.

2.3.3 Biological characteristics

2.3.3.1 Biocompatibility

Zirconia has been shown to be highly biocompatible in both vitro and vivo, especially when its radioactive components are removed ^{64,65}.

2.3.3.2 Degree of toxicity

Zirconia has been demonstrated to be less hazardous in vitro than titanium oxide and alumina. Neither fibroblasts nor blood cells have shown any signs of cytotoxicity, carcinogenicity, mutation, or chromosomal disruption as a result of this substance' ⁵⁹.

2.3.3.3 Radioactivity

Thorium (Th) and uranium (U) are two long-lived radioactive elements commonly found in zirconia. These ingredients are difficult and expensive to separate. Zirconia is associated with alpha and gamma radiation ⁵⁹. In zirconia-based ceramics utilized in the manufacturing of surgical implants, significant levels of alpha radiation have been found. They are highly ionized; therefore they can damage both hard and soft tissues. There is no concern about zirconia's gamma radiation levels, according to the literature ⁵⁹.

2.3.4 Type and fabrication of zirconia blanks

Fully sintered zirconia is machined in a 1:1 ratio using CAD/CAM technology from a solid block. Zirconia that has been partially sintered must be machined up to 25% larger than the final dimensions necessary due to shrinkage caused by the sintering process. Before constructing the framework or coping designed by a computer for both the partially and fully sintered processes, the die is scanned first ⁶⁶. When using the CAD/CAM technology, zirconia blanks from three different types are used. Even though they share many physical features (i.e. porosity, density, purity, strength), they may or may not be clinically relevant ⁶⁷. The first kind is a densely sintered blank used for hard machining CAD/CAM technology and hence for direct machining. Sintering (soft machining) is essential for the creation of the other two types of CAD/CAM blanks in order to achieve the desired final product strength. Pre-sintered blocks or blanks at the green stage are included in this category, whereas the other type comprises blanks at the raw stage, in the form of partially stabilized zirconia powder mixed with a binder ⁵².

2.3.4.1 Soft Machining

Pre-sintered yttria-stabilized zirconia direct ceramic manufacturing has been increasingly prevalent in dentistry since 2001 and is now being expanded by an increase in the number of manufacturers. To summarize, the die or wax pattern is scanned, increased size of the prosthesis is created using computer-aided design, and a pre-sintered ceramic blank is manufactured utilizing⁵². Following that, the prosthesis is sintered at an elevated temperature. Numerous versions of this method exist, determined by a variety of aspects, including how the scanning is performed and how the significant sintering shrinkage of yttria-stabilized zirconia is compensated for (about 25 percent). It is possible to employ contact and non-contact scanners. Non-contact scanners often provide a better data point density and faster digitization than contact scanners⁵². To render the 3Y-TZP powder suitable for pressing, it contains a binder that makes it easier to handle. After the pre-sintering step, a binder is eliminated. The chemical composition of these powders is slightly different. The blanks are produced via cold isostatic pressing⁵². Mostly during pre-sintering heat treatment, the binder is eliminated. The heating rate and pre-sintering temperature must be closely monitored by producers throughout this step of the process. Cracking of the blanks occurs when the binder and other burnout products are removed at a rapid rate during heating. Because of this, low heating rates are chosen. Blank hardness and machinability are influenced by their pre-sintering temperature⁵². In manipulating the blanks, a certain degree of hardness is required; nevertheless, if the hardness is excessive, it can affect machinability. The roughness of the machined blank can be significantly influenced by the temperature of the pre-sintering heat treatment. Pre-sintering temperatures that are too high can result in rougher surfaces. The temperature of the pre-sintering process is quite important. Because each blank's density is precisely measured, the final sintering process may apply the correct amount of compensating shrinkage. The final density of the pre-sintered blanks is roughly 40% of the theoretical density⁵².

A two-step machining technique is more efficient than a one-step process. First, a low feed rate is used for rough machining, and then a greater feed rate is used for fine machining⁶⁸. This method prevents stress-induced transformation from tetragonal to monoclinic and leads to a final surface that is essentially devoid of monoclinic phase unless grinding changes

are required or sandblasting is performed. However, most manufacturers of yttria-stabilized zirconia blanks for the dental market do not recommend grinding or sandblasting in order to avoid the T M transformation and to avoid the generation of surface defects that may be detrimental to long-term performance⁵². A solution of different metals, such as cerium, bismuth, iron, or a mixture, can be used to color the prosthesis after it has been machined⁶⁹. During the final sintering stage, the color is formed. Color can be added to zirconia by incorporating different metal oxides into the powder⁷⁰. It is critical to regulating the sintering process of the machined prosthesis, which is typically done in a specially programmed furnace. at 1000 °C, shrinkage begins and reaches a maximum of about 25%. Product-specific sintering conditions must be followed. More than 99 percent of the predicted density can be achieved with final sintering temperatures between 1350 °C and 1550 °C and dwell periods between two and five hours. To reduce residual stresses⁵² and give the prosthesis a more pleasing appearance, it is furnace-cooled to temperatures below 200 °C⁶⁷.

2.3.4.2 Hard machining

Zirconia dental prosthetics can be hard machined utilizing either Denzir® from (Cadesthetics AB) or DCZirkon® from (DCS Dental AG). Pre-sintering the blocks at temperatures below 1500 °C results in a density of at least 95% of the theoretical density. After that, the blocks are exposed to a hot isostatic pressing technique in an inert gas atmosphere at temperatures between 1400 and 1500 °C^{71,72}. This method results in a density of more than 99% of the theoretical density. Zirconia processing in its densely sintered stage offers a benefit because it minimizes undesirable dimensional changes caused by sintering shrinkage during machining heat treatment⁵². While grinding can be tough and time-consuming, the increased wear on grinding tools is a downside. Monoclinic zirconia has also been shown to be present in the hard-machined yttria-stabilized zirconia blocks used to create the prosthesis. Surface microcracking, greater low-temperature deterioration capabilities, and reduced dependability are all prominent causes of this phenomenon⁷³.

2.3.5 Aging

Aging, commonly known as low-temperature degradation, is the spontaneous, slow change of the metastable tetragonal phase into the more stable monoclinic phase, which occurs in the absence of any mechanical stress and occurs over time at low temperatures⁷⁴. It is aggravated in the presence of water, steam, or other fluids. Low temperature degradation (LTD) necessitates the presence of t-ZrO₂ grains in thermodynamic metastability, which are capable of undergoing a t-m transformation. It is believed that the progressive change of tetragonal crystals to the stable monoclinic phase begins at the surface of the material in isolated grains and advances inwards to the bulk of the material through a stress corrosion type mechanism. During the transformation of one grain, the neighboring grains experience a rise in volume, which causes stress on the surrounding grains⁷⁴. Surface uplift and microcracks are created as a result, creating an opening for the water to permeate down into the specimen and out through the opening. This further accelerates the disintegration of the surface, and the change spreads from one neighbor to the next⁷⁴. Aging is connected with roughening, which will result in increased wear and microcracking, which will result in grain pull-out and the formation of particle debris, as well as slow crack propagation, which will result in premature failure of the structure or structural component. Aside from these disadvantages, zirconia crystals that have previously been converted into the m-polymorph are unable to demonstrate Phase transformation toughening (PTT), in the same way that a used match cannot be ignited again⁷⁵. This phenomenon has the potential to have a negative impact on the mechanical characteristics of zirconia. The grain size, the type of stabilizer used, the amount of stabilizer used, and the existence of residual stress are the primary elements that influence the aging process. Despite the fact that zirconia's mechanical properties deteriorate with age, the deterioration is within clinically acceptable limits⁷⁶.

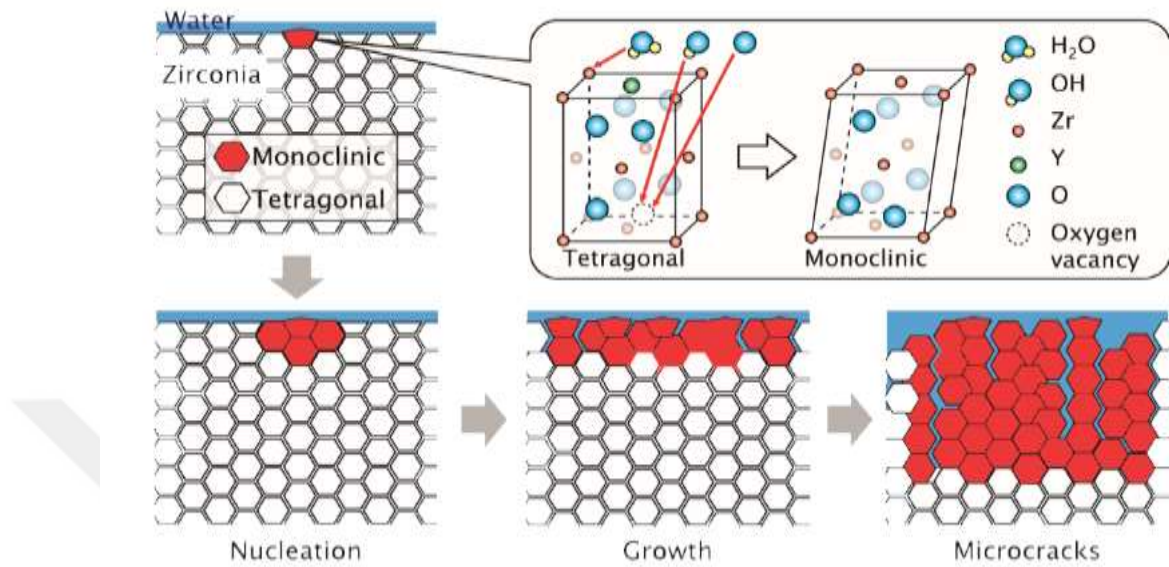


Figure 2.2. Schematic of the progress of LTD (aging of zirconia)⁷⁷

2.3.6 Phase transformation toughening

A remote macroscopic tensile load is applied to a zirconia surface crack that contains metastable t -ZrO₂. Metastable t- ZrO₂ undergoes monoclinic crystallization when tensile stress is concentrated at the fracture tip. Due to the surrounding crystals' ability to exert a compressive force on the crack's surfaces, the subsequent increase in the volume of the crystals slows the crack's spread. Transformation toughening or phase transition toughening is a term used to describe this process⁵⁹.

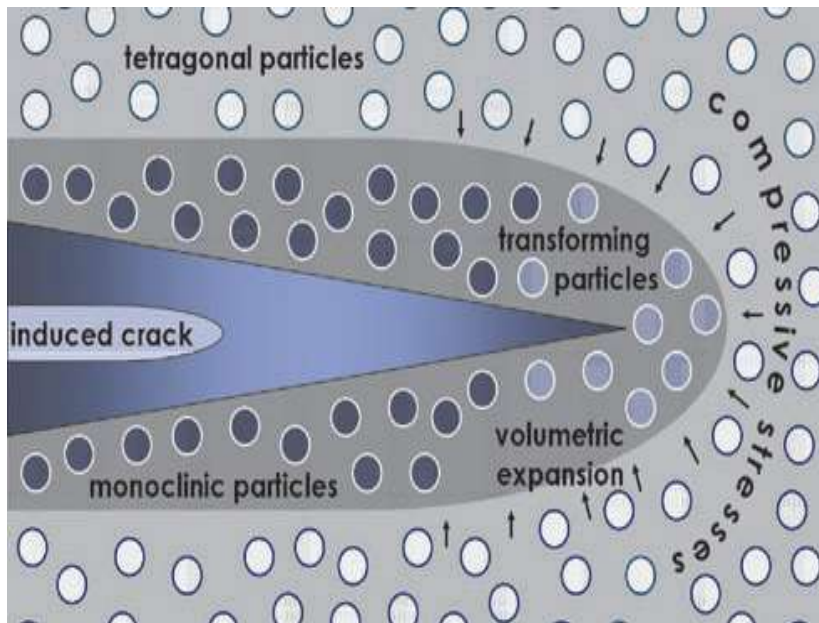


Figure 2.3. Phase transformation toughening of zirconia⁶⁰

2.4 Monolithic zirconia

In 2011, this zirconia was approved for clinical application due to the fact that it was expected to prevent the chipping of the veneering ceramic⁷⁷. As a result, monolithic zirconia materials were only used in the mouth's posterior region because of their low optical translucency. Translucent monolithic zirconia ceramics have recently become more practical thanks to improvements in material fabrication and sintering. Some people are worried about their long-term viability⁷⁸.

2.4.1 Microstructure and optical properties of monolithic zirconia

The main distinctions between veneered zirconia and monolithic zirconia are the microstructure and chemical constitution of the materials. Sintering additive number is commonly used to determine the optical characteristics of zirconia⁷⁹. Zinc oxide and metal oxides are commonly used as sintering agents, and their addition alters the zirconia's refractive indices and increases light scattering⁸⁰. Intense light scattering results in an opaque substance because the light beam is scattered. Aluminum oxide is the most used zirconia

addition because it inhibits the formation of zircon crystalline grains during the sintering process⁸¹.

It has been found that the addition of alumina in zirconia's structure increases its resistance to LTD to a significant extent⁷⁵. While only a small quantity of alumina (0.1 mass percent) is spread uniformly across the micro-structural of monolithic zirconia, it significantly enhances translucency when compared to traditional zirconia, which is normally constituted of 0.43 mass percent by weight of alumina⁸². A variety of other characteristics, such as grain size, increased density, and a reduction in the number of impurities, defects, and porosities, could potentially contribute to the translucency of polycrystalline ceramic CAD/CAM materials^{83,84}. The fabrication of zirconia ceramics results in finished restorations that have a high density and possess extremely low impurity levels, defects, and porosities regularly. Despite this, material designers still have difficulty controlling the crystalline particle size⁸⁵. Polycrystalline alumina ceramics can be made more translucent by increasing the size of the crystalline grains between their microstructures⁸⁶. In general, ceramics with a larger grain size have fewer granular borders and as a result, less light scattering. In the case of zirconia, however, the weaker mechanical characteristics and lesser durability of the tetragonal phase mean that this approach cannot be employed, which increases the probability of the LTD phenomena occurring⁸⁷. Lastly, it has been hypothesized that zirconia's translucency could be improved by shrinking the crystalline grains⁸³.

Approaches like these are based on an assumption that the crystalline grain is too large and so has a negative impact on the birefringence phenomena, as a result, the material becomes less opaque⁸⁴. It happens because zirconia has a high percentage of tetragonal crystalline phase (>90%). In the microstructure, the refractive indices of tetragonal crystals vary according to their spatial orientation. To put it another way, the light traveling through zirconia is significantly scattered due to its anisotropic behavior. An anisotropic structure's birefringence might be reduced significantly with smaller crystalline grain size, resulting in an increase in translucency^{83,84}.

In recent monolithic zirconia ceramics, tetragonal and cubic zirconia grains are integrated. We couldn't call this material Y-TZP because it has so much cubic zirconia (>25 percent) in its constitution⁸⁸. Because the cubic zirconia phase comprises regions with an isotropic refraction index, monolithic restorations constructed of the material have a higher translucency than standard zirconia. Cubic zirconia is expected to have less light scattering since the refractive index is not affected by the crystallographic orientation of the grains⁵.

It is likely that as a result of the birefringence phenomena and the remaining tetragonal grains, the material will become weaker over time. To be clear, the addition of cubic zirconia grains would enhance the translucency of translucent monolithic zirconia. Simultaneously, transparent monolithic zirconia's mechanical properties deteriorate significantly as compared to regular monolithic zirconia⁸⁹. Despite the fact that numerous applications may benefit from the optical features of monolithic zirconia, more advancements are required in order to provide more pleasing aesthetics in the anterior region⁷⁷. The low-fusing glazed ceramic, which includes colorful oxides, has been utilized on monolithic zirconia FDPs ever since.

2.4.2 Mechanical properties of monolithic zirconia

When determining the mechanical properties of ceramic materials, consideration is given to parameters like flexural strength, fracture toughness, and hardness⁹⁰. Zirconia has been dubbed "ceramic steel" because of its extremely high flexural strength, which is far more than that of many other ceramic materials⁹⁰. When compared to traditional veneered zirconia monolithic zirconia exhibits better flexural strength but the same fracture toughness as the traditional veneer⁹¹. The hardness value of 13.1 could be considered to be much higher than that of dental enamel (3.2 GPa) or feldspathic ceramic (4.5 GPa) when compared to other mechanical properties. Extremely elevated hardness ratings, as well as other notable mechanical properties, have the potential to wear down the opposing tooth or the restorative material over time⁹². Because zirconia is not used as a veneering ceramic in monolithic reconstructions, it comes into direct contact with the opposing dentition, which complicates matters significantly. Following the publication of recent study findings, it was discovered

that superior finishing and polishing of zirconia might greatly minimize antagonist wear⁹³. Although monolithic zirconia FDP surfaces and their antagonists must be checked periodically to ensure the quality of the finish and possible wear, clinical information on this subject is currently inadequate⁹⁴.

2.5 Resin cement

For an indirect cosmetic restoration to survive in the patient mouth, it must have the proper cement and the proper luting process⁹⁵. In order to ensure that the cement adheres to the bonding surfaces properly, it is critical that the luting cement and the bonding substrate have a thorough understanding of each other's properties⁹⁶. The increasing popularity of ceramic indirect restorations among patients for esthetic reasons has resulted in an increase in the use of resin-based cement in dental offices. Due to the advancement of resin cement in recent years, it has become viable to adhere to both the tooth surface and the fitting surface of a restoration. Traditional materials, zinc phosphate, and zinc polycarboxylate are referred to as 'passive' materials since they retain the repair mechanically. between the rough surfaces of the teeth and the cement used in the restoration. Composite resin kinds of cement are because of the adhesive's fundamental interaction with the dentine via micromechanical bonding, they are termed active materials, which is accomplished through the establishment of a hybrid layer and bond to dental materials⁹⁷.

2.5.1 Classification of resin cement

It is currently possible to classify resin cement into three distinct categories: total etchants, self-etchers, and self-adhesives⁹⁷.

2.5.1.1 Total-etch resin cement

To adhere the tooth to the cement, the phosphoric acid etching agent and adhesive are used in conjunction with the cement. Compared to other types of cement, these have an elevated bond strength of resin cement to a tooth, as well as improved retention and enhanced mechanical qualities⁹⁷. The use of these materials, however, necessitates a multi-step process that could be technique-dependent and may result in a higher relative incidence of post-

operative sensitivity. The outcome of a patient's treatment is determined by various factors such as operator expertise, restoration design, material characteristics, and intra-oral conditions ⁹⁸.

2.5.1.2 Self-etching resin cement

It is essential to implement a self-etch primer to the tooth's surface, which is achieved through the application of a cement mix over the primer to create a bond between the tooth and the indirect restoration ⁹⁷.

2.5.1.3 Self-adhesive resin cement

It is kinds of cement have been the most recent contributors to the advancement of cement technology (SACs). Due to both the need of both physicians and operators for a more efficient luting procedure and a reduced risk of contamination, certain forms of cement have been developed ⁹⁷. The first (SACs) resin cement (RelyX Unicem, 3M ESPE) was based on phosphoric acid-modified acrylates (SACs). It is possible to use these resin cement without micro-abrasion or etchant treatment because they are dual-cured. Alternatively, the cement can be placed directly to a non-treated tooth surface and luted ⁹⁷. With a non-treated tooth surface, they have similar bonding strength as self-etching systems luted to that surface. Bond strength is comparable to self-etch systems with a single-step process that eliminates the limitations of those methods ⁹⁷.

2.5.2 Delivery systems

In most cases, they can be obtained in two-part systems: a liquid component (normally the monomer) and a powder component (typically the filler) that incorporates the classic monomer and Bis-GMA, UDMA, HEMA, and TEGDMA are all examples of photoinitiator systems, respectively ⁹⁹. To avoid the early acid-base reaction in the acidic monomer and the ion dissolved glass, it is necessary to separate the redox initiator components necessary for free radical polymerization (chemical cure) and to inhibit the inactivation of the photoinitiator system (tertiary amine or other electron donating compound) by the acidic monomers and spontaneous polymerization procedure. Among the

three most common methods of delivering are capsule delivery systems, hand-mixed paste systems, and auto-mixing syringes⁹⁹.

2.5.3 Setting and curing mechanism

Self-cure or light exposure can be used to activate the radical polymerization process, which is followed by the setting reaction¹⁰⁰. However, dual-cured materials (chemical and light activation) have been proven to have better monomer conversion and higher mechanical characteristics⁹⁹. There is a two-minute working period followed by three to seven-minute setting periods. Following the implantation of the restoration and once extra cement has been removed, an enhanced photo-curing procedure can be performed using a regular dental curing machine^{95,101}. For dual-curing resin cement, studies have found that chemical cure just

2.5.4 Physical properties

The physical qualities of SACs are believed to be slightly less than those of non-self-adhesive resin cement and significantly more than those of non-resin-based forms of cement⁹⁹.

2.5.5 Bond strength

It has been found that SACs have a weaker bond strength than total-etch and non-self-adhesive resin cement, but they are comparable to bond strength self-etch cement and stronger than the bond strength of the resin-modified glass ionomers¹⁰².

2.5.6 Marginal leakage

An important factor in determining whether or not SACs are clinically successful is their ability to adapt well and seal the margins of the repair. When it comes to marginal adaptation/fit, Resin-modified glass-ionomer and compomer types of cement, as well as normal self-etching resin cement, are surpassed by SACs¹⁰³.

2.5.7 Durability

Researchers have found that SAC-luted indirect restorations can endure more fatigue cycles than zinc phosphate-luted indirect restorations, yet, there is no noticeable difference between SACs and other resin cements¹⁰⁴.

2.5.8 Postoperative sensitivity

It was found that when the six-month period has ended a year following the procedure, no one complained of any post-operative discomfort¹⁰².

2.5.9 Biocompatibility

Despite conflicting findings addressing the potential cytotoxicity of SACs on pulp, it has been proposed that they are well tolerated by the pulp, provided that an adequate dentine barrier exists¹⁰².

2.6 Surface modification to improve resin bond to zirconia

The substrate must be dry, clean, and free of impurities to produce a strong adhesive bond. An orderly sequence of steps must be performed to improve the surface's affinity for the adhesive agent and boost its energy. In order to have the best wettability, this substrate must have higher surface energy than the adhesive agent's molecule's cohesive forces¹⁰⁵. There has been an investigation into alternative zirconia-resin cement bonding procedures due to zirconia's mechanical and chemical bonding difficulties⁹⁷. Several key procedures for the dental use of zirconia surface conditioning are outlined in the following sections.

2.6.1 Airborne particle abrasion

To roughen and clean the bonding surface of zirconia, the universal agreement is that airborne abrasion using alumina particles with a diameter of 50-110 micrometers at a pressure of 0.25 MPa is a viable solution¹⁰⁶. However, it has been debated whether air abrasion has an influence on the mechanical properties of Y-TZP materials., and both good and unfavorable effects have been described in the literature¹⁰⁷. In addition, it has been reported that particle abrasion causes zirconia to be more vulnerable to radial cracking during

service¹⁰⁸. Because of this, the idea of decreasing the pressure throughout the air abrasion procedure and utilizing particles as small as 50 micrometers in diameter may be beneficial¹⁰⁹. Zirconia alumina bond strength is lower than that of porcelain, which is why air abrasion of zirconia with alumina is not recommended. In the opinion of the authors, mechanical adhesion alone isn't enough to ensure a resin-substrate connection will be strong. So, they recommend that zirconia bonding be done via chemical adhesion^{110, 111}. In contrast, others claim that the removal of the particle abrasion from the surface treatment may result in a significant drop in bond strength¹¹². They claim that zirconia's surface modification is a key component in adhesion.

2.6.2 Discs and diamond rotary devices for grinding

The most significant disadvantage of grinding is the tendency for microcracks to form on the zirconia surfaces¹¹³. Zirconia grinding requires a coarse diamond rotary tool with a grain size of 120 to 200 mm¹¹⁴. because of its high hardness. Coarse-grained diamond grinding has already been used to produce rougher surfaces than previous methods, However, microcracks and damages to zirconia surfaces might result from this vigorous approach, making it unsatisfactory¹¹⁵.

2.6.3 Application of a tribochemical silica coating

Air abrasion at a pressure of 0.28 MPa is used in this process, where silica particles are implanted on the surface of zirconia ceramic¹¹⁶. In ceramic, silica particles provide a foundation for micro-mechanical and interlocking bonding. The next step involves the use of a silane, which creates a chemical link amongst the resin cement and ceramic. Silane coupling agents have many mechanisms of action; they lower the substrate's surface tension, moist it, and raise its surface energy, all of which improve bonding strength¹¹⁶. Because the silica has hydrophilic surfaces, hydrophobic resin cement can cling to it. It is also possible to generate strong covalent connections with zirconia coated in silica because of the hybrid agent's inorganic-organic silanes composition. The outcomes of a basic procedure to produce efficacy and long-term bond durability are controversial. There is evidence in the literature

that employing Cojet increases the binding strength between zirconia and other resin cements¹¹⁷. Non-uniform silica accumulation on the bonding surface may lead to a variance in bond strength as a result of TBC (tribochemical coating). Additionally, zirconia's hardness leads to a reducing concentration of silica on the bonding surface, which is a drawback of this approach¹¹⁸. Zirconia and resin bond strength can be improved by increasing operating pressure, which may help¹¹⁸. In addition, several studies found that tribochemical treatment with self-adhesive cement had no effect because of the zirconia surface's inert properties¹¹⁹. Over a period of 30 days, water storage for the long term, and hydrolysis of the zirconia-resin bond were all procedures and consequences that could be assessed¹¹⁹.

2.6.4 Chloro silane treatment

When used in conjunction with the vapor phase pretreatment procedure, chloro-silane forms a silica-like coating on the zirconia surface that is impermeable to water. SixOy binding sites (SixOy) are increased by a very thin layer that can be applied to the organ-silane primer used in the classic adhesive approach (until 2.6 nm)¹⁰⁹. For resin cement, chloro-silane film application increases the adhesion strength, resulting in a change in micro tensile bond strength values. Furthermore, the thickness of the layer and the topography of the surface have a big impact on the results. It was also shown that roughened surfaces had 60% mixed (adhesive/cohesive) failure modes due to the deposition of a light coating of SixOy on top¹⁰⁹.

2.6.5 Selective infiltration etching (SIE)

Using a specific temperature regime, an SIE A method for inter-grain of metastable tetragonal grains was created. that were produced during the production process when the surface grain was thermally pre-stressed. Through the application of this healing method, the region to be bonded is able to accept the adhesive resin., which infiltrates and interlocks the zirconia particles¹²⁰. Zirconia surfaces that are thick, nono-retentive, generally smooth and low energy are transformed into surfaces that are highly active and have a good bonding with the use of SIE¹³. This approach made use of the ultrastructural characteristics of zirconia to achieve its results¹¹². Because zirconia crystals possess the ability to transition between

tetragonal and somewhat larger monoclinic phases in reaction to mechanical and thermal stresses, they have elevated fracture toughness and are used in aerospace and defense applications. When provided with sufficient stimuli such as temperature and time, the surface and bulk grains of grains can expand in size on a grain, micro-scale. Furthermore, grain boundary sections allow for the diffusion of a variety of elements, for example, potassium, sodium, silica, calcium, and titanium, among others. This process affects the surface characteristics of zirconia, imposes significant capillary and tension forces on the material, and as a result, increases nano-rearrangement motions of grains, as well as their cracking and sliding ¹²¹.

It is deposited to zirconia's surface in the SIE process by means of a glass-containing conditioning agent, such as silica (65% weight), alumina (15%), sodium oxide (5%), potassium oxide (5%), and titanium oxide (5%). In terms of thermal expansion, the coating is a good match for zirconia. Furthermore, the materials are heated beyond its glass transition temperature till the desired grain boundary diffusion occurs. Afterward, the material is dissolved in an acidic bath to remove any traces of the conditioning agent. A computer programmed induction furnace regulates the cooling and heating ratios¹²². Because of the good results obtained through infiltration etching, it is important to underline the importance of a sealed interface on a modified zirconia surface, which is capable of resisting nano-leakage during artificial aging. Aside from the positive results, there is one area of worry regarding the effect of inter grain porosities on the mechanical properties of SIE zirconia. According to some additional research, the proposed therapy results in porosities of roughly 1.5 microns in size, which are not considered critical ¹²².

2.6.6 Hydrofluoric acid etching

The most commonly utilized surface modification for ceramic ¹²³. By decomposing the glassy matrix of the ceramic, HF acid produces a substrate with high surface energy and micro-porosities that allow resin cement to penetrate easily, hence affecting the micromechanical interlocking of the ceramic¹²⁴. Despite this, HF acid etching does not create significant changes in the arithmetic roughness (Ra) of zirconia restoration¹²⁵. In the absence

of a glassy matrix on the zirconia surface, the HF acid does not affect the surface of the zirconia, resulting in extremely low bond strength ¹²⁶.

2.6.7 Hot acid

This method was developed established on a corrosion-controlled procedure and the metallic characters belong to zirconia, among other factors. Micro-retentions can be observed on the surface of zirconia by modifying the grain boundaries of zirconia and deleting the atoms that are less structured on the surface ¹²⁷. Increased initial bond strength and long-term durability can be achieved by utilizing very hot acid to etch with a collection of highly corrosive acids for example (HNO₃, H₂SO₄, HF) ¹²⁸, according to the researchers. The use of an experiment hot (HCl) solution markedly expanded the roughness of the zirconia surface while also controlling corrosion at a fundamental level. An HCl/Fe₂Cl₃ treatment that lasted 30 minutes had a stronger impact on binding strength than the usual APA ¹²⁹. A positive impact on the zirconia-resin cement bonding strength appeared to be observed when sulfuric acid was combined with hydrogen peroxide (H₂O₂) (Piranha solution) ¹³⁰.

2.6.8 Functional monomers

In order to improve adhesion to ZrO₂, functional monomers have been used¹³¹. Such materials create a chemical bond to metal oxides and are therefore suitable for use in resin cement and adhesive compositions, as well as in a direct path across the ceramic surface ¹³¹. ZrO₂ is chemically bonded to phosphate ester monomers, including such 10-methacryloyloxydecyl-dihydrogenphosphate (10-MDP), which forms a water-resistant link with tightly sintered zirconia ceramic¹³². Because of the necessity for improved adherence to ZrO₂, MDP-containing resin cement is advised¹³³.

A chemical connection to the zirconia surface has been demonstrated even with (6-MHPA), No evidence available regarding the influence of 6-MHPA on bond -strength between resin cement and zirconia ceramics following extreme aging conditions ¹³⁴. The use of MEPS, a common monomer in ceramic priming materials, has been tested, however, the findings have shown no noticeable improvements ^{131,135}. It was decided to test several non-

phosphate metal primers, including (VBATDT) (4-META), and chemical link with zirconium/metal oxides^{131, 134, 136}. When using primers, to elevate the adhesion capability to ZrO₂, functional monomers including MDP (for instance, Alloy Primer and Clearfil Ceramic Primer, both from Kuraray Medical Inc., Japan) or even other phosphoric acid acrylate monomers (for instance, Metal/Zirconia Primer, also from Ivoclar-Vivadent) are widely advised. As a result, despite the fact that the outcomes are frequently insignificant, the use of combining air-abrasion and primers contributes to the development of more favorable bond strength, especially over the long term¹³⁶.

2.6.9 Silane coupling agents

They are trialkoxysilanes, which hybrid inorganic-organic compounds have two functions capable of building a siloxane networks on the surfaces of ceramics with the hydroxyl (OH) of Si and copolymerizing with the resin matrix of composites; additionally, Silanes have the ability to reduce the surface tension of a substrate, as well as increasing its surface energy¹³⁷. The hydrophobic matrix of the (resin composite) may form bonds with hydrophilic surfaces for example silica, glass, and glass ceramics¹³⁸. Numerous silanes were investigated, but none of them demonstrated the same level of efficacy on surfaces with no or low Si concentration as ZrO₂¹³⁹. Furthermore, siloxane bonds may be susceptible to hydrolytic breakdown, impairing the adhesive interface's stability^{140,141}.

It was found that the first two organosilanes methacrylatooxypropyltrimethoxysilane, 3-acrylatooxypropyltrimethoxysilane, and 3-isocyanatooxypropyltriethoxysilane) had the best results¹³⁸. Acrylate groups are more reactive than methacrylate's in the silane organo functional group. Dental materials researchers have not before reported using the 3-isocyanatopropyltriethoxysilane as an adhesion promoter¹³⁸.

2.6.10 Effect of lasers

2.6.10.1 (Nd: YAG) laser

The use of an Nd: YAG laser enhanced the surface roughness of zirconia as well as the bond strength among zirconia and resin ¹⁴². However, the point of application affected the esthetic and changed the color of zirconia by leaving a silver spot and abnormally elevated the monoclinic phase at the surface of zirconia by (26.5 percent and 30.5 percent) ¹⁴².

2.6.10.2 Carbon dioxide (CO₂) laser

From 2.3 to 10.6 μm , ceramics are capable of absorbing the radiation's wavelength. Using a laser at a 3 W and 4 W setting with varied settings improved the bonding. A CO₂ laser was found to improve surface roughness and the zirconia-porcelain binding in a recent study¹⁴².

2.6.10.3 Uses of (Er: YAG) laser

Several clinical applications for the YAG laser in operative dentistry have been documented ¹⁴². As a result, its effect on ceramics of high tensile strength was thoroughly investigated. In addition, micro-explosions and vaporization can be used to remove particles by ablation¹⁴². Because of temperature variations (heating and cooling), the zirconia undergoes a phase transformation, resulting in its destruction. Surface irradiation with constant water cooling has been promoted as an alternative to reducing laser power. In vitro trial results, on the other hand, are still questionable because laser irradiation appears to be less effective at raising bond strength than air-particle abrasion¹⁴².

2.6.10.4 Nanosecond fiber laser

There are several types of ions that can be discovered in fiber lasers' active media, including Nd, Yb, Er, and Th. For several years, the maximum output power of rare-earth-doped fiber lasers was only just a few mW, although Elias Snitzer constructed its first fiber laser in 1963. Almost two decades ago, mostly in the 1980s, the first widely viable fiber laser with a single-mode diode pumping system and a maximum power of several hundred milliwatts was made available ¹⁴³.

2.6.11 Plasma oxyfluoride

That approach can be used to chemically alter zirconia by creating a thin coating of oxyfluoride on its surface, allowing organosilane attachment ¹⁴². The inductively coupled reactor (ICP), as well as a vacuum (35 mT), and the management of fluorine-containing precursor gases; are required for the fluorination procedure recommended in this paper. With silane and MDP-containing resins, the process is designed to increase the binding strength of zirconia by using fluorinated plasma on the surface of the zirconia ¹⁴².

2.6.12 Glazing technique for zirconia ceramic

Because of the formation of an intermediary etchable layer of the glazing material with a low melting temperature for zirconia surface coating, shear test results have been markedly increased. Because of the great thickness of the covering (120 μm), this approach had several significant drawbacks ¹⁴⁴.

2.6.13 Coatings of low melting temperature porcelain micro-pearls

Fusing glass which has low melting temperature (porcelain) pearls to the zirconia surface is also another way to create a tight connection among the zirconia surface and the resin luting substance. To avoid endangering the crown design or the fit of the restoration to the tooth, this treatment should be done carefully ¹⁴².

2.6.14 Fusion sputtering technique for zirconia modification

It's a new technology for creating rough zirconia surfaces that involve spraying un sintered zirconia frameworks with an air-water jet transporting zirconia particle. When it comes into contact with the surface, the particles achieve good contact and adherence. Following sintering, these particles became structurally bonded to the underlying framework and generate undercuts that are ideal for resin adhesives to mechanically adhere to surface ¹⁴².

2.6.15 Silicoating technique for zirconia modification

Silicon is pyrolytically decomposed to generate a SiOx-C layer with a thickness of 0.1 micrometers ¹⁴², Metal and resin cement can form stronger connections to this surface once it has been silanated ¹⁴². Butane gas is burnt with atmospheric oxygen in a container containing tetraethoxysilane using specialized laboratory instruments through a chemical reaction ¹⁴², The substrate is coated with a layer of SiOx-C. The problem is that this method is costly and difficult, and it isn't appropriate for use in the dental office¹⁴².

2.6.16 Plasma spray technique

This is a technique another sort of silicoating in order to apply a Siloxane layer on top of the surface. Ionized plasma consists of ions, electrons, atoms, and neutral regions, as well as many other charged particles. A thin (1µm) siloxane layer was formed when the surface was treated with hexamethyl disiloxane plasma spraying¹⁴². When a zirconia experiment is exposed to 1-chloro silicide gas (SiCl₄) and water vapor for approximately 15 minutes, a an active siliconized surface is formed on the surface ¹⁴².

2.6.17 Nano alumina coating technique

Adding a nano-alumina coating on zirconia is a simple and non-destructive technique to enhance the binding between the two material¹²⁰. AlN powder hydrolysis in aqueous suspensions results in the rapid deposition of aluminum hydroxides, according to this idea. Aqueous solutions have been used to accelerate this process. TZP is employed as a substrate in this application. In each case, the nanostructured coatings are made of 6 nm thick and 240 nm connected polycrystalline aluminum oxide lamellas that grow perpendicular to the surface of zirconia and are deposited on the surface of zirconia. With such a heat treatment up to 900°C, these coatings are transformed into transient alumina, while the morphology of the coatings remains unaltered ¹⁴⁵.

2.7 Determination of the bonding strength between resin and zirconia

2.7.1 Assessing surface retention

2.7.1.1 Usage of profilometer

In most cases, profilometers are used to analyze the surface roughness of a zirconia sample before and after it has been treated with a surface modification agent ¹⁴⁶. When it comes to managing the adhesion strength between resin and zirconia, surface roughness is well recognized as a major component. When the zirconia surface is mechanically roughened, it not only increases the surface area, which in turn increases micromechanical retention, but it also decreases surface tension, which increases wettability

2.7.1.2 SEM as an imaging technique for measurement

SEM is a technologically extensively used microscope that scans samples with a focused stream of electrons, allowing images at the micron level to be obtained ¹⁴⁸. Secondary electron detectors of type can identify the interaction between atoms in the specimen and electrons, resulting in the generation of rich signals that include valuable information on the surface topography and composition of the sample¹⁴⁹. When photographing the surface of a specimen with a scanning electron microscope, it is necessary to adhere to a rigorous routine¹²⁹. Each representative specimen is, first and foremost, a sample that should be selected from a variety of study groups and well prepared in a size that is suitable for fitting into the specimen chamber. Mounting the specimen on the specimen holder and placing it in the SEM chamber are the first steps before it can be examined. The image which created by SEM can be displayed on the screen of the computer by adjusting the SEM parameters. It is possible to adjust the focus to generate a clear image. To get better resolution, the spot size and operating distance can also be modified. As a result, it is possible to evaluate the microstructure of the sample surface, and SEM observations have become a popular laboratory tool ¹⁴⁸.SEM may produce detailed direct micro-images of sample surfaces, as well as qualitative and semi-qualitative data on the surfaces of the samples. Compared to ordinary light microscopes, The SEM's magnification may be varied from approximately 15 times to 5000 times, making it far more powerful. The fractography of fractured surfaces can be assessed using SEM, and it produces images that are clearer than those produced by an optical microscope ¹⁴⁸. On the contrary, there are some restrictions to search engine

marketing. Only two-dimensional images are produced, and it is unable to analyze a surface at the nanoscale. In some cases, during sample preparation, a coating operation may be required, which would make the longitudinal examination of the same area unfeasible. The size of the sample is also dictated by the size of the vacuum chamber ¹⁴⁹.

2.7.1.3 AFM measurement

It is one of the more advanced imaging techniques that evaluates a sample by determining the forces between a scanning tip and its surface on an atomic level ¹⁵⁰. Atomic force microscopy (AFM) is a type of scanning tip that measures the forces between the tip and the sample surface on an atomic level ¹⁵⁰. It is among the most prevalent types of AFM devices is a cantilever along a scanning tip, it has the ability to penetrate and measure the surface of an object, to collect both micrographic and numerical data at the nanoscale level. The beam deflection method, which may be discovered ¹⁴⁹, is the most frequently used measuring method since it produces a cantilever deflection of less than 10 nm (due to thermal noise). In any case, AFM is capable of producing 3D images with an atomic resolution with minimal sample preparation¹⁵². These are some of the three AFM measuring methods, such as contact, tapping, or non-contact, which is now available for AFM measurements. Before the scan begins, it is necessary to customize parameters such as scanning size and scan rate. The mean surface roughness over the area (Sa) obtained from each scanning is computerized and expressed as a numeric value by software when each scanning is completed. The information can be converted into a topographic image in the appropriate manner ¹⁵³.

An AFM unit is getting a famous measurement device, because of the following advantages: AFM develops a three-dimensional surface micrograph¹²⁹, Particular preparation of the sample, for example, metal or carbon coating, is not necessitated ¹⁵³, so that the specimen surface is not distorted which could be reused for further SEM evaluation. The coating phase in SEM can be skipped, resulting in fewer picture artifacts. SEM assessment requires a vacuum environment, although most AFM modes can be operated in air or even liquids. Thus, AFM can be used to assess biological macromolecules and living things. SEM,

on the other hand, has a lower resolution and can only identify chemical bonding under specified circumstances ¹⁵².

2.7.2 Bond strength evaluations test

2.7.2.1 Tensile bond strength test

This test is a commonly used method for determining the strength of adhesion among the surfaces of two structures. Usually, the test is performed through the application of a "pulling" force that is uniformly distributed through the bonding contact in order to break down and separate the joining structures ¹⁵⁴. This test is used to determine the strength of the resin-ceramic bonding. First, the resin composite and ceramic material are attached to each other. To fracture the sample, two sets of stresses are given upright to the interface of two bonding structures and conducted in the opposite direction of each other until the sample breaks. The ultimate tensile bond strength (MPa) is determined by calculating the loading force (N) at fracture and then estimating the cross-sectional area of the broken sample with a digital caliper ¹⁵⁵.

2.7.2.2 Shear bond strength test (SBS)

SBS is another macro-test used for adhesion evaluation ¹⁴⁸, but it is still the most commonly used test for adhesion ¹⁵⁶. For testing resin-zirconia bonding, the universal testing machine was used. Operates alongside the resin-zirconia interaction in similar way proximity of the shear blade to the interface is sought. Separation of the zirconia substrate from the resin composite is accomplished using a loading force shear. The broken specimen's cross-sectional area is ¹⁵⁷. The shear bond strength value can then be determined ¹⁵⁸. The shear bond strength test can be performed in a matter of minutes using basic, rapid, and straightforward procedures. Zirconia bonding can be evaluated with this method since it uses as the reference size for sectioning the extremely hard fully sintered zirconia ¹⁵⁹. For example, the uneven distribution of the shear force could lead to a specific fracture pattern in the substrate, which would be a major drawback of this test. Shear testing is not a viable approach for analyzing bonding performance in the presence of water, since water can only reach the outer edges of

two bonding structures, while the majority of bonded area is not impacted. As a result of the lengthy immersion period, a reasonably precise test result is required ¹⁶⁰.

2.7.2.3 Micro tensile bond strength test

Micro tensile bond strength (MTBS) used for evaluation of resin-zirconia bonding strength has become increasingly popular ¹³. Evaluation of resin-zirconia bond strength can be done by assessing the maximum "pulling" force, which is spread uniformly across the cross-sectional area of the resin-zirconia microbeam to separate them from each other ¹⁶¹. Using a universal test machine, two opposing "pulling" forces are applied perpendicularly via the resin-zirconia contact ¹⁶¹. The resin-zirconia microbeam is then prepared and placed in place. After the resin-zirconia microbeam has cracked, a digital caliper is used to measure the loading force (N) at fracture and determine the fractured microbeam's cross-sectional area. The micro-tensile bond strength is measured in MPa and is used in engineering calculation ¹⁶². Tensile bond strength can be reliably evaluated with this method because it ensures a uniform force distribution at the microbeam's bonded interface ¹⁶³.

2.7.2.4 Micro shear bond strength test

The MSBS test is a further micro-method for the measurement of the shear bond strength of the tested sample ¹⁶⁴. When doing a similar macro shear bond strength test ¹⁶⁵, it was designed to combat uneven stress distribution. The shear force in an MSBS test used to evaluate resin-zirconia bonding is dispersed to a small area of the interface. One of the most commonly used molds in MSBS resin-zirconia adhesion tests is an inch-long, 1mm-diameter tube. Each time, a universal test machine is employed to apply the shear force to the bonded tiny region till it cracks. It is recorded and divided by the bonded area (mm^2) to create the micro shear bond strength value of the tested sample in MPa under a shear force ¹⁶⁶, instead of the shear force utilized in MTBS testing. Small testing areas make the MSBS test a highly sensitive method of testing ¹⁶⁵.

2.8 Storage conditions

2.8.1 Dry condition

Before bonding tests, pre-tested samples that are kept in dry circumstances typically serve as baseline results and as a control¹³⁸, respectively. The goal is to determine the initial bond strength and adhesion of the bonded samples before putting them through various aging scenarios such as water storage or thermocycling. In any adhesive experiment, the initial bond strength must be taken into consideration. Before conducting bond strength testing, samples of resin-zirconia bonding are typically held in dry conditions for one to two days so that the baseline adhesion may be established¹³. As crucial as long-term bond strength is the strength of the initial bond. For example, to assess the fatigue deterioration in dry settings, it is important to analyze the dental adhesion's initial bond strength¹⁶⁷.

2.8.2 Water storage

At 37C⁰, distilled water is always used as a medium for water storage (de-ionized water). It is the most extensively researched and widely used approach of artificial aging in vitro to enhance saliva production in the oral cavity. Water has the potential to negatively impact bonding in the majority of oral environments, making long-term success questionable¹⁶⁸. The hydrolytic impact of the resin-zirconia adhesion must be determined and compared to the initial bond strengths achieved under dry conditions following the assessment of the resin-zirconia adhesion¹⁶⁹. Due to the durability of the resin-zirconia adhesion, it has been demonstrated that the presence of distilled water has a significant impact on the adhesion, and hydrolytic degradation is the primary process that results in the bond being broken¹⁶⁷.

2.8.3 Thermocycling

Thermocycling is a laboratory technique that simulates the oral environment by using a synthetic and accelerated aging process. There must be both water penetration and temperature alteration for it to work. It is the second most frequently used aging method in the measurement of dental bond strength, behind only aging with time¹⁶⁸. Several different study designs could be used to examine the impact of the resin-zirconia adhesion on the

thermocycling process. The thermocycling temperature fluctuated between 51°C and 55°C regularly. Living times at both temperatures were determined to be 30 seconds, The time required to transfer from one bath to another was discovered to be 2 seconds¹³⁸. ISO Standard 10477 was developed¹⁷⁰. Although 6,000 cycles are frequently used, the number of cycles can range from 300 to 100,000 cycles.

2.8.4 Fatigue

Throughout the functional movements, the fatigue test seeks to replicate as closely as possible the chewing interactions¹⁷¹. Frustration can be identified as one of the most significant factors contributing to the failure of resin-zirconia adhesion in the oral environment¹⁷². The accumulation of stress concentrations at the resin-zirconia interface during a fatigue test of resin-zirconia adhesion could result in the creation and spread of microcracks at the resin-zirconia interface, as well as the destruction of the interfacial microstructure¹⁷³.

3 MATERIALS AND METHODS

To analyses, the influence of seven various surface modifications on the shear bond strength of two highly translucent CAD/CAM monolithic zirconia and one self-adhesive resin cement, this research was conducted at Yeditepe University Faculty of Dentistry, Prosthodontics Department, in Turkey.

3.1 Materials used in this Study

Two brands of highly translucent monolithic zirconia were evaluated in this study. The first brand is Zenostar Zr translucent (Wieland Dental; Pforzheim, Germany) (Figure 3.1) and second brand is Ceramill zolid fx pre shade (Amann Girrbach AG, Koblach, Austria) (Figure 3.2). Both brands were provided by the manufacturers in large disc-shaped milling blocks. Pre-sintered blocks of monolithic zirconia from two different brands were created using a 5-axis CAD/CAM system (VHF K5 Germany) (Figure3.3) and then sintered to the required last dimensions (10 mm in diameter and 3 mm in height) in a dedicated high-temperature furnace (Figure 3.4). In accordance with ISO requirements for dental ceramics (ISO 6872, 2008), the specimen dimensions were created (Figure 3.5, 3.6).



Figure 3.1. Zenostar ZR translucent (Wieland Dental;Pforzheim, Germany)



Figure 3.2. Ceramil zolid fx preshade (Amann Girrbach AG, Koblach, Austria)



Figure 3.3. Milling unit of CAD/CAM system



Figure 3.4 Furnace for zirconia sintering

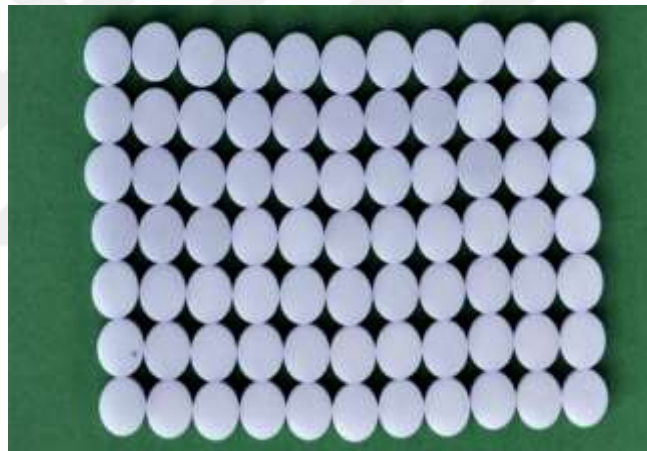


Figure 3.5. Zenostar ZR translucent disc (n= 77)

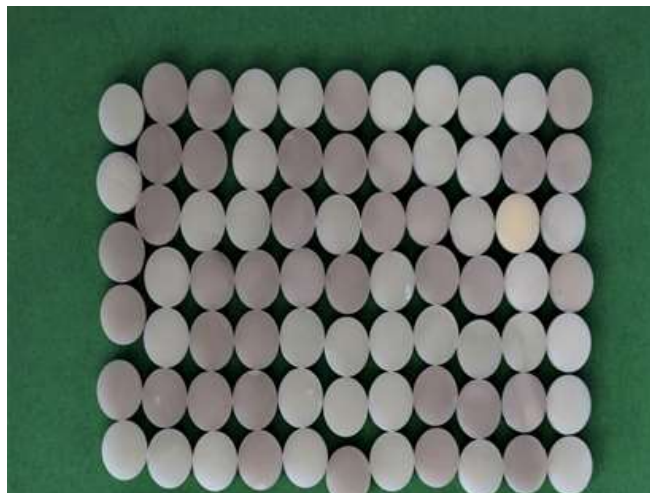


Figure 3.6. Ceramill Zolid fx preshade disc (n=77)

Table 3.1. Materials used in this study

Material	Manufacturer	Composition	Lot No.
Zenostar ZR translucent	Wieland Dental; Pforzheim, Germany	ZrO ₂ + HfO ₂ + Y ₂ O ₃ > 99.0%, Y ₂ O ₃ >4.5-≤6.0%, HfO ₂ ≤5.0%, Al ₂ O ₃ + other oxides ≤1.0%	20110407-24
Ceramill zolid fx preshade	Amann Girrbach AG, Koblach, Austria	ZrO ₂ + HfO ₂ + Y ₂ O ₃ : ≥ 99.0%, Y ₂ O ₃ : 8,5 – 9,5% HfO ₂ : ≤ 5 Al ₂ O ₃ : ≤ 0.5% Other oxides: ≤ 1%	1707000 1706000
Cojet	3M ESPE, Seefeld, Germany	30 µm silica/alumina particles	4360501
Siljet	Danville Materials Inc, S. Ramon, CA, USA	30 µm silica/alumina particles	93596
ESPE-Sil	3M ESPE, Seefeld, Germany	g-MPTS, ethanol	3745537
S-Bond	Danville Materials Inc, S. Ramon, CA, USA	g-MPTS, ethanol	LOLPO
Bisco, Porcelain Etchant (9.5%)	Bisco, USA	9.6% Hydrofluoric acid	E70557
Aluminium oxide		50 µm Al ₂ O ₃ sand	343608
Z-Prime Plus	Bisco, USA	MDP,BPDM, HEMA, ethanol	18800007072
RelyX U200 automix A2	3M ESPE, Seefeld, Germany	Bis-GMA, TEGDMA, Methacrylate monomers containing phosphoric acid groups, methacrylate monomers, silanated fillers, initiator components, stabilizer components, rheologic additives, alkaline fillers, pigments, rheologic additives (filler = 70 wt%).	4806100
Filtek Z250	3M ESPE, Seefeld, Germany	BisEMA, BisGMA, TEGDMA, UDMA, zirconium, silica, pigments, camphorquinone	N970669

Table 3.2. Instruments and equipment used in the study

Machine	Manufacture
CAD/CAM machine	VHF k5 Ammerbuch, Germany
Ceramic furnace	Vita Zahnfabrik. Germany
Polishing machine	Phoenix Beta Grinder/ Polisher, Buehler, Germany
Sandblasting machine	Renfert, Basic master Germany
Light cure unit	Kerr Optilux 501 USA
Universal testing machine	Model 3345, Instron Corp., Norwood, MA, USA
Stereomicroscope	Stereomicroscope (ZEISS Stereo Discovery.V20 Germany
sputter coater	BAL-TEC (Sputter Coater SEM Sample Prep)
Sacaningelectron miroscope	EVO10,ZEISS,Oberkochen Germany
Fiber optic laser	Rofin-Sinar Laser GmbH Germany
Thermocycling machine	Salibrus Technica, Turkey

3.2 Method

3.2.1 Preparation of experimental specimens

152 monolithic zirconia discs upon a diameter of 10 mm and a length of 3 mm (10mm x 3mm) were utilized in this research, 140 discs were utilized to determine the shear bond strength, 12 discs were utilized to measure surface roughness via SEM. To achieve standardized surface roughness on monolithic zirconia specimens, the bonding surface was polished sequentially with 320, 600, 800, and 1200 grit silicon carbide papers (English Abrasive, London, England) by a polishing machine (Phoenix Beta Grinder/Polisher, Buehler, Germany) under water cooling (Figure 3.7).



Figure 3.7. Polishing machine (Phoenix Beta Grinder/ Polisher)

After ultrasonically cleaning the sintered specimens in a deionized water bath for 5 minutes (Figure 3.8), they were gently air-dried. Each zirconia disk was put face-up on a epoxy glass mold (Figure 3.9).



Figure 3.8. Ultrasonic scaler



Figure 3.9. Epoxy glass mold

3.2.2 Experimental groups

Randomly selected specimens were undergone to one of the subsequent surface modification regimens.

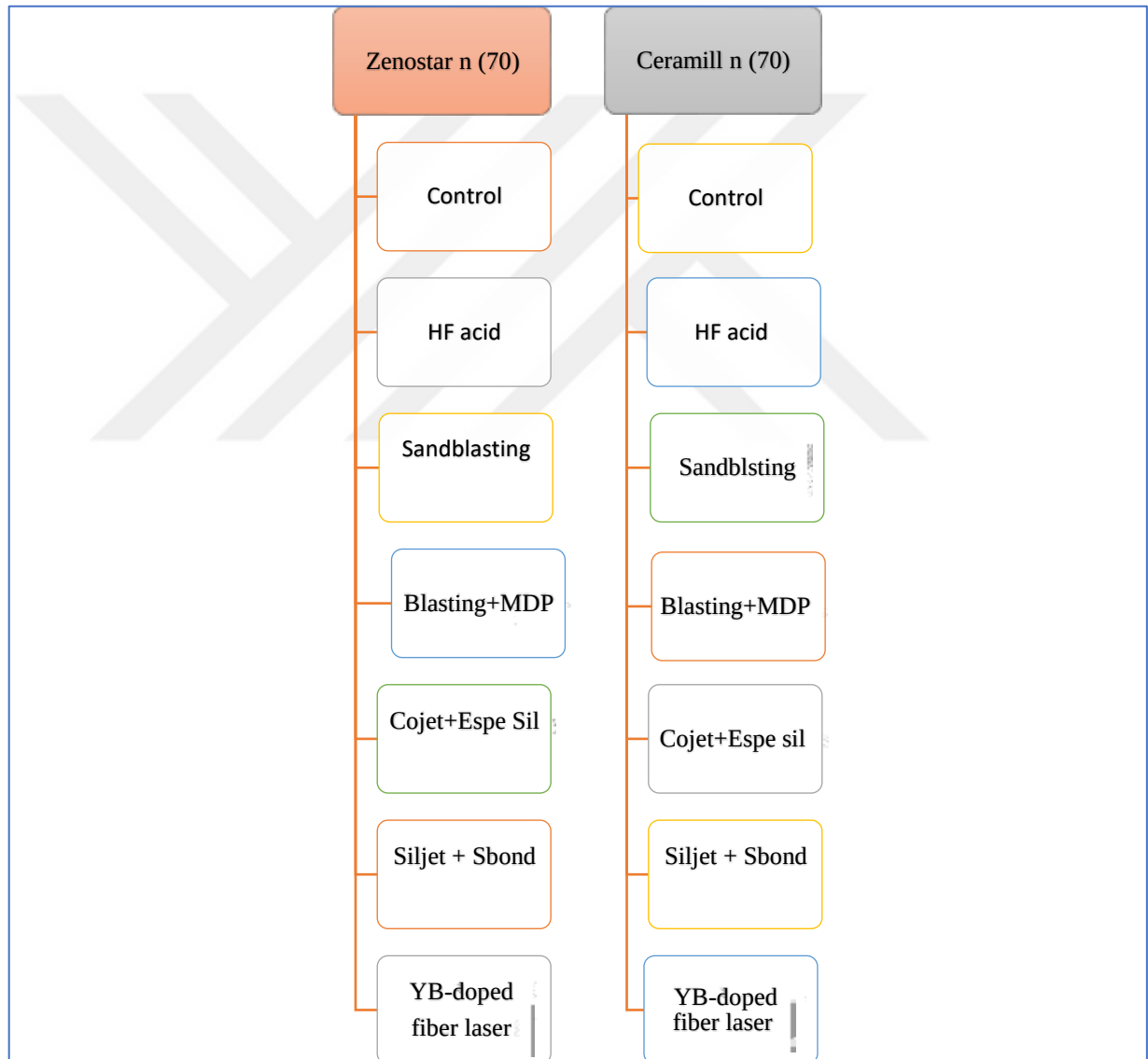


Figure 3.10. Flow-chart showing experimental group

3.2.3 Zirconia specimen surface treatments

Control (no treatment) group

Zirconia samples have been sintered in accordance with the manufacturer's specifications and did not undergo any surface treatment prior to cementation.

HF acid group

Following sintering, the samples were etched for 1 hour in HF Acid 9.5 percent (Figure 3.11, 3.12), subsequently ultrasonically washed for approximately 5 minutes in a deionized water bath, and professionally air-dried.



Figure 3.11. 9.5% Hydrofluoric acid gel

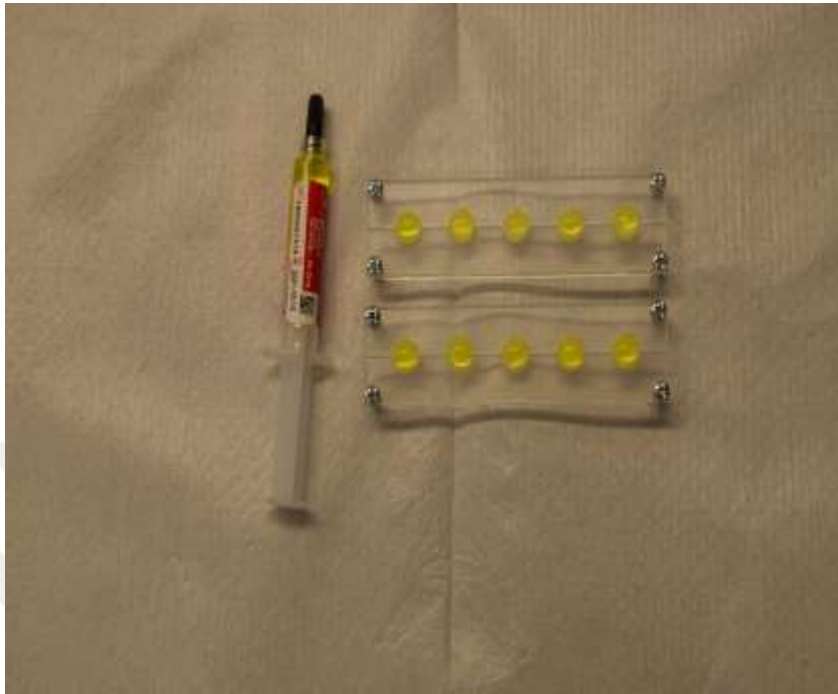


Figure 3.12. Zirconia surface treated with an acid gel

Air blasting group

Bonding side of the zirconia surface was air-abraded with 50 μm alumina particles (Mega Strahikorund Germany) at 2.5 bar after sintering (Figure 3.13). Perpendicularly, the distance between the blasting sand outflow and the zirconia top was maintained at 10 mm. The blasting time was determined at 20 seconds. The zirconia surface was sandblasted in a circular manner throughout the entire surface. Renfert basic master (sandblasting machine) is used for all procedures (Figure 3.14). They were then carefully air-dried after being cleansed with deionized water via ultrasonically for 5 minutes at room temperature.

Blasting MDP group

The methodology for particle deposition was followed as stated in air blasting group. The Z prime plus was carried out in two layers using an applicator brush, evenly wetting the prepared monolithic zirconia surface and drying for 3 seconds with an air syringe (Figure 3.15).



Figure 3.15. Z-Prime Plus

Cojet Group

When spraying the surface with Cojet in a direction perpendicular to boning surface of zirconia sample for 20 seconds and at an operating pressure of 2.8 bar, with an operating distance of 10mm. (Figure 3.16). Renfert basic master (sandblasting machine) is used in the blasting process (Figure3.14). The samples were ultrasonically cleaned and in a deionized water bath for 5 minutes carefully air-dried. Before bonding, using only a disposable micro applicator for application of Espe Sil, silanization was administered corresponding to the manufacturer's instructions (Figure 3.17) and left to dry for 30 seconds.



Figure 3.16. Cojet sand



Figure 3.17. ESPE Sil

Siljet group

When spraying the surface with siljet in a direction perpendicular to boning surface of zirconia sample for 20 seconds and at an operating pressure of 2.8 bar, with an operating distance of 10mm. (Figure 3.18). (Renfert, Basic master) is used in the blasting process (Figure3.14). The samples were ultrasonically cleaned in a deionized water bath for 5 minutes and carefully air-dried. Before bonding, using only a disposable micro applicator for application of S-bond, silanization was administered corresponding to the manufacturer's instructions (Figure 3.19) and left to dry for 30 seconds.



Figure 3.18. Siljet sand



Figure 3.19. S-bond (silan)

Fiber laser group

The zirconia discs surfaces were irradiated with a 20W Yb-doped fiber-based nanosecond pulsed laser (Rofin Germany) following sintering (Figure3.20). The irradiation was carried out with YbPL at a wavelength of 1064 nm and a frequency of 100 kHz, with an operating distance of 0 mm perpendicular to the zirconia bonding surface, and operating time was the 20s. For all samples, the device was set at 350mm/s.t.



Figure 3.20. Fiber optic laser machine (Rofin-Sinar Laser GmbH Germany)

3.2.4 Composite discs preparation

Packing composite resin in two increments into a transparent plastic mold (Figure 3.21) and then light-curing for 40 seconds at an operating distance of 1 mm from the mold using a light-curing device was used to create a 5mm diameter and 3mm thick discs (Figure 3.22).



Figure 3.21 Composite disc preparation



Figure 3.22. Light cure unit (Kerr Optilux 50)

3.2.5 Bonding procedure

On the blocks, bonding sites were specified utilizing polyethylene sticky tape with a 20-micron thickness and circular hole of 5 mm diameter. RelyX U200 (3M/ESPE) resin cement was tested for all groups (Figure 3.23). The cement was placed on the prepared surface of the zirconia disk according to the manufacturer's instructions. Subsequently, 5mm wide composite disks were put on top of the zirconia disks and a force of 2000 g was exerted. After removing extra cement, light-curing devices with only a power density of 600 mW/cm were employed to cure the cement for approximately 20 seconds on each side.



Figure 3.23. Self-adhesive resin cement (RelyX U200 (3M/ESPE))

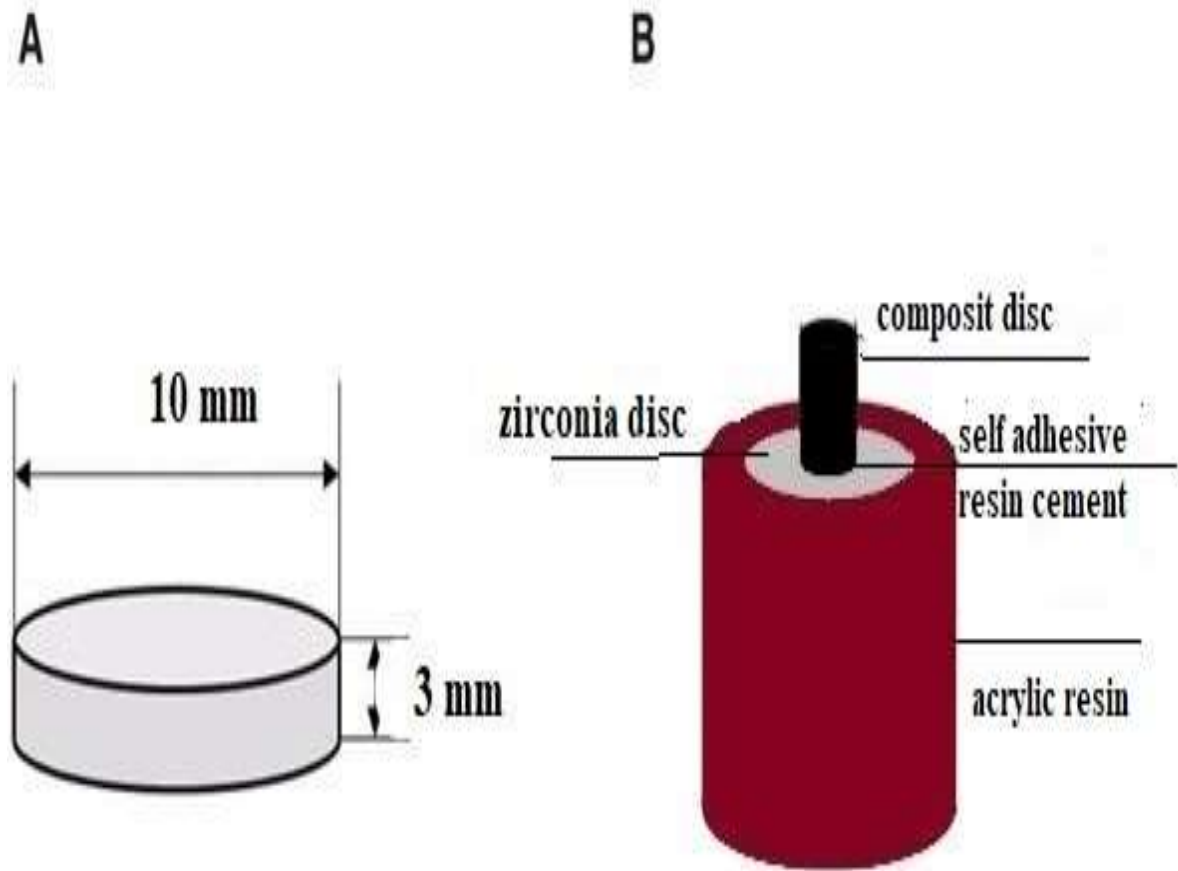


Figure 3.24. Bonding composite with zirconia

3.2.6 Aging procedure

Throughout 24 hours, specimens were preserved at 37 degrees Celsius. The specimens following thermocycling (Salibrus Technica, Turkey): 5000 cycles at temperatures ranging from 5 to 55 °C, 15 s dwell time, and 10 s transfer time between baths, all following ISO 10477 standards (Figure 3.2 5). Six months of clinical use is equal to 5000 cycles.



Figure 3.25. Thermocycling machine

All specimens were fixed in a metal mold utilizing chemically cured acrylic resin. Following that, all specimens were prepared for the shear bond test (Figure 3.26, 3.27).



Figure 3.26. Zenostar . A ControL, B. HF Acid, C. Air Blasting, D. Air blasting+ Z prim Plus , E.Cojet , F .Siljet ,G. Fiber Laser



Figure 3.27. Ceramil , A.Control , B.HF Acid , C. Air blasting, D. Airblasting +Z prim Plus , E. Cojet , F .Siljet , G. Fiber Laser

3.2.7 Shear bond strength test

The shear bond strength of specimens was determined using a universal testing machine (Model 3345, Instron Corp., Norwood, MA, USA) in accordance with (ISO/TS 11 405:2003) (Figure 3.28). All samples were subjected to shear bond testing at a crosshead speed of one millimeter per second. As close as possible to the interface between the monolithic zirconia and the resin cement, a knife-edge blade equipment was used in a parallel to shearing force configuration to cut the monolithic zirconia. This was accomplished by using the formula $R \text{ (in MPa)} = F/A$, where F is the load required to cause specimen failure (N) and A is the cross-sectional interfacial area (mm^2).



Figure 3.28. Shear bond strength testing machine

3.2.8 Failure analysis

Stereomicroscope (ZEISS SteREO Discovery.V20 Germany) (Figure 3.29) 20 x zoom was used to assess the mode of failure, which was classified as (1) adhesive failure when fracture between monolithic zirconia and composite resin cement; resin-free monolithic zirconia surface, (2) cohesive failure when the fracture within the composite resin or cement (3) mixed failure when the surface exhibiting monolithic zirconia and remnants of composite cement (adhesive and cohesive phases).

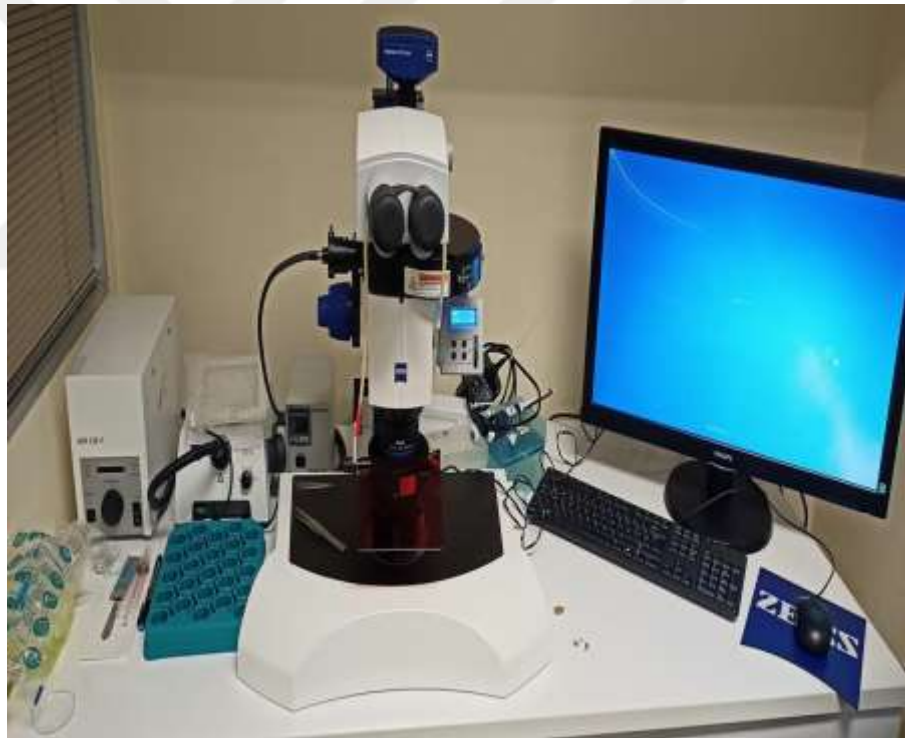


Figure 3.29. Stereomicroscope (ZEISS SteREO Discovery.V20 Germany)

3.2.9 Scanning electron microscopic (SEM) analysis

One specimen from each group, except the blasting MDP group (n12), was gold plated with a sputter coater (Figure 3.29) to evaluate the surface characteristics of surface-treated Y-TZP specimens. and then studied using SEM (EVO10, ZEISS, Oberkochen Germany) (Figure 3.30) at magnifications of X1000, X2000, and X5000.



Figure 3.29. BAL-TEC (Sputter Coater SEM Sample Prep)

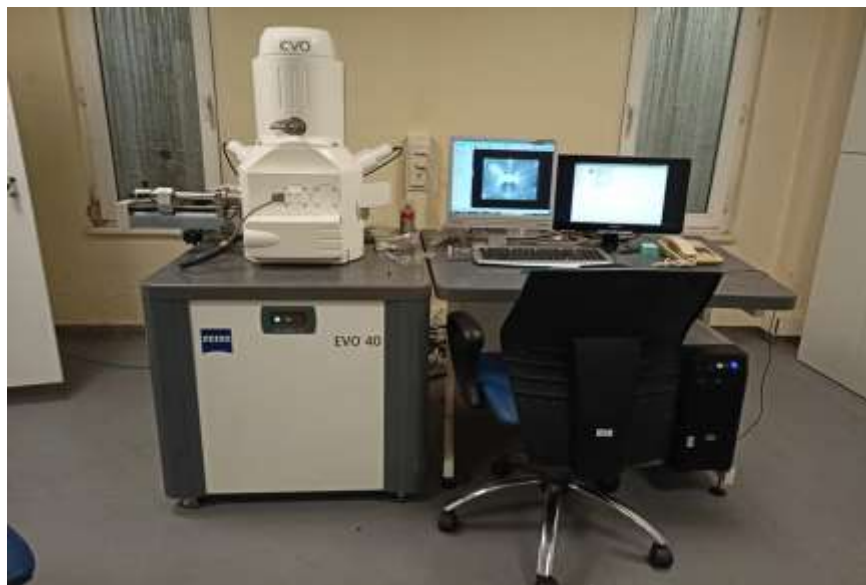


Figure 3.30. SEM (EVO10, ZEISS, Oberkochen German)

3.2.10 Statistical evaluation

During the assessment of the data obtained in the study, IBM SPSS 22 (IBM SPSS, Turkey) program was used for statistical analysis. During the assessment of the study data, conformity of the parameters to the normal distribution was assessed by the Kolmogorov–Smirnov and Shapiro Wilks tests and it was determined that the parameters were conformed to the normal distribution. Two-way analysis of variance (ANOVA) was used to analyze the effects of monolithic zirconia type, surface treatment, and their interaction on SBS. One-way ANOVA was used to test the differences in SBS between monolithic zirconia and resin cements. Tukey Honest Significant Difference test was used for multiple comparisons. Student t test was used for the intergroup comparisons of parameters with normal distribution. The significance was evaluated at $P < .05$. Chi-Square test and Fisher's Exact Chi-Square test were used to compare qualitative data. Significance was evaluated at a level of $p < 0.05$.

4 RESULTS

Shear bond strength, mode of failure and SEM analysis were evaluated.

4.1 Shear bond strength

Descriptive statistics about shear bond strengths (MPa) for all groups were shown at table (4.1).

Table 4.1. Descriptive statistics about shear bond strengths (MPa) for all groups

groups	N	mean	Standart deviation	Min.	Max.	Standart error	skewness
Zenostar controll	10	0,239	0,096	0	0,380	0,030	-1,681
Ceramill controll	10	0,322	0,144	0,150	0,630	0,046	1,186
Zenostar HF Acid	10	0,177	0,103	0	0,280	0,032	1,053
Ceramill HF Acid	10	0,359	0,077	0,220	0,480	0,024	0,002
Zenostar air blasting	10	5,150	0,922	3,390	6,310	0,292	-0,507
Ceramill air blasting	10	5,291	0,756	4,120	6,470	0,239	0,249
Zenostar air blasting + Zprime plus	10	10,828	1,362	8,000	12,420	0,431	-0,838
Ceramill air blasting + Zprime plus	10	10,406	1,186	8,690	13,000	0,375	0,979
Zenostar Cojet	10	11,689	1,321	10,000	13,680	0,418	0,212
Ceramill Cojet	10	11,580	1,640	9,360	13,540	0,519	-0,076
Zenostar Siljet	10	12,797	1,613	9,610	15,580	0,510	0,501
Ceramill Siljet	10	12,534	2,107	8,450	15,000	0,666	-0,966
Zenostar fiber laser	10	17,814	2,003	14,000	17,130	0,633	-0,877
Ceramill fiber laser	10	21,703	3,546	20,200	27,300	1,121	0,270

Table 4.2. Evaluation of the effect of zirconia type and surface treatment on shear bond strength

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	6164,530	13	474,195	202,453	0,000*
Intercept	10438,68	1	10438,68	4456,699	0,000*
Material	8,755	1	8,755	3,738	0,055
Surface Treatment	6087,314	6	1014,552	433,154	0,000*
Material *Surface Treatment	68,462	6	11,41	4,872	0,000*

The two-way ANOVA test demonstrated that the mean shear bond strength values of the two zirconia CAD/CAM materials did not differ statistically significantly ($p:0.055$; $p>0.05$). The mean shear bond strength varied statistically significantly dependent on surface treatment ($p:0.000$; $p<0.05$). The zirconia types interacted with the surface treatment in terms of bond strength in the experiment ($p:0.000$; $p<0.05$) (Table 4.2).

Table 4.3. Evaluation of bond strength (MPa) of various monolithic zirconia types according to different surface treatment

Surface treatment	Zenostar	Ceramill	¹ p
	Mean±SD	Mean±SD	
Control	0,24±0,1	0,32±0,14	0,147
HF Acid	0,18±0,1	0,36±0,08	0,000*
Airblasting	5,15±0,92	5,29±0,76	0,713
Blasting MDP	10,83±1,36	10,41±1,19	0,470
Cojet	11,69±1,32	11,58±1,64	0,872
Siljet	12,8±1,61	12,53±2,11	0,758
Fiber Laser	17,81±2	21,7±3,55	0,007*
² p	0,000*	0,000*	

¹Student t-test

²Oneway ANOVA Test

*p<0.05

Table (4.3) demonstrate that the comparison of the shear bond strengths of distinct surface treatments on Zenostar and Ceramill materials clearly shows that there is no statistically significant in the mean shear bond strengths of Zenostar and Ceramill materials in the control group, as determined by the student t-test ($p > 0.05$).

Ceramill material's mean shear bond strength was statistically significantly greater than Zenostar material's mean shear bond strength in HF acid groups ($p: 0.000$; $p < 0.05$).

It has been shown that there is no statistically significant difference between the mean shear bond strength of Zenostar and Ceramill materials in the air blasting groups ($p > 0.05$).

When comparing the mean shear bond strength of Zenostar and Ceramill materials in the Blasting MDP group, there is no statistically significant difference ($p > 0.05$).

When comparing the mean shear bond strength of Zenostar and Ceramill materials in the Cojet group, there is no statistically significant difference ($p > 0.05$).

When comparing the mean shear bond strength of Zenostar and Ceramill materials in the Siljet group, there is no statistically significant difference ($p > 0.05$).

The mean shear bond strength of Ceramill material was found to be statistically substantially greater than the mean shear bond strength of Zenostar material in the Fiber Laser groups ($p: 0.007$; $p < 0.05$). Bar-chart demonstrate the shear bond strength MPa According to different surface treatment (Figure 4.1)

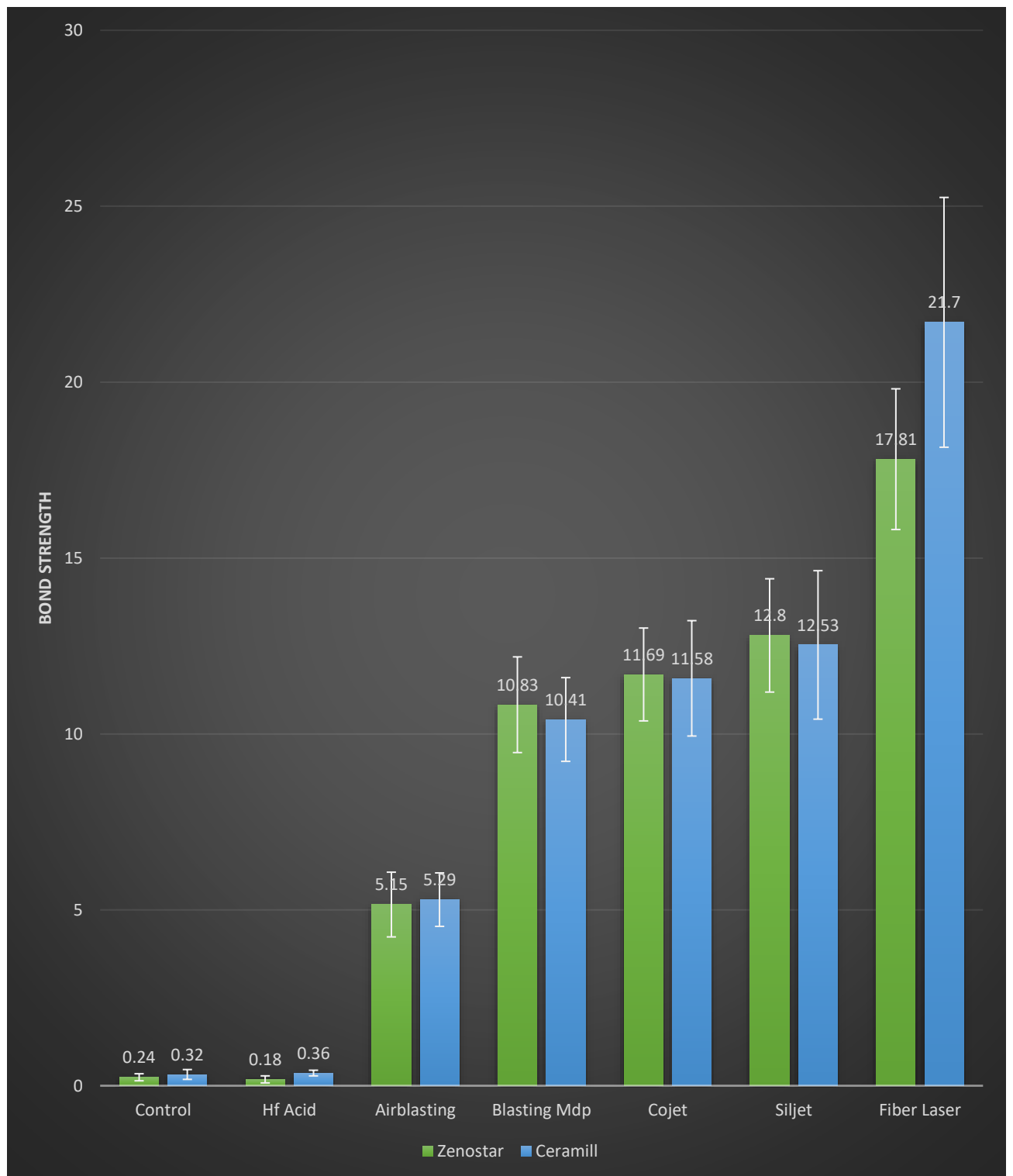


Figure4.1. Bar-chart for Shear Bond Strength (MPa) According to different surface treatment

Table 4.4. Post hoc Tukey's multiple comparison test.

		Zenostar	Ceramill
Control	HF ACID	0,985	1,000
	Airblasting	0,000*	0,000*
	Blasting Mdp	0,000*	0,000*
	Cojet	0,000*	0,000*
	Siljet	0,000*	0,000*
	Fiber Laser	0,000*	0,000*
HF Acid	Airblasting	0,000*	0,000*
	Blasting Mdp	0,000*	0,000*
	Cojet	0,000*	0,000*
	Siljet	0,000*	0,000*
	Fiber Laser	0,000*	0,000*
Air blasting	Blasting Mdp	0,000*	0,000*
	Cojet	0,000*	0,000*
	Siljet	0,000*	0,000*
	Fiber Laser	0,000*	0,000*
Blasting MDP	Cojet	0,979	0,845
	Siljet	0,169	0,265
	Fiber Laser	0,000*	0,000*
Cojet	Siljet	0,915	0,999
	Fiber Laser	0,000*	0,000*
Siljet	Fiber Laser	0,000*	0,000*

Zenostar

The one-way ANOVA test revealed a statistically significant difference between the shear bond strength values of the surface treatment at Zenostar (0.000; $p < 0.05$) (Table 4.3). As a result of post hoc analysis in (Table 4.4) to identify which surface treatment was responsible for the difference, it was determined that the mean shear bond strength of the Fiber Laser group was substantially greater than the mean shear bond strength of the other surface treatments ($p < 0.05$).

The Control group's mean shear bond strength was considerably less than that of the Airblasting, Blasting MDP, Cojet, Siljet, and Fiber Laser groups ($p < 0.05$).

The HF Acid group's mean shear bond strength was considerably less than that of the Airblasting, Blasting MDP, Cojet, Siljet, and Fiber Laser groups ($p < 0.05$).

The Airblasting group's mean shear bond strength was found to be considerably less than that of the Blasting MDP, Cojet, Siljet, and Fiber Laser groups ($p < 0.05$).

No statistically significant difference exists between the other surface treatment groups ($p > 0.05$).

Ceramill

Ceramill, there was a statistically significant difference between the surface treatment's shear bond strength values ($p: 0.000$; $p < 0.05$) (Table 4.3). Following post hoc analysis to discover the cement type responsible for the difference (Table 4.4), it was shown that the Fiber Laser group's mean shear bond strength was considerably greater than all other surface treatments ($p < 0.05$).

The Control group's mean shear bond strength was considerably less than that of the Airblasting, Blasting MDP, Cojet, Siljet, and Fiber Laser groups ($p < 0.05$).

The HF Acid group's mean shear bond strength was considerably less than that of the Airblasting, Blasting MDP, Cojet, Siljet, and Fiber Laser groups ($p < 0.05$).

The Airblasting group had a significantly lower mean shear bond than the Blasting MDP, Cojet, Siljet, and Fiber Laser groups ($p < 0.05$).

There is no statistically significant difference between other surface treatment groups ($p > 0.05$).

4.2 Mode of failure

Table 4.5. Number (percent) of modes of failure in each group

Failure mode		Zenostar	Ceramill	p
		n (%)	n (%)	
Control	Adhesive	10 (%100)	10 (%100)	-
HF Acid	Adhesive	10 (%100)	10 (%100)	-
Air blasting	Adhesive	9 (%90)	8 (%80)	1,000
	Mixed	1 (%10)	2 (%20)	
Blasting MDP	Adhesive	4 (%40)	5 (%50)	1,000
	Mixed	6 (%60)	5 (%50)	
Cojet	Adhesive	2 (%20)	3 (%30)	1,000
	Mixed	8 (%80)	7 (%70)	
Siljet	Adhesive	1 (%10)	2 (%20)	1,000
	Mixed	9 (%90)	8 (%80)	
Fiber Laser	Cohesive	7 (%70)	6 (%60)	1,000
	Mixed	3 (%30)	4 (%40)	

Fisher's Exact test

Percent of failure mode in all groups were shown in (Table4.5, 4.6).

In the control group, adhesive failure was detected in all materials. All materials in the HF Acid category demonstrated adhesive failure. In the air blasting group, adhesive failure occurred in 90% of Zenostar and 80% of Ceramill materials, with no statistically significant difference between them ($p > 0.05$).

In the Blasting MDP group, 40% of the Zenostar material failed due to adhesive failure, 60% failed due to mixed failure, 50% of the Ceramill material failed due to adhesive failure, 50% failed due to mixed failure, and there was no statistically significant difference between them ($p > 0.05$).

In the Cojet group, mixed failure was observed in 80% of the Zenostar material and 70% of the Ceramill material, with no statistically significant difference ($p > 0.05$).

The mixed failure occurred in 90% of the Zenostar material and 80% of the Ceramill material in the Siljet group, with no statistically significant difference between them ($p > 0.05$).

In the fiber laser group, 70 percent of Zenostar material was cohesive, 30 percent was a mixed failure, 60 percent of Ceramill material was cohesive, 40 percent of it mixed failure, and there was no statistically significant difference between them ($p > 0.05$).

Table 4.6. Mode of failure of each surface treatment for both zirconia type

	Failure mode	Control	HF Acid	Air blasting	Blasting MDP	Cojet	Siljet	Fiber Laser	p
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
Zenostar	Adhesive	10 (%100)	10 (%100)	9 (%90)	4 (%40)	2 (%20)	1 (%10)	0 (%0)	0,000*
	Cohesive	0 (%0)	0 (%0)	0 (%0)	0 (%0)	0 (%0)	0 (%0)	7 (%70)	
	Mixed	0 (%0)	0 (%0)	1 (%10)	6 (%60)	8 (%80)	9 (%90)	3 (%30)	
Ceramill	Adhesive	10 (%100)	10 (%100)	8 (%80)	5 (%50)	3 (%30)	2 (%20)	0 (%0)	0,000*
	Cohesive	0 (%0)	0 (%0)	0 (%0)	0 (%0)	0 (%0)	0 (%0)	6 (%60)	
	Mixed	0 (%0)	0 (%0)	2 (%20)	5 (%50)	7 (%70)	8 (%80)	4 (%40)	

Chi-Square test

* $p < 0.05$

There is a statistically significant difference between the failure types according to the surface shapes applied in the Zenostar material ($p: 0.000$; $p < 0.05$) (Table 4.6, Figure 4.2). The rate of cohesive failure in the Fiber Laser group (70%) was significantly higher than all other groups ($p < 0.05$). The adhesive failure rate in the Control and HF Acid groups (100%) was significantly higher than the Blasting MDP, Cojet, Siljet, and Fiber Laser groups. It was found to be high ($p < 0.05$). The rate of adhesive failure (90%) in the air blasting group was significantly higher than the Cojet, Siljet, and Fiber Laser groups ($p < 0.05$). There is no

statistically significant difference between the other surface treatment groups ($p > 0.05$) (Table 4.6).

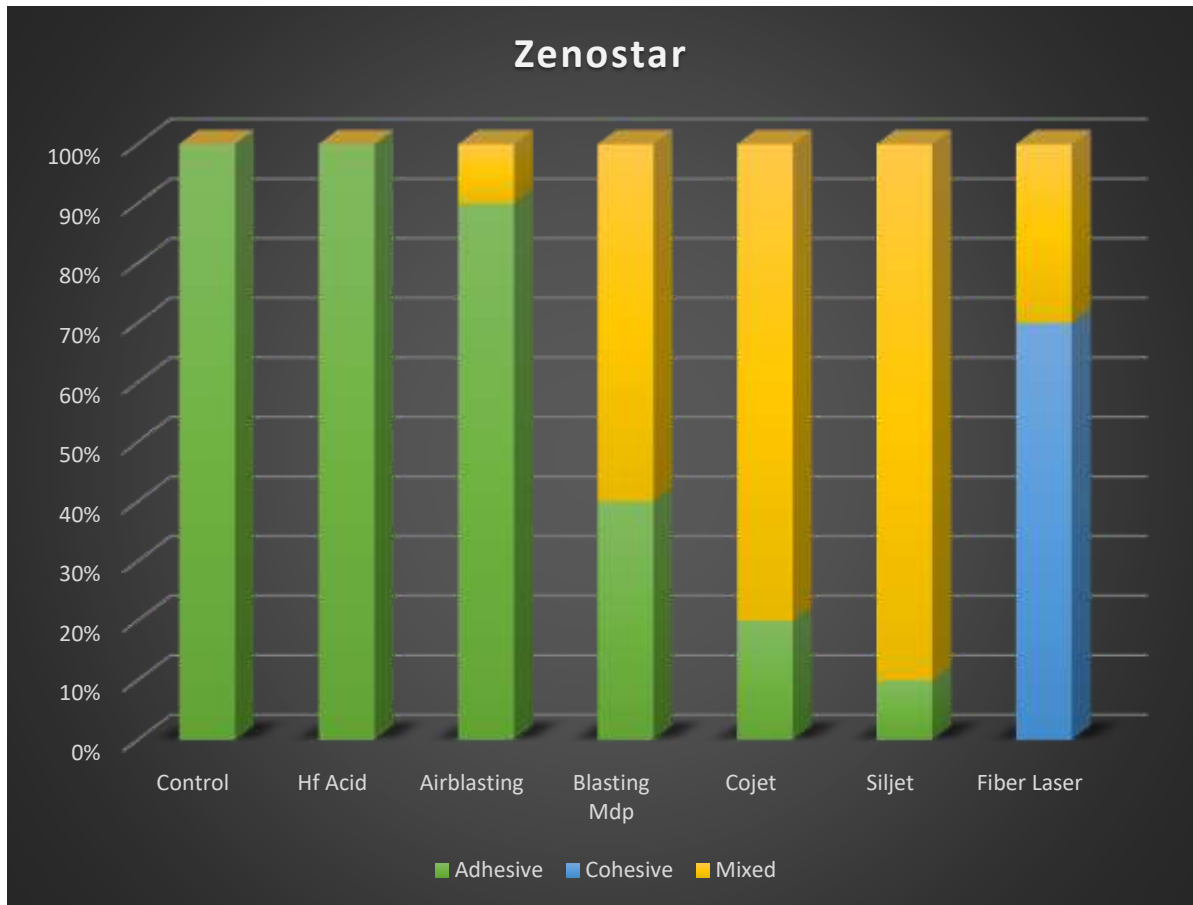


Figure 4.2. Bar-chart for failure type of different surface treatment in Zenostar

There is a statistically significant difference between the failure types according to the surface treatment applied in the Ceramill material ($p: 0.000$; $p < 0.05$) (Table 4.6, Figure 4.3). The rate of cohesive failure in the Fiber Laser group (60%) was significantly higher than in all other groups ($p < 0.05$). The rate of adhesive failure in the Control and HF Acid groups (100%) was significantly higher than the Blasting MDP, Cojet, Siljet, and Fiber Laser groups. It was found to be high ($p < 0.05$). The rate of adhesive failure in the air blasting group (80%) was significantly higher than the Siljet and Fiber Laser groups ($p < 0.05$). There

is no statistically significant difference between the other surface treatment groups ($p > 0.05$) (Table 4.6).

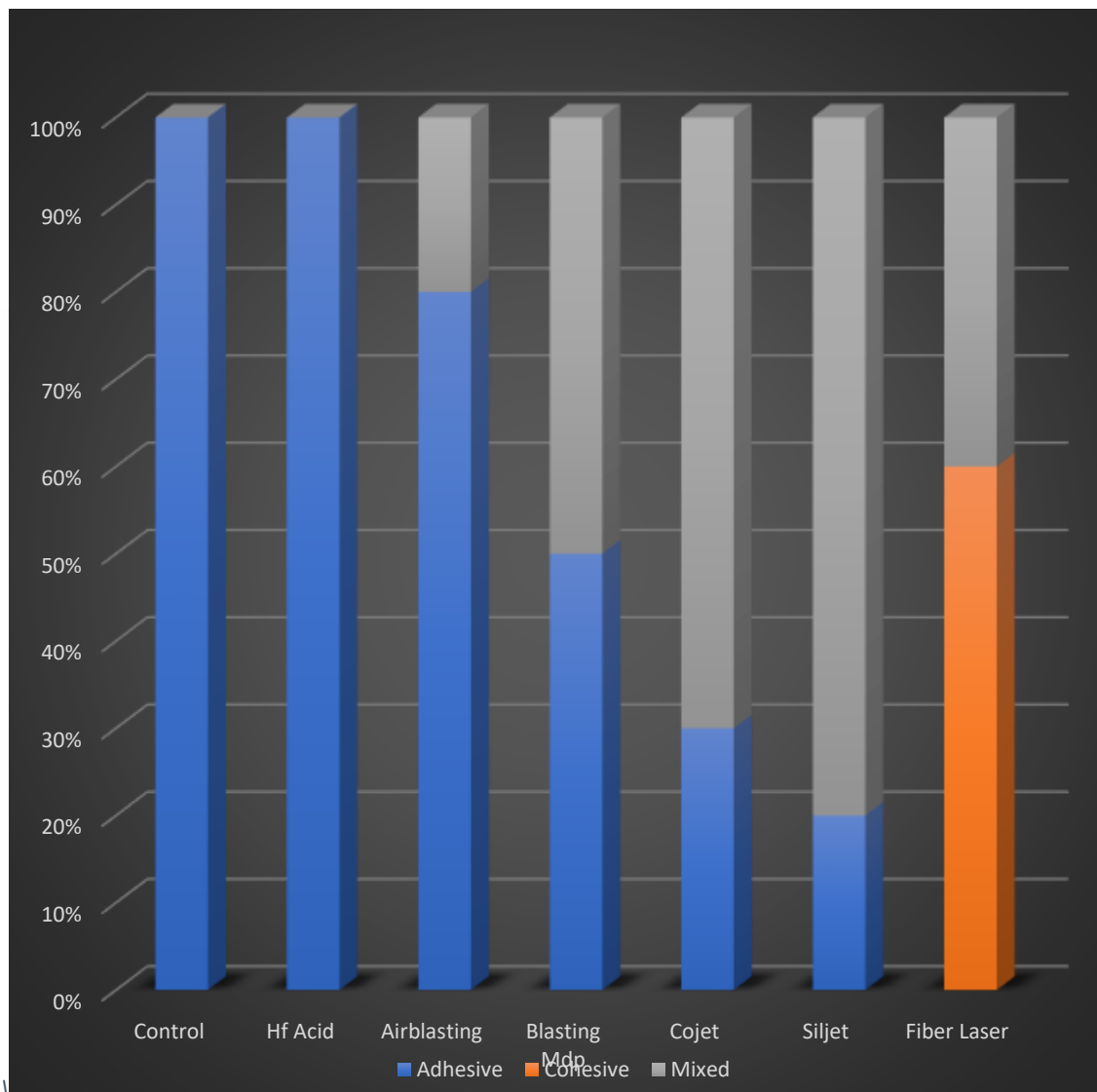


Figure 4.3. Bar-chart for failure type of different surface treatment in Ceramill

4.3 Stereomicroscope evaluation

4.3.1 Mode of failure

Bonding of failures, Stereomicroscope images of three type were showed in figures from Figure 4.4 to Figure 4.6.



Figure 4.4. Stereomicroscope images of adhesive failure



Figure 4.5. Stereomicroscope images of mixed failure



Figure 4.6. Stereomicroscope images of cohesive failure

4.3.2 Zirconia colour change due to fiber laser scanned using stereomicroscope

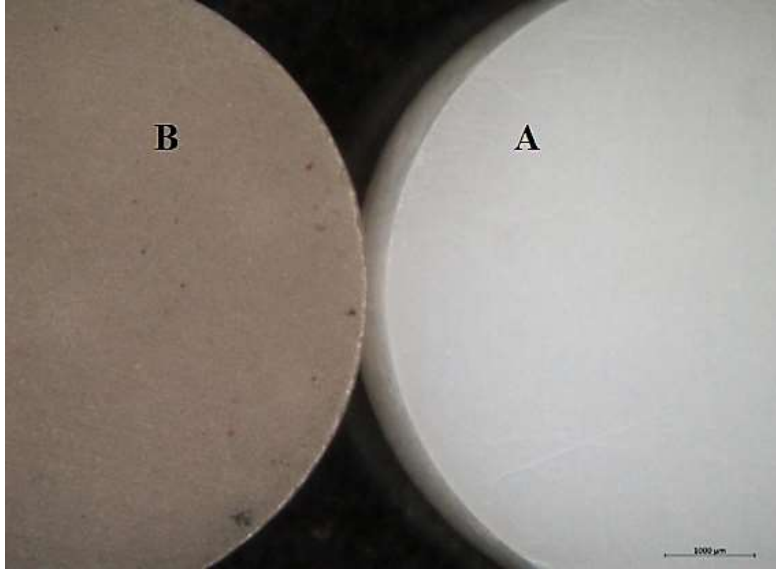


Figure 4.7. **A.** Stereomicroscope image untreated Zenostar with fiber laser, **B.** Stereomicroscope image of treated Zenostar with fiber

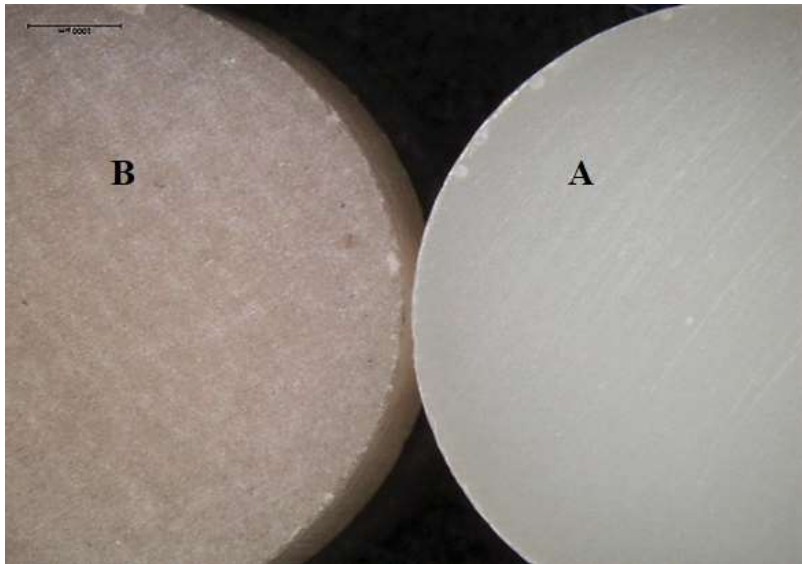


Figure 4.8. **A.** Stereomicroscope image untreated Caramill with fiber laser, **B.** Stereomicroscope image of treated Caramill with fiber laser

4.4 SEM evaluation

4.4.1 Bonding failure SEM analysis

Bonding failure SEM image of three groups were shown in figures from figure 4.9 to figure 4.11.

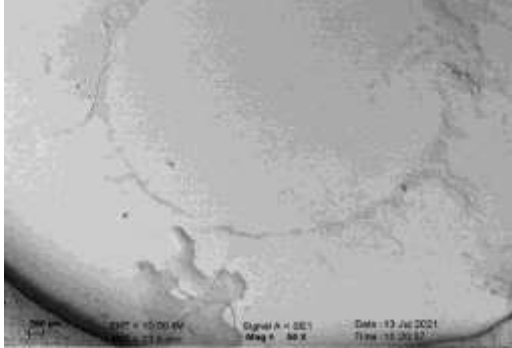


Figure 4.9. SEM image of adhesive failure

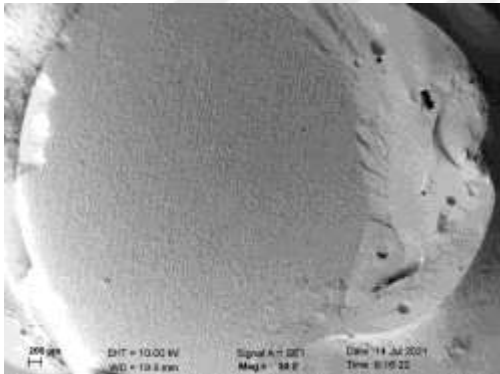


Figure 4.10. SEM image of mixed failure

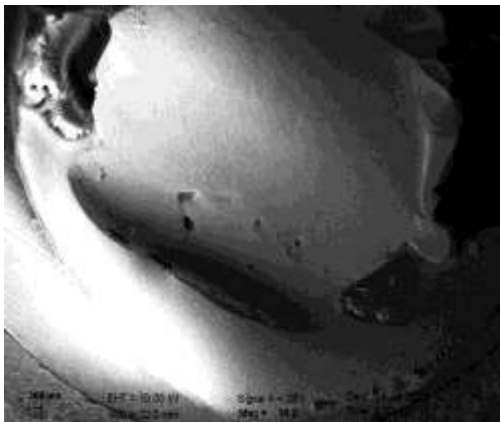


Figure 4.11. SEM image of cohesive failure

4.4.2 SEM analysis for surface treatment

SEM image of all different surface treatment and untreated groups except MDP blasting group shown in figure from 4.12 to 4.47 X1000 X2000 X500 magnification of SEM images were showed all groups.

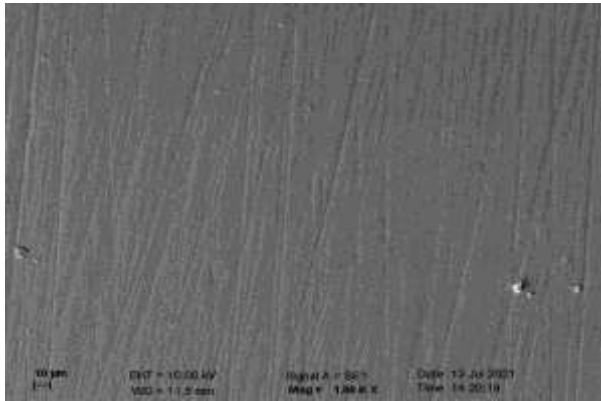


Figure 4.12 SEM (1000X) image of untreated Zenostar

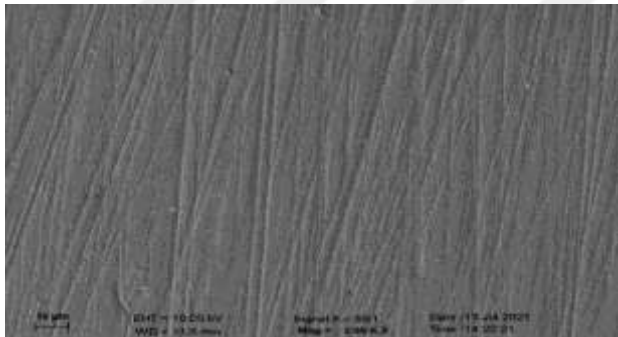


Figure 4.13. SEM (2000X) image of untreated Zenostar

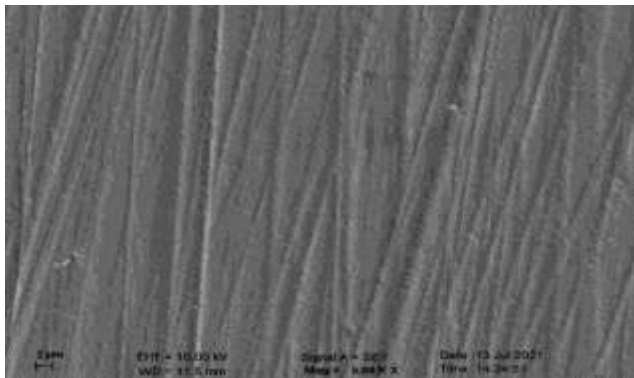


Figure 4.14. SEM (5000X) image of untreated Zenostar

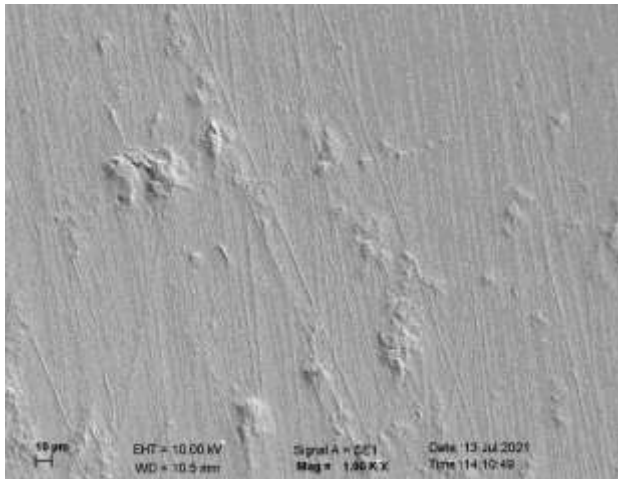


Figure 4.15. SEM (1000X) image of untreated Ceramill

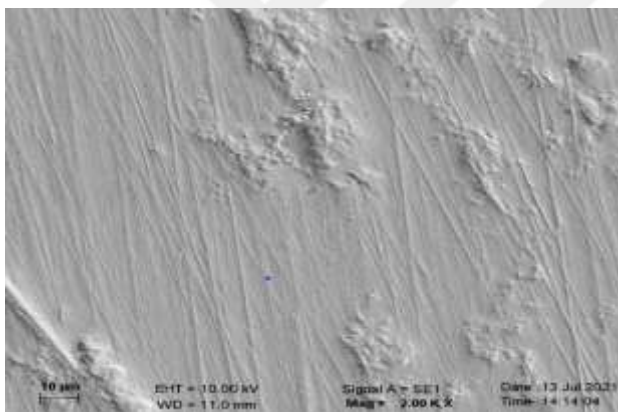


Figure 4.16. SEM (2000X) image of untreated Ceramill

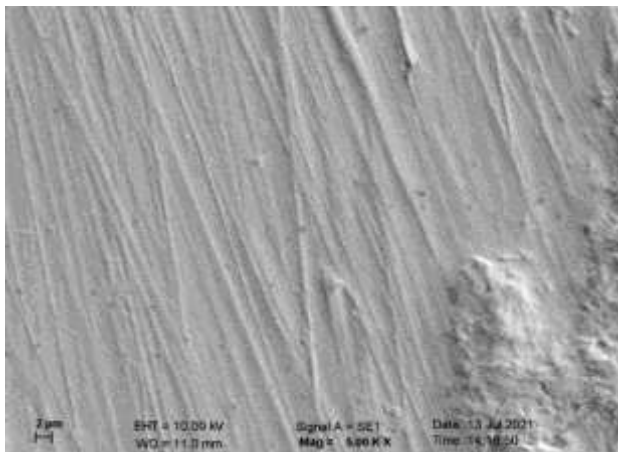


Figure 4.17. SEM (5000X) image of untreated Ceramill

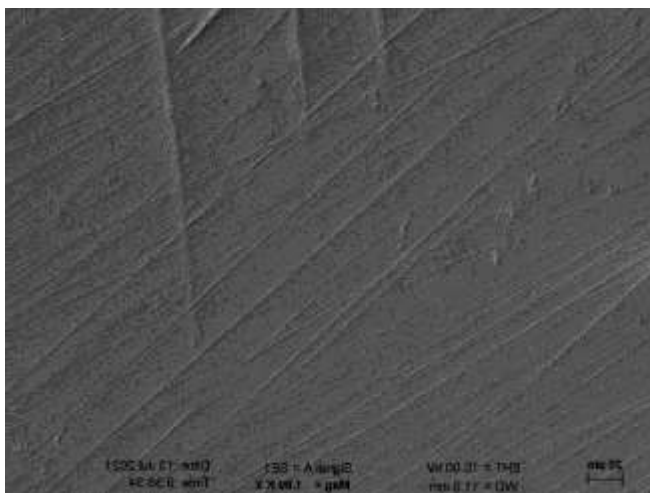


Figure 4.18. SEM (1000X) image of treated Zenostar with HF acid

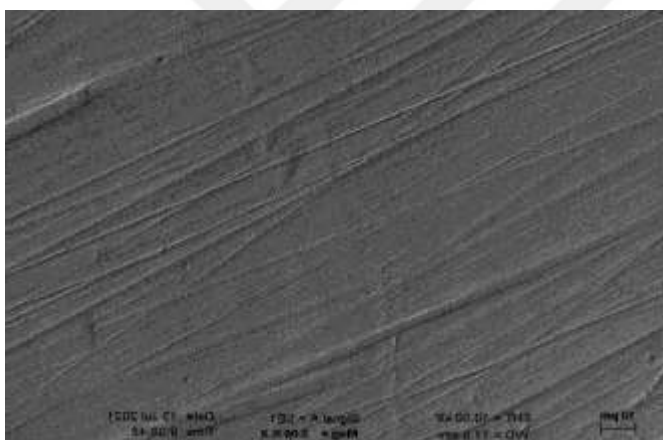


Figure 4.19. SEM (2000X) image of treated Zenostar with HF acid

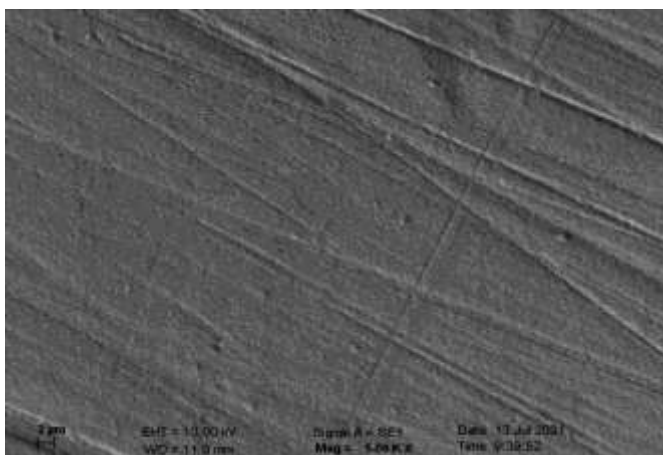


Figure 4.20. SEM (5000X) image of treated Zenostar with HF acid

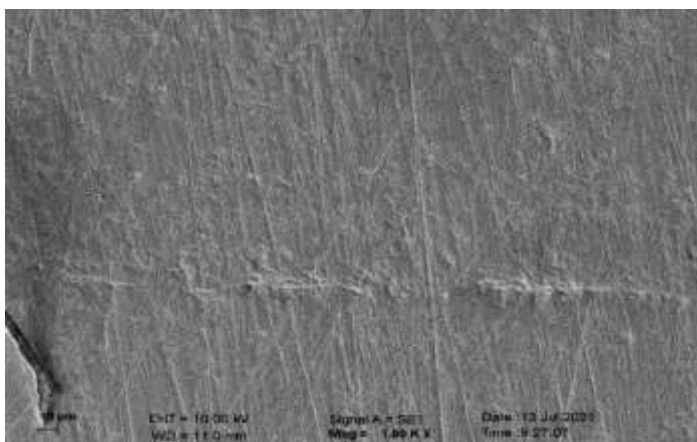


Figure 4.21. SEM (1000X) image of treated Ceramill with HF acid

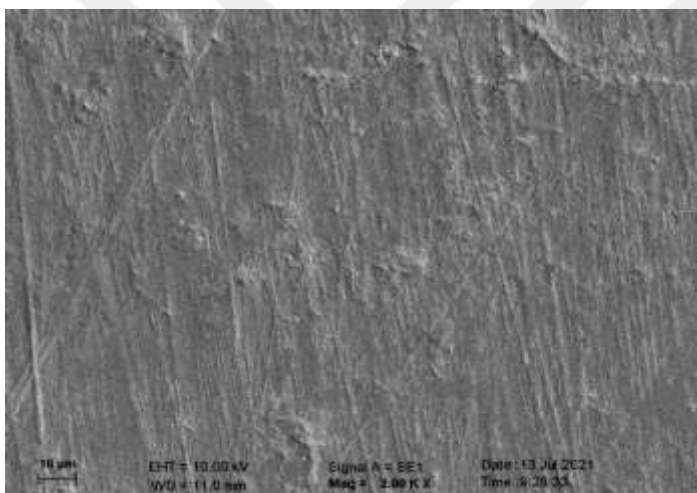


Figure 4.22. SEM (2000X) image of treated Ceramill with HF acid

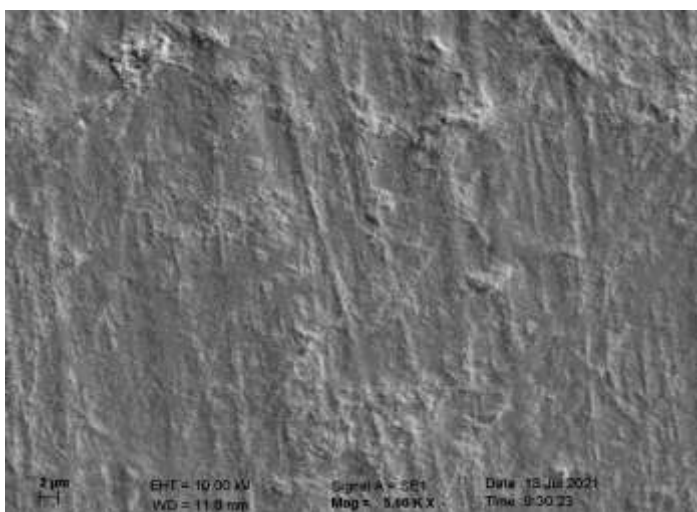


Figure 4.23. SEM (5000X) image of treated Ceramill with HF acid

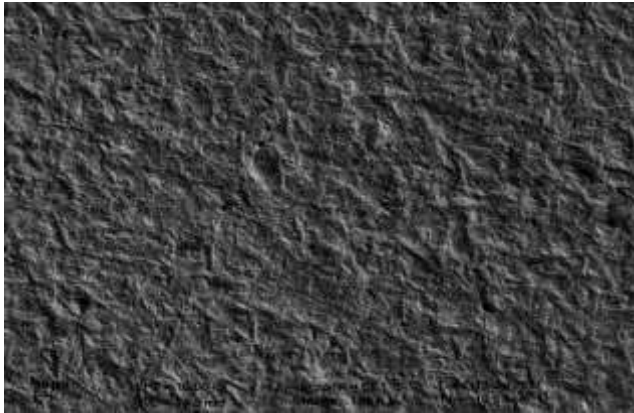


Figure 4.24. SEM (1000X) image of treated Zenostar with alumina particle 50 μm

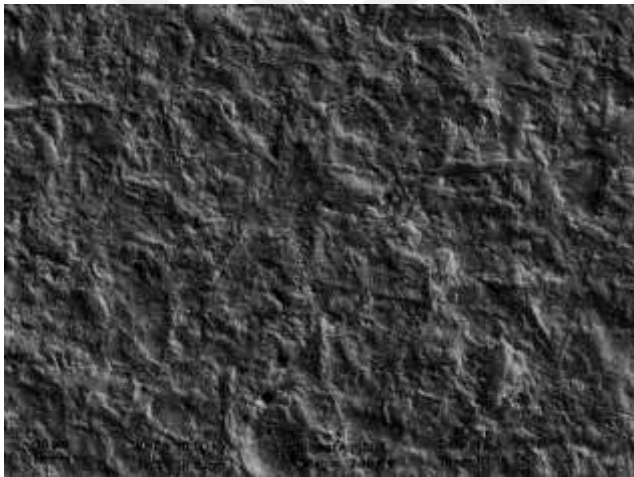


Figure 4.25. SEM (2000X) image of treated Zenostar with alumina particle 50 μm

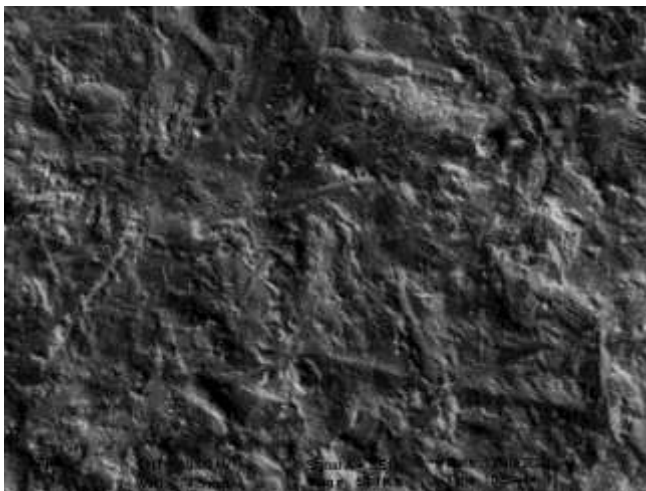


Figure 4.26. SEM (5000X) image of treated Zenostar with alumina particle 50 μm

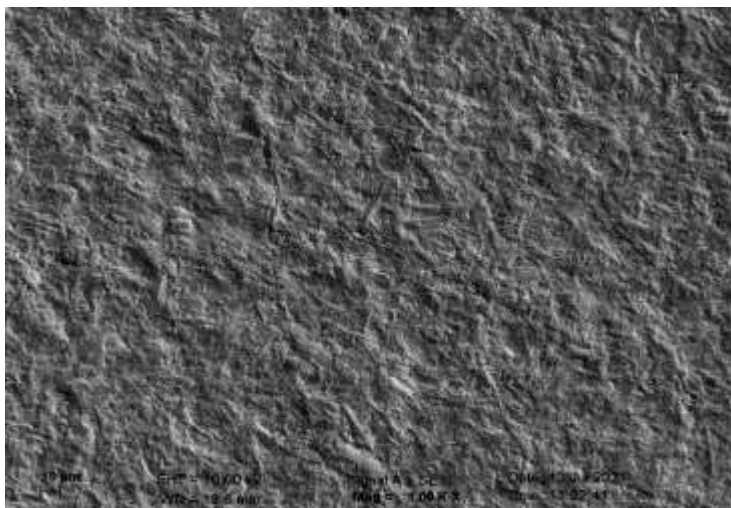


Figure 4.27. SEM (1000X) image of treated Ceramill with Alumina particle 50 μm

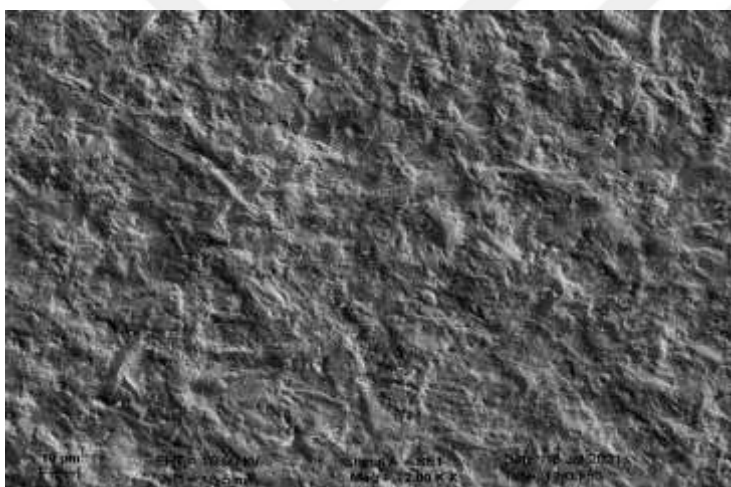


Figure 4.28. SEM (2000X) image of treated Ceramill with Alumina particle 50 μm

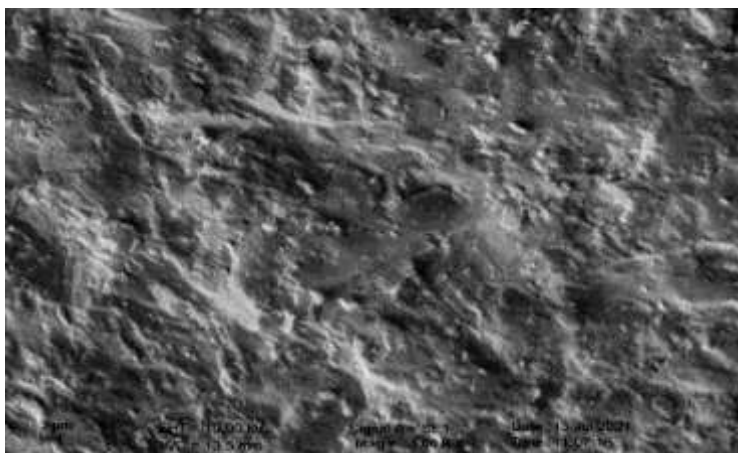


Figure 4.29. SEM (5000X) image of treated Ceramill with Alumina particle 50 μm

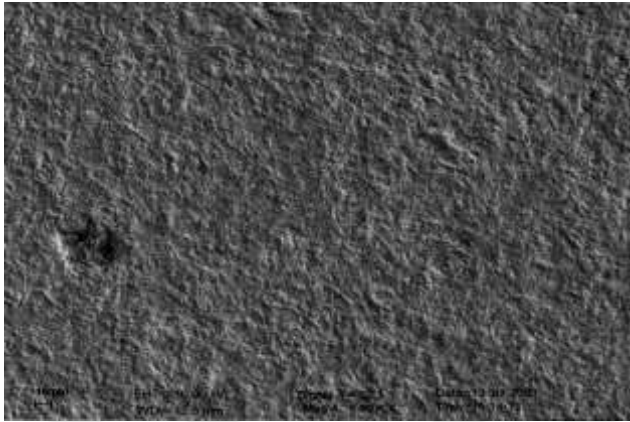


Figure 4.30. SEM (1000X) image of treated Zenostar with Cojet particle 30 μm

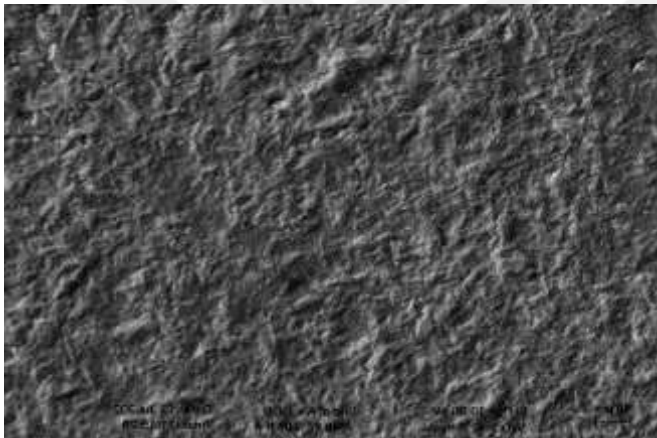


Figure 4.31. SEM (2000X) image of treated Zenostar with Cojet particle 30 μm

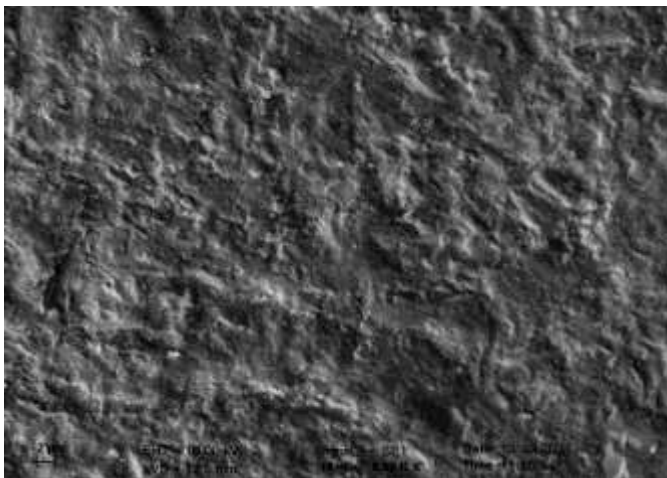


Figure 4.32. SEM (5000X) image of treated Zenostar with Cojet particle 30 μm

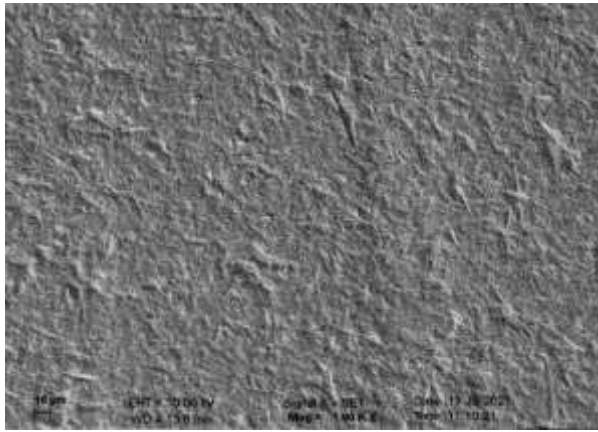


Figure 4.33. SEM (1000X) image of treated Ceramill with Cojet particle 30 μm

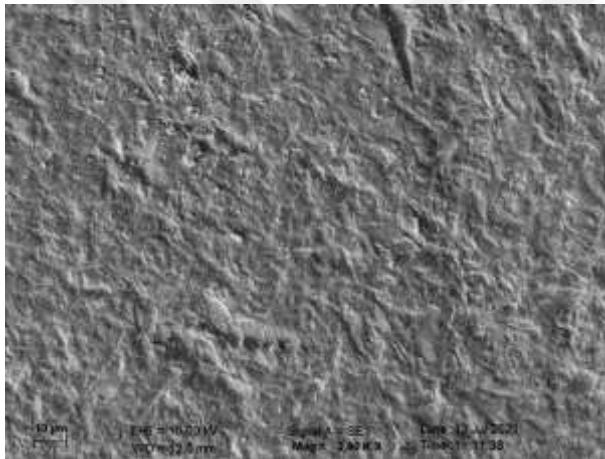


Figure 4.34. SEM (2000X) image of treated Ceramill with Cojet particle 30 μm

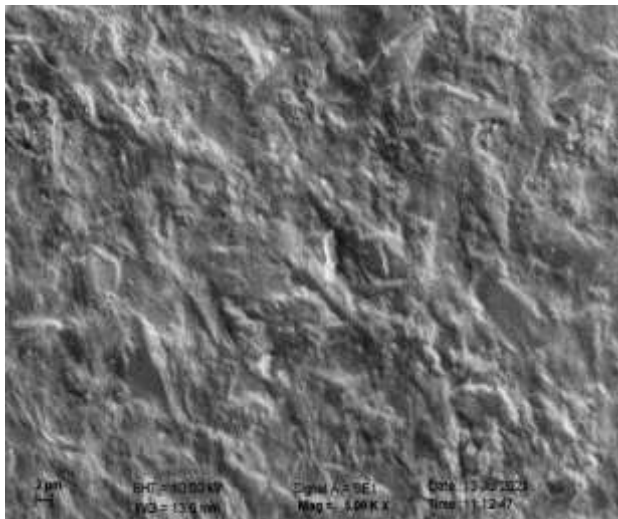


Figure 4.35. SEM (5000X) image of treated Ceramill with Cojet particle 30 μm

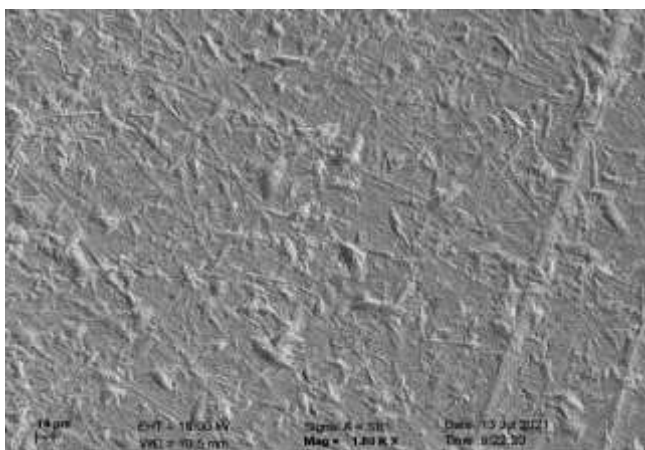


Figure 4.36. SEM (1000X) image of treated Zenostar with Siljet particle 30 μm

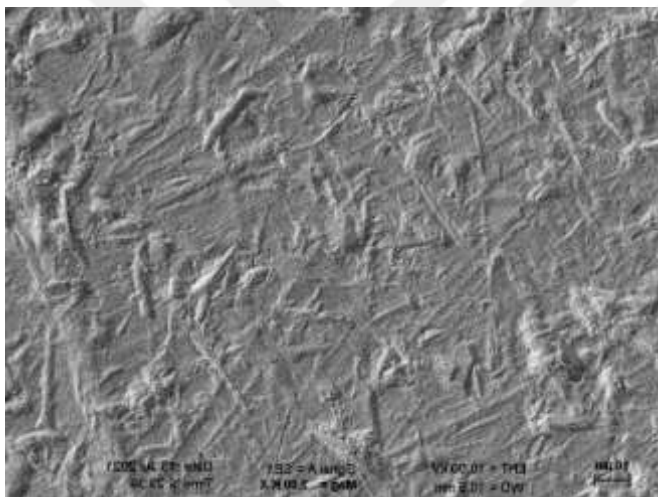


Figure 4.37. SEM (2000X) image of treated Zenostar with Siljet particle 30 μm

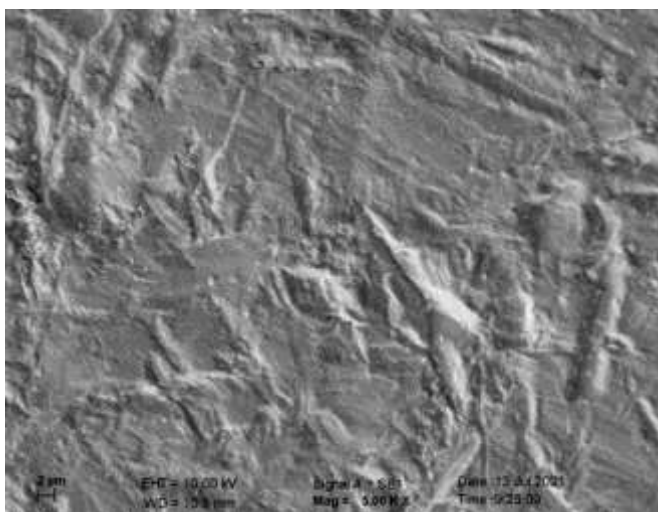


Figure 4.38. SEM (5000X) image of treated Zenostar with Siljet particle 30 μm

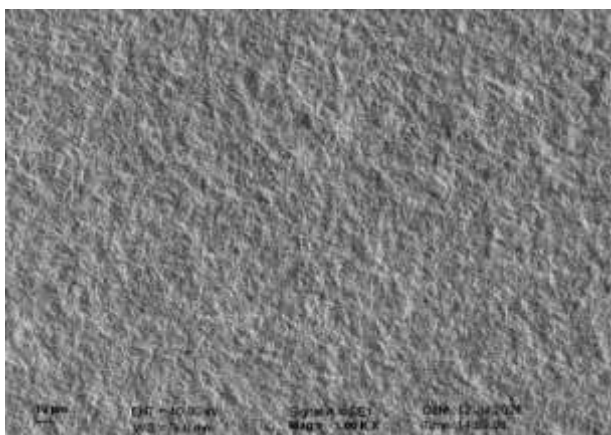


Figure 4.39. SEM (1000X) image of treated Ceramill with Siljet particle 30 μm

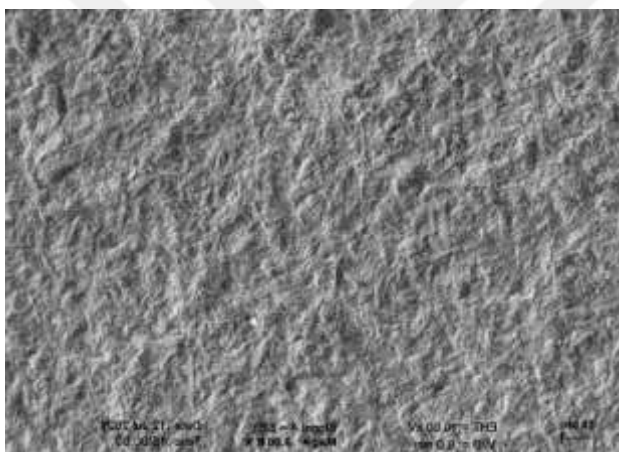


Figure 4.40. SEM (2000X) image of treated Ceramill with Siljet particle 30 μm

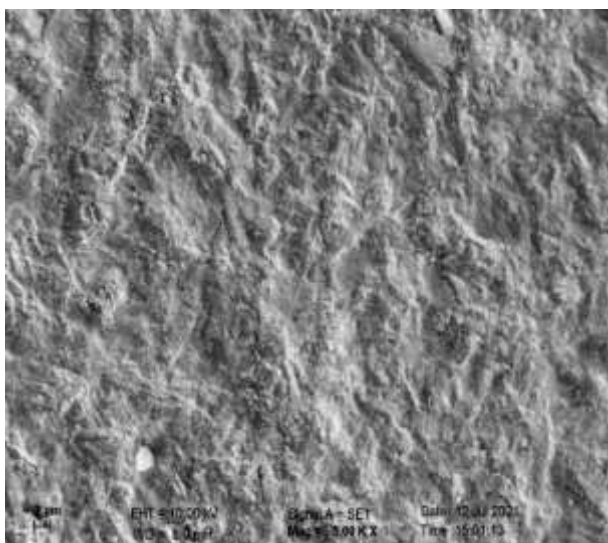


Figure 4.41. SEM (5000X) image of treated Ceramill with Siljet particle 30 μm

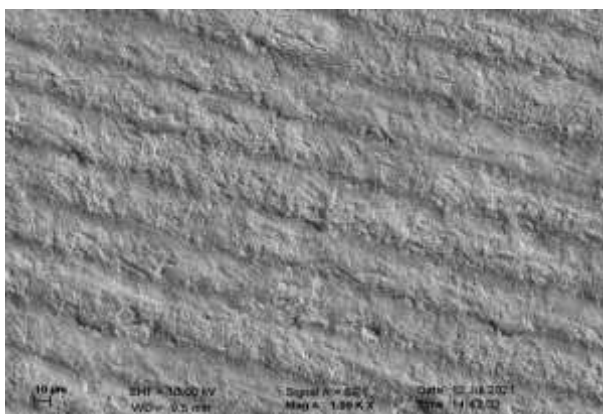


Figure 4.42. SEM (1000X) image of treated Zenostar with fiber laser

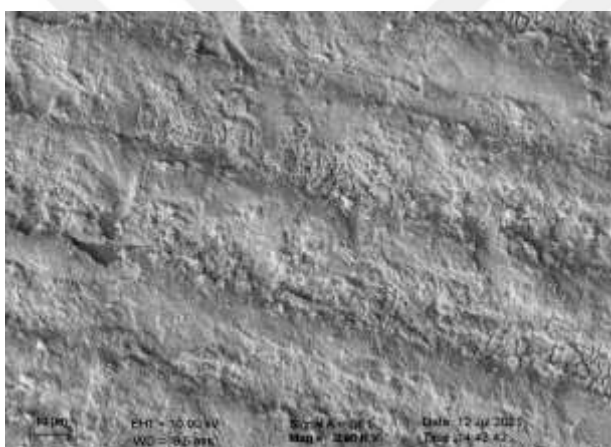


Figure 4.43. SEM (2000X) image of treated Zenostar with fiber laser

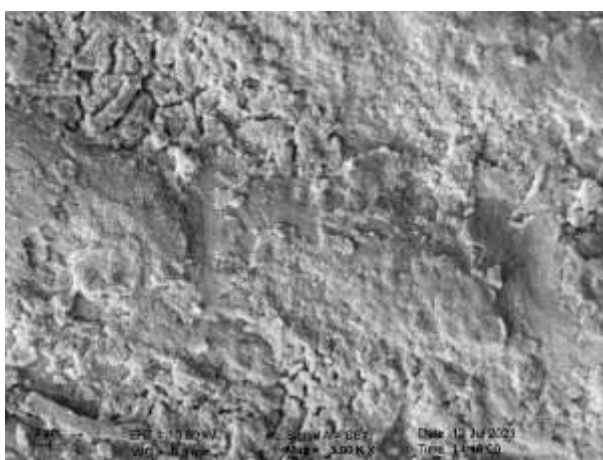


Figure 4.44. SEM (5000X) image of treated Zenostar with fiber laser

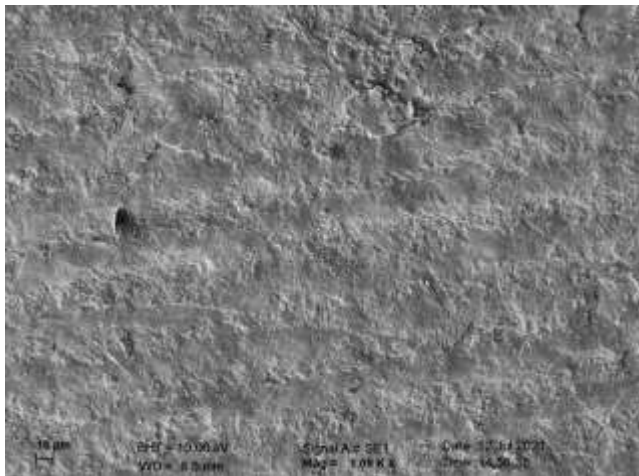


Figure 4.45. SEM (1000X) image of treated Ceramill with fiber laser

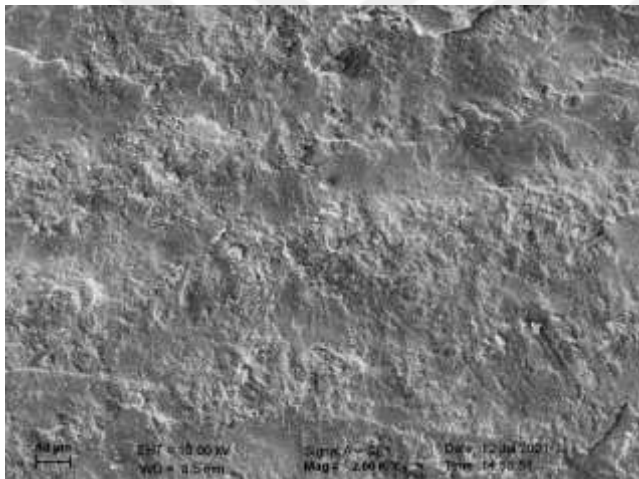


Figure 4.46. SEM (2000X) image of treated Ceramill with fiber laser

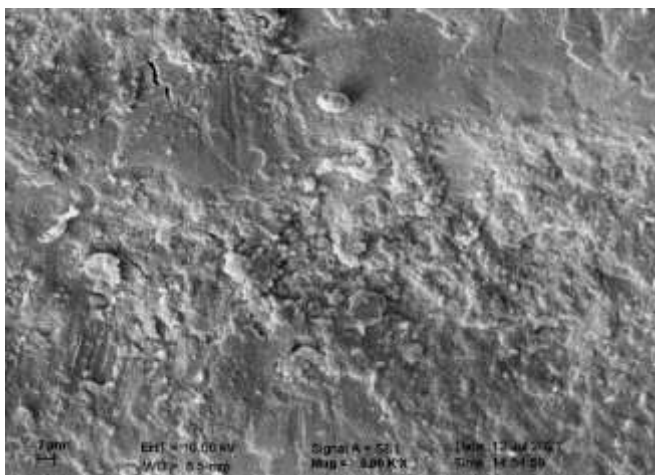


Figure 4.47. SEM (5000X) image of treated Ceramill with fiber laser

5 DISCUSSION

Zirconia is one of the tooth-colored materials with a variety of advantages, including excellent esthetic qualities, improved mechanical and biological behavior, and the ability to be used in a variety of clinical circumstances. Additionally, it is less costly as compared to precious alloys, which has led to its wider use in restorative dental treatments¹⁷⁴. Their five-year survival rates for tooth-supported prostheses range from 93.5 percent to 97.8 percent, while their survival rates for implant-supported prostheses range from 97.1 percent to 100 percent^{175,176,177}. Because of the opaque look of zirconia, the esthetic implications are negatively influenced.

The initial generation of 3Y-TZPs contained 0.25 percent sintering aid Al_2O_3 . and displayed flexural strengths greater than 1 GPa in flexion. Despite this, the zirconia exhibited increased opacity because the non-cubic zirconia phases have inherent birefringence, which, as a consequence, the light was scattered across grain boundaries and pores. as well as from additive inclusions. They were primarily used as framework materials in the fabrication of porcelain-veneered dental restorations. Long-term clinical failure rates were higher for ceramic-core implants than for metal-core implants^{178,179}, largely due to chipping but also due to interfacial delamination in rare cases, Due to its more natural coloring, higher resistance to wear and corrosion, and superior biocompatibility and soft tissue integration, as well as a decreased affinity for bacterial plaque accumulation and peri-implantitis, 3Y-TZP has also been recommended as a titanium implant and abutment alternative. Nonetheless, numerous clinical investigations proved that zirconia implants fracture at a greater rate than titanium implants, when they are placed too quickly^{180,181}, As a result, mechanical integrity enhancement becomes the major objective.

Chipping the veneering ceramic with the occurrence of layered materials was offered. Porcelain chipping, on the other hand, has been described as one of the most often encountered technical issues with veneered zirconia crowns, with annual rates ranging from 0 to 54 percent. This phenomenon takes place as an adhesive failure because of the weak link

between the core and the veneering porcelain, or as a cohesive failure due to a fracture within the veneering porcelain body ^{182,183}.

Layering via CAD/CAM technology ¹⁸³ or modifying the veneering technique ¹⁸⁴ did not completely solve this complex problem ¹⁸⁶. Chipping is most common in the molar area and typically necessitates the removal of the current repair for both aesthetic and functional reasons ¹⁸⁷. Poor framework designs, insufficient porcelain to zirconia bond strength, lower thermal conductivity and elastic modulus of zirconia when compared to porcelain veneer ^{188,189}, and some preparation faults are among some of the contributing factors ⁷⁷. For both teeth- and implant-supported prostheses, zirconia veneering ceramic chipping has been identified as the most common complexity ^{177,190}. Another disadvantage is that this form of prosthesis necessitates substantial tooth reduction, and the diminished transparency of the core detracts from the prosthesis's otherwise appealing appearance ^{191,192}.

To reduce the risk of porcelain chipping in an all-ceramic prosthesis, the following alternatives have been proposed. A low-melting ceramic is used as an adhesive to adhere to the lithium-disilicate veneer, and the cooling procedure is changed throughout the application of the veneering material ¹⁸⁷. A fully contoured restoration is then created using monolithic lithium-silicate or zirconia material ¹⁹³, which was previously the optional material used to restore single anterior and posterior restorations ¹⁹⁴. When compared to typical zirconia restorations, which need occlusal and axial tooth reductions of 1.5-2 mm ¹⁹⁵, monolithic zirconia restorations eliminate the possibility of chipping of the veneering material, providing a minimum as 0.5 mm for occlusal and axial reduction of tooth ¹⁹⁵. When compared to veneered zirconia infrastructure and glass ceramics ¹⁹⁶, the fracture resistance of monolithic zirconia prosthesis is significantly higher. To achieve the best mechanical qualities, A thickness of at least 0.5 mm is requested ¹⁹⁵. Manufacturing of the following generation of 3Y-TZPs was refined to produce better monolithic zirconia with satisfactory translucency. This was accomplished principally by dramatically lowering the alumina additive content and removing porosity via sintering at a higher temperature during the fabrication process. Translucent saw a modest improvement as a result of this ¹⁹⁷. This second-generation zirconia, while suited for monolithic posterior prostheses, was still unacceptably aesthetically

unappealing if utilized as monoliths in the anterior area, however, it did open the way for further advancement ¹⁹⁷.

The decision to introduce some transparent phase into the final product was the next phase in developing monolithic zirconia to lower the opacity of the material. This was accomplished via utilizing a higher yttria concentration to generate partially stabilized zirconia at 4 mol percent (4Y-PSZ) or 5 mol percent (5Y-PSZ), which included higher concentrations of nonbirefringent cubic phase than previously reported. Due to the fact that There are no stress-induced changes in cubic zirconia ¹⁹⁸, this resulted in a substantial elevate in transparency, but a diminishing in strength and toughness.

The majority of translucent 5Y-PSZ materials were recommended for widespread use as anterior crowns and fixed dental prostheses (FDPs). An up-to-date study, they found that the anterior zone saw a failure rate of more than 2 percent over a 5-year period¹⁹⁹. The use of restorations with a minimum of intervention such as dental veneers, inlays, and onlays, among other things, has yet to be fully evaluated. As a result, appropriate attention must be given while using this type of zirconia restorative ceramic ¹⁹⁹. Grain sizes of monolithic zirconia from the first and second generations have traditionally been in the range of 0.5 to 1µm, involving the full visible light wavelength spectrum and, in conjunction with t phase birefringence, responsible for the characteristic opacity ¹⁹⁹. The increased translucency in third-generation zirconia is attributed to larger grain size (1.5µm) and a higher proportion of cubic phase than in the previous generations¹⁹⁹. In our study, we used two types of highly translucent monolithic zirconia (third generation), highly translucent non colored Zenostar Zr translucent (Wieland Dental; Pforzheim, Germany), which contained >4.5-6.0 percent Y₂O₃ and super highly Ceramill zolid fx pre shade (Amann Girrbach AG, Koblach, Austria), which contained 8,5-9.5 percent Y₂O₃.

As compared to the traditional zirconia cores and glass ceramics, a monolithic transparent zirconia prosthesis generates reduced wear on the antagonist's tooth ^{200,201}, regardless of whether the prosthesis is polished or glazed ²⁰². After testing the prosthesis, it is recommended that you polish it carefully to keep the surface roughness and phase transformation as low as possible ²⁰³. The increased translucency of monolithic translucent

zirconia restorations, when compared to traditional zirconia infrastructures, provides improved cosmetic effects, as demonstrated by the following studies. Its aesthetic properties are improved by bringing in different colors, employing colored liquids to stain the core of the monolithic zirconia prosthesis, and coloring the occlusal surface¹⁸⁷, among other methods of improving its appearance. Furthermore, because they do not require the use of ceramic veneers, they are expected to be more affordable restorations²⁰⁴. Preliminary findings indicate that complete arch and single-unit tooth- and implant-supported prostheses, as well as implant-supported prostheses, have high survival rates^{55,205,206}. The findings of Carames et al²⁰⁵, a two-year study of 14 patients having implant-supported full-arch prosthesis, revealed that they had a 96 percent survival rate. Another study, Venezia et al²⁰⁶, and another, Moscovitch⁵⁵, both demonstrated 100 percent survival over three-year and 68-month follow-up periods, respectively.

It was demonstrated on milling pre-sintered blanks that the soft machining technique became the most widely utilized production process for 3Y-TZP. Green is a term used to describe the status of the pre-sintered blanks, which are created by compacting ZrO₂ powders with a binder and pressing them together using a cold, isostatic pressing method²⁰⁷. Fixed dental prostheses are created by scanning the supporting abutments or the wax patterns of the crowns in the die and fixing them in place. Following the scanning process, modern computer software is utilized to create a virtual, expanded framework. Then, using a computer-aided design milling process, a framework for the prosthesis is manufactured out of the blank with increased and precisely controlled proportions²⁰⁷. Software flaws and the accuracy of milling machines can both have an impact on the fit of CAD/CAM dental restorations. Most clinicians believe that the marginal gap must not exceed 100 microns²⁰⁸. Regardless of the various benefits that high crystalline ceramics provide, they have a considerable disadvantage when it comes to cementation.

Glass-ceramics, on the other hand, demonstrate a well-established approach for cementation that incorporates HF acid conditioning or aluminum oxide blasting followed by the employing of a silane agent²⁰⁹. Regarding hydrofluoric acid's efficiency on glass-based ceramics, it cannot be utilized on alumina or zirconia reinforced ceramics because of the

lower glass content, which is essential for the formation of surface porosity; thus, they are categorized as an acid-resistant material ²¹⁰. The duration of service provided by an indirect restoration is highly correlated with the preservation of goodness in the restoration. It is essential for keeping the cement's integrity at the margin (prevention of microleakage) ¹⁶⁰ and to improve the fracture and fatigue resistance when using high retention ^{113,160}. According to the findings of three-year research of zirconia single crowns, 7 % of all Y-TZP crowns put in the posterior portion of the mouth debonded ²¹¹. This problem may suggest that the problem of generating a long-lasting bonding among the Y-TZP and tooth structure is yet unsolved, making adhesive dentistry a difficult challenge. Even though the loss of retention with Y-TZP restorations has never been a topic of discussion because it has never been recorded, efforts have been made to create methods of achieving a long-lasting link among Y-TZP crowns and resin cement ²¹².

According to evidence from a literature review, following five years of operation, all-ceramic systems, with the exception of zirconia, experience a 2.8 % losing of retention rate ²¹³, but a ceramic fused to the metal system has a 0.7 % losing of retention rate after 10 years of service ²¹⁴. As a consequence, the influence of bond strength between the substrate and ceramic makes a substantial contribution to prolonging the longevity of restorative treatments, as well as the prevention of microleakage ²¹⁵. Commercially available dental materials for the cementation of ceramic restorations include a wide range of options for example the zinc phosphate cement, both conventional and resin-modified glass ionomer kinds of cement, resin cement, and self-adhesive resin cement are among the materials used in this process ²¹⁶. Traditional cementation procedures do not give acceptable binding strength for several clinical applications²¹⁶. Resin cement provides various advantages over other types of materials when compared to other types of materials since it has lower solubility, greater resistance, and improved esthetic characteristics ²¹⁶. Furthermore, the adhesive interface between the resin cement and the ceramic may improve the restoration's resistance to occlusal loads ²¹⁶, hence increasing its overall durability.

Eleven different kinds of cement were tested for their shear bond strength. to a Y-TZP ceramic was measured and found to be ²¹⁶. The findings revealed that zinc phosphate,

standard glass ionomer cement, and resin-modified glass ionomer cement were all unable to make a long-lasting binding to Y-TZP ²¹⁶. According to the findings of another investigation, glass-ionomer cement, and a conventional Bis-GMA-based resin composite are much less effective at bonding Y-TZP ceramics than traditional Bis-GMA-based resin composites, especially during thermal aging ²¹⁷. For these reasons we use self-adhesive cement for our study.

It is quite common to utilize nominal bond strength tests, including macro-shear, micro-shear, macro-tensile, and micro-tensile bond strength tests, to evaluate the bond strength of a material by testing its adhesion quality, to determine the bond strength by dividing the highest force by the bonding area. Because there is currently no internationally recognized standard for the experimental research of the bond between composite cement and zirconia, according to the investigators, there is a broad range of tests used by researchers, as well as difficulties in going to compare information obtained under different test conditions. It was found that the macro-shear bond test was the most often utilized method for assessing the adhesion capacity between composite cement and zirconia ¹⁵⁵, Regardless of the fact that there is no consensus on which tests should be used. This is most likely due to the fact that both the sample preparation and the test itself are quite straightforward ²¹⁸. The macro-tensile bond test is also less commonly using it as a shear bond test, which is likely due to the difficulties in installing the samples in the testing machine, as well as the negative impact that incorrect orientation may have on stress distribution and, subsequently, on the reliability of the results, among other reasons ²¹⁹. For both macro-shear and macro-tensile specimens, the stress distribution at the bonded contact is nonuniform, as established by finite element analysis ²²⁰. It was Van Noort et al. ²²⁰ that discovered the stress distribution and bonded interface in opposition to the elastic modulus of bonded materials, which is influenced by factors such as the model, the point of load application, and the form of the sample, all of which effect the stress distribution. These conditions can occur in a discrepancy in stress distribution at the bonded surface, which may improve the chances of the substrate breaking cohesively as a consequence of the discrepancy in stress distribution ²²⁰.

Due to these circumstances, there may be a discrepancy in the stress distribution at the bonded surface, which may increase the risk of the substrate failing cohesively as a result of the difference in stress distribution ²²⁰. When compared to bond strength, cohesive failure of the specimen along either side of the interface provides information on the mechanical characteristics of the checked material on each side of the interface ²²¹. Fortunately, along with its complexity, the microtensile adhesion test was successful in overcoming concerns about cohesive failure in the substrate ²²². By decreasing the dimension of the specimen, it is possible to produce heightened stress distributions, and also less cohesive failures, and a lowering in defect density. Due to the increased likelihood of adhesive failure in these trials, it is believed that they will be able to get a more precise explanation of the real adhesive bond strength in the field of application ²¹⁸.

When the bond strength is lower than 5 MPa, measurements might be challenging to interpret by micro-tensile bond test, it is technically rigorous, labor-intensive ²¹⁸. Moreover, unlike the macro-shear and macro-tensile bond tests, the micro-shear bond test is affected by unequal stress distributions and the bond interface, and as a consequence, the data gained may not be indicative of the correct bond strength ²²³. It is focused on deciding the quantity of energy resulting in the release of controlled fracture progression in conjunction with the bonded interface in specimens set in a 4-point bending configuration that the strain energy release rate test is performed on ²²⁴. Compared to the nominal bond strength test, which was traditionally utilized, it is believed that this test gives a more precise approximation of real bond strength than the conventional bond strength test ²²⁴. A few researchers have examined the bond strength as a function of the strain energy release rate, regardless of the fact that more investigation into his test methodologies is required.

New dental restorative materials' long-term performance is decided by their ability to withstand the harsh conditions of the oral environment²²⁵. Even if durability and effectiveness are features that should be offered by any restorations in an ideal world, these features are still goals that must be met. The circumstances in which patients are placed are unexpected, and so are the materials used to restore their teeth and restore their smiles. Materials' longevity may be influenced by uncontrollable components such as those produced

by mastication and other forces, occlusal habits, dietary considerations, humidity, and temperature variations ²²⁶. When predicting the longevity of dental materials, in-vitro simulations can be used to examine the mechanical and structural decay characteristics of the materials as they age in the clinical setting ²²⁶. It is possible to replicate the oral cavity circumstances to a certain extent through all the aging of teeth and/or restorations, even if laboratory assessments and vitro research cannot completely recreate conditions in the oral cavity, such as those found in the clinical setting ²²⁶, moisture content, and stresses inflicted on both natural tooth structure and dental implants. Thus, it appears as though the outcomes of experimental research are, to the greatest extent feasible, comparable to the outcomes achieved in clinical settings involving complicated occurrences in the oral cavity ²²⁷.

Thermal cycling was among the most widely used process in laboratory studies, and it is Additionally, it is extensively accepted in international research. Thermal cycling is a few of the technologies that can replicate dynamic stresses that are now commercially available, and it is also one of the most commonly used processes in international literature that is currently available. The materials used in dental restorations, on the other hand, are vulnerable to long-term and irreversible alterations in the oral environment as a result of temperature and pH fluctuations ²²⁸. The process of thermal cycling mimics the passage of hot and cold materials into the oral cavity and illustrates the connection between the linear coefficient of thermal expansion among the tooth and dental material ²²⁹.

Thermal cycling has the potential to provide a two-fold influence on the body's artificial aging process. Initially, the deterioration of collagen and the elimination of poorly polymerized resin oligomers may be accelerated by using hot water, subsequently, the greater thermal contraction/expansion coefficient of the restorative dental material may be a factor in this, as compared to that of tooth tissue, repeated contraction/expansion stresses are developed at the tooth-biomaterial interface as a result of the thermal contraction/expansion coefficient of the restorative dental material (as compared to that of tooth tissue ²³⁰. Pathogenic fluids can enter and leave a gap caused by cracks propagating across bonded interfaces, which is termed percolation. Once a crack has been developed, it may be difficult to stop it from spreading ²³⁰.

Histologically, the most difficult problem was determining which maximum values should be used in the oral cavity after replicating the normal aging process of biomaterials in the oral cavity. Temperature extremes cause overstressing of the material, while a temperature range that is too low causes under-stressing of the material, ultimately caused in the production of clinically defective materials and introducing them to the dental field ²³¹. It is suggested in ISO 11405 guidelines that a temperature range of 5–55 degrees Celsius should be maintained (International Standards Organization, 1994)^{232,233}. The amount of time that a specimen of test material is submerged in a bath at a specific temperature is known as the dwell time ²³³. If you eat or drink something hot or cold, you will experience a latency period, which is the time it takes for your oral capacity to recover to its normal body temperature. The choosing of dwell times in exploratory studies seems to be random, and no influence of dwell time on results has been proven in any of the studies to which this has been applied ^{226, 230 ,234}.

Amaral and colleagues stated in their study that individuals will not be able to resist extended close communication with incredibly hot or extremely cold substances on a critical tooth ²³⁵. Many studies have proposed that shorter dwell periods (10 s or 15 s) be used, since this may more accurately simulate the abrupt temperature fluctuations that occur within the mouth cavity ²³⁶. The experimental investigation conducted by Doerr and coworkers even came to the conclusion that a reduced dwell time of 5s would be more acceptable ²³⁷. Interestingly, Schmid-Schwab et al.²³⁸ reported that the maximum in vivo exposure duration of a tooth to either the highest hot or cold temperatures may be expected to be between 2 and 5 seconds, in which the tooth recovers to its normal oral temperature. The most difficult problem was figuring out just how many cycles make up a year of oral cavity physiological aging. It's been a problem for years now. It is not known how many thermal cycles per unit time happen in vivo, as no research has been carried out to this point. There has been no empirical evidence to support the number of cycles in a thermal cycling regimen that has been proposed in the past, it's possible that numerous researchers have arbitrarily chosen this factor, which would explain the large disparity in their results. Since the number of cycles

can be adjusted arbitrarily, it can be hard to compare earlier published data to the current results ²³⁵.

According to ISO 1994 ²³², a protocol consisting of 500 cycles was sufficient for designed to simulate the aging of biomaterials in 1994, nevertheless, many studies have indicated that 500 cycles are a reducing number when trying to represent an acceptable aging time and also that the number of cycles must be improved considerably ^{233,235}. It has been estimated by Michailesco et al. that each meal contains 30 thermocyclers, which equates to around 33,000 cycles per year if three meals are consumed daily (assuming three meals per day) ²³⁹. Those such as Stewardson et al., for instance, claimed that the 500 cycles represented simply the number of cycles projected to occur in less than 2 months in the mouth following a single injection ²⁴⁰. Bayne hypothesized that the temperature of snacks and drinks, as well as the amount ingested and the frequency with which they are consumed, differed amongst persons, according to his research ²⁴¹. If a person drinks 100 ounces of water per day, the likelihood of experiencing cold cycling over the duration of a year is roughly 50,000. If we are worried the about 10-year clinical service of repair, it is expected that thermal cycling should be maintained for 500,000 cycles.

It was hypothesized by Gale and Darvell that approximately 10,000 heat cycles would correspond to one year of clinical treatment ²³³. This prediction is based on the assumption that such cycles may occur somewhere between 20 and 50 times every day, and it is acknowledged by a large number of authors like De Munck et al., 2005 ²³⁰, Amaral et al., 2007 ²³⁵, Ulker et al., 2010 ²⁴², Xie et al., 2010 ²⁴³; Bektas et al., 2012 ²⁴⁴. It is determined by the ISO standard for the metal–resin adhesion test that the number of the cycle (5000) must be completed ²⁴⁵. For our study, we utilized that the number of cycles 5000.

Three experiments by Keul et al. ²⁴⁶, Seto et al. ²⁴⁷, and Eun ²⁴⁸. The authors analyze the shear bond strength between self-adhesive resin cement and zirconia prior to and the following thermocycling in these tests. Two investigations, one by Keul et al. ²⁴⁶ and the other by Seto et al ²⁴⁷, reveal that the shear bond strength decreases after thermocycling when compared to when it is not. It has been confirmed that thermal cycling has been shown to have a massive effect on cement's ability to bond. Lee et al ²⁴⁸ conducted a study in which

they examined the shear bond strength of six self-adhesive resins on zirconia before and after 5000 cycles of heating and cooling ²⁴⁸. Compared to other cement, PermaCem 2.0 exhibited superior shear bond strength before thermocycling. When compared to other types of cement, the Clearfill SA luting displayed the strongest shear bond strength after being experienced to thermocycling. Except for Clearfill SA Luting cement, the shear bond strength of the majority of self-adhesive resin cement decreases during thermocycling. Celik et al.²⁴⁵ investigated different aging procedures such as thermocycling, water storage, and mechanical fatigue, and found that thermocycling appears to be the most effective aging method for assessing the quality of the connection between zirconia and composite materials, after thermocycling, the researchers discovered a significant decline in bond strength across all of the aging procedures they utilized in their research. As a result, we have chosen thermocycling as the aging method for our investigation in this regard.

When it comes to ZrO₂ ceramics, surface roughness is critical for achieving micromechanical retention. Consequently, the scientists study the efficiency of various surface modifications on post-sintered ZrO₂ to enhance the bonding strength between the ZrO₂ and veneering porcelain or resin cement to improve the bonding strength between the ZrO₂ and veneering porcelain or resin cement ²⁴⁹. However, some investigations have shown that post-sintered surface modification enhances the hazard of fracture and damage ZrO₂ by elevating the concentration of the monoclinic phase ²⁴⁹.

Not only is appropriate polymerization required for mechanical qualities, but it is also required for the biocompatibility of resin-based composites²⁵⁰. The amount of light that is exposed to dual-cured resin cement has been shown to affect the polymerization features of the cement²⁵⁰. As a result, the translucency of restorative materials can have an influence on the total of light transmitted as well as the efficiency of polymerization in dual-cured resin cement. To overcome the shortcomings of ordinary resin cement, which was time-consuming, technical skill-dependent, and hard to apply, the researchers developed self-adhesive resin cement which can be polymerized in a dual-curing system ²⁵¹.

Because of the opacity of zirconia, which interferes with the transmission of halogen light ²⁵², dual-cure resin cement is the cement of choice for zirconia cementation over other

forms of cement, such as photoactivated or chemically activated cement ²⁵². After reviewing the bonding of zirconia, Thammajaruk et al,²⁵³ discovered a total of 1,632 test results, of which 1,359 groups utilized on light or dual-cured resin cement and 261 groups used self-cured resin cement, the curing process in the other 12 groups was not known ²⁵³. It was because of this that we decided to conduct our investigation using dual-cure self-adhesive resin cement. As an antagonist, composite cement was employed in 781 (47.9%) of the testing results, while cemented composite resin and zirconia have been used in 679 (41.6%) and 172 (10.5%) of the findings, correspondingly. Round interface specimens were employed in 1,455 studies compared to 177 square interface specimens for both tensile and shear bond evaluation in micro and macro research, respectively ²⁵³. We used round interface specimens for zirconia and composite in our experiment.

Storage conditions for bond strength testing included distilled water, silane, 0.05 percent saturated solution of thymol, 0.5 percent chloramine-T, 2 percent gluteraldehyde, and 10% formalin solutions, all of which were investigated as the storage medium for the experiments ²⁵⁴. We used distilled water as a storage medium before the test in our investigation.

It was discovered in all studies related to the repairing process that the thickness of the composite varied between 2 and 5 mm. Additionally, it was discovered that the crosshead speed of the testing machine is 0.5 or 1mm/s, demonstrating the most commonly used values (46 and 41 percent, respectively), which is in agreement with a recent survey²⁵⁵. The loading speed that is used during the process of applying the test methods has an impact on the bond strength results. It has been demonstrated that loading speeds between 0.5 and 1 mm/min do not affect the findings, but that loading speeds more than 1 mm/min result in erroneous results ²⁵⁶. The composite height in our investigation was 3mm, and the crosshead speed was one millimeter per second.

Because of the extreme hardness and crystallinity of zirconia ¹⁵, No matter how they're treated, zirconia cores are virtually unaffected. Due to the inability of zirconia to be etched, the advantage of greater adhesion achieved via the use of resin cement may be lost¹⁵.

Nonetheless, under the right conditions, resin cement provides a stronger bond for zirconia restorations while also providing superior mechanical qualities than standard cement ¹⁵.

Hydrofluoric acid is considered to be inorganic acid formed by the reaction of hydrogen fluoride with oxygen. In the industrial setting, HF acid is utilized before electroplating, to cleanse metal surfaces and dissolve the silica from silica-based compounds, and etch silicon wafers in electronic semiconductor materials, among other things ²⁵⁷. For example, in the dentist's office and dental lab, HF concentrations ranging from 4 % to 10 % are often used in practice. According to the current consensus, these doses are safe for use in dental applications ²⁵⁸. Glass is dissolved chemically by HF acid, which does so by interacting with silicon oxide, which is the primary ingredient of the material. Porcelain that is utilized in dentistry is made of two phases: the glassy phase and the crystal phase. Surface roughness can be produced by the removal of the glassy phase and the formation of the crystalline phase ^{259,260}. An improved crystallinity of the zirconia core combined with a glassy phase below one percent and an extremely low level of silicon dioxide makes it nearly indestructible by HF acid treatment, with no improvement in bond strength ^{261,262}. It was not statistically significant that the modest increase in the binding strength of zirconia with resin cement occurred after the application of HF ²⁶³. In their study, Smielak and Klimek²⁶⁴ found that using 40 % HF for 15 minutes dramatically enhanced the roughness of a zirconia surface, but applying 5 % and 9.5 % HF for the same amount of time had no effect on the surface ²⁶⁴.

This was demonstrated by SEM images of the untreated zirconia ceramic surface after milling of the zirconia block, it exhibited a sequence of linear cuts and numerous debris covering practically the whole surface with minor roughness, as well as shallower porosities in some areas. (Figure 4.11-4.16), which can be attributed to the low bond strength observed in control groups. Due to the limited number of articles that have been published on the long application period of low concentration HF, we conducted an investigation in which the surface of zirconia was analysed after the application of 9.5 % HF for 1 hour after that the bonding strength between zirconia and resin cement was determined. A statistically insignificant variation in shear bond strength was discovered in shear bond strength among the monolithic zirconia and the corresponding control groups. Because of the high viscosity

of the self-adhesive resin cement, it is unlikely that it will penetrate the nano porosity of the etched zirconia surface, as demonstrated by HF acid ^{265,266}. The SEM picture of HF acid (Figure 4.17-4.22) explaining the decreased bond strength, on the other hand reveals no differences from images from the control.

When they tested the shear bond strength of two resin cement to 112 zirconia specimens over a period of one or two hours, H Lee and C Hee Lee²⁶⁷ confirmed our results, for both cement types, shear bond strengths of 20%, 30%, and HF acid for 1 hour were equivalent to those of corresponding control groups. However, in contrast to our research, Lee et al²⁶⁸. evaluated the shear bond strength of resin to dental zirconia etched with HF acid at room temperature with the shear bond strength of air-abraded zirconia, which was not part of our research. In comparison to the control group, they found that etching sintered zirconia plates with 10%, 20%, or 30% HF acid for 5 or 30 minutes significantly enhanced zirconia roughness and binding strength to resin cement.

As a roughening agent for zirconia and dental hard tissues including enamel and dentin, sandblasting has been recommended as a technique to elevate mechanically interlock and overall contact area¹⁵. Sandblasting considerably increased bond strength for both monolithic zirconia brands in our investigation when it is compared to the corresponding control group. SEM images of samples sandblasted with 50µm Al₂O₃ demonstrate that impurities were eliminated, roughing of the surface resulted in the formation of identifying grooves and sharp edges, which were accompanied by a wide distribution of zirconium granules and increased inter-granular distance. This roughness and irregularity on the surface account for the increased bonding strength when it is compared to the corresponding control groups (Figure 4.23-4.28). Shaymaa E.⁹ study, which concurs with ours, examines the effect of 50 µm alumina on two monolithic zirconia brands, Zenostar T ZT and Prettau Anterior PA, proved that sandblasting with 50µm alumina considerably increased bond strength as compared to the control groups⁹.

Another agreement with many in vitro studies demonstrated that alumina particles are used in the sandblasting process is the most frequently used method of surface modification for zirconia in order to produce a long-lasting bond since it is a straightforward,

practical, and cost-effective method^{269, 270, 271}. When comparing sandblasting to other surface cleaning techniques such as phosphoric acid treatment, water washing, and isopropanol²⁷², Yang et al. discovered that sandblasting is the most effective approach for surface cleaning after spit contamination. During their research, Subasi and Inan²⁷³ investigated the impact of various surface roughness procedures on the zirconia surface, when comparing untreated zirconia surfaces to treated zirconia surfaces, they revealed that all forms of surface conditioning treatments enhanced the surface roughness ratios, Furthermore, they observed that sandblasting was the most effective technique. Abrasion with and without air particles was used to evaluate six different types of self-adhesive resin cement on zirconium oxide ceramic by Markus B. et al.⁸ sandblasting has been shown to elevate the bond strengths of self-adhesive resin cement to zirconia in this investigation, according to the findings. Altay Uludamar et al.²⁷⁴, examine the shear bond strength of two self-adhesive resin types of cement on zirconia using different surface roughness techniques (Sandblasting, finishing diamond bur, ER-YAG laser irradiation). When specimens were conditioned by sandblasting, the bond strength values of both types of cement were the greatest²⁷⁴.

Sandblasting method is utilized to create irregularities roughen the surfaces of zirconia to create micromechanical interlocking with the resin cement, and increase the surface area and wettability of the zirconia to allow for the flow of resin cement onto the roughened surface¹⁵. When it comes to alumina particle abrasion in the air, numerous rules must be taken into mind to produce more effective particles¹⁵. The size of the particle is the first of these guidelines. There is a wide range of alumina grain sizes, ranging from 25 to 250 μm in diameter¹⁵. The second rule is that the pressure should be between 0.05 and 0.45 MPa (2 to 4 bar). There were three measurements taken, each of which ranged from 5 to 20 mm between the nozzle and the sample¹⁵. The fourth guideline is the employment duration of alumina particles, which can be anywhere between 5 and 30 seconds in length. Another consideration is that particles should be positioned at an angle of 45° or 90° to the surface of the sample. As quickly as feasible (about 20 seconds) at 2.8 bar, air-particle abrasion was used in our investigation¹⁵. Preferably, only particles containing alumina and silica-coated alumina with particle sizes between 30 and 50 μm were used.

It was discovered through the findings of the meta-analysis that the application of an airborne particle abrasion surface conditioning approach to Y-TZP raised the flexural strength of the material. Interestingly, this conclusion appears to be in contrast with some past studies, which suggested that the higher intensity energy of the particles on the Y-TZP surface generates micro-cracks and plastic deformation of the material on the Y-TZP surface^{275, 276}. It had been claimed that the high impact energies of the particles on the Y-TZP surface are responsible for the reduction in the strength of the ceramic^{275, 276}. Even this, minor cracks, flaws, and imperfections that could cause fracture seemed to be restricted to the transformation layer, where they are being likely repaired by the 4% elevating in volume in the grain's trough attributed to phase transformation throughout the transformation layer²⁷⁷. According to observations, the compression stress caused by transformation toughening on the material surface seemed to counter any adverse effects of sandblasting²⁷⁸. The air abrasive techniques may have raised the stress necessary for crack formation, resulting in greater Y-TZP fracture strength values²⁷⁸. Studies show that more aggressive abrasion can impair mechanical YTZP's properties²⁷⁸. Concerns have been expressed about surface degradation following sandblasting Y-TZP with Al₂O₃ particles ranging in size from 50 to 120 µm at pressures ranging from 2.8 to 4 bar (0.28 to 0.40 MPa)²⁷⁸.

The research concluded chemical and structural parameters such as particle size, concentration, dispersion, and oxide stabilizer content may impact the rate of monoclinic phase generated by air abrasion when compared to as-sintered zirconia, the monoclinic phase rises with all types of air abrasion and surface roughness measures²⁷⁹. Monoclinic phases account for between 9.5 percent and 27.21 percent of dependent on the research guidelines, all research phases may be included. An increase in pressure (>3.5 bar), increased particle size (110 and 250 µm), an increase in deposition duration (>30 seconds), and an undesirable particle morphology in comparison with the shape of silica-coated alumina (30 or 110 µm particle size) all make a contribution to the heights of monoclinic phase and reduced of biaxial flexural strength in alumina particles when compared with silica-coated alumina²⁷⁹. To be compatible with the International Organization for Standardization, ISO 13356 states that the maximum permitted quantity of monoclinic phase in zirconia is 25 percent (ISO).

Even in the most extreme environments, the highest quantity of evidence documented thus far has only barely exceeded this limit of a percentage of the population ²⁷⁹. Creating a clean surface and establishing a relatively rough surface for enhancing resin cement adherence to zirconia while preventing monoclinic phase development, potentially damaging to zirconia fatigue performance, involves a sensitive air-abrasion procedure ²⁷⁹. It is feasible to mark the region to be air-abraded due to its free-hand application and the reality that the restoration's bonding zone controls the deposition time. Until it's been clinically proven that air-particle abrasive does not promote long-term deterioration of zirconia, specifically in the case of resin-bonded FDPs, dentists should use it as rapidly as possible, about 20 seconds at less than 2.8 bar ²⁷⁹. They should also utilize particles shape with less sharp morphologies than alumina, such as silica-coated alumina or silica only with particle sizes of 30–50 μm ²⁷⁹. On zirconia, we utilized the same value advised by Mutlu Ozcan²⁷⁹ for sand blasting, which we found to be effective.

Even though sandblasting is effective, it is not sufficient for the hydrolytic breakdown to result in a long-lasting resin-zirconia bonding. For the time being, the combination of sandblasting and MDP-monomer is the golden rule for elevating the adhesion among non-silica-included ceramic and resin in dry circumstances ²⁸⁰. Although other coupling agents have been tested, such as carboxylic acid primers, 4-META, and MAC-10, it has been demonstrated that the functional phosphate esters can bond immediately with the surface hydroxyl groups of the zirconia, which is not silica-contained, and that this is true for the functional phosphate esters ²⁸¹. It is considered that the use of MDP monomer, which is a kind of phosphate monomer, Improved bonding strength between resin and zirconia can be achieved by using a highly effective chemical surface preparation method. With the use of a functional phosphate ester group, MDP can chemically interact with zirconia and produce a specific chemical covalent connection. The hydrophobic acidic monomer was thought to establish an oxy-zirconate kind link (-O-Zr-O-) among the acid and the zirconia surface layer. when subjected to water ¹³⁴. TOF-SIMS examination of fragmentations has even shown the formation of a chemical link, denoted by the letters -P-O-Zr-, among the monomer of the

MDP primer and hydroxyl groups existing on the surface of zirconia as revealed by the results of the experiment²⁸².

In comparison to the control group without the primer, after seven days in water storage, 180 days in water storage, or thermocycles for 10,000 cycles, it was demonstrated that an MDP-containing primer could form superior chemical interactions with zirconia that were superior to those formed by the control group that did not use a primer. A chemical link between zirconia and phosphate-based MDP monomers may be formed, which makes the material more stable to aging conditions⁵⁹. Various investigations, on the other hand, have demonstrated that the single usage of MDP monomer does not produce long-standing resin-zirconia bonding. Despite the fact that MDP monomer could be preferable to other acidic monomers for zirconia bonding since there was no mechanical pre-conditioning, De Souza et al.²¹² establish that a standalone executable of MDP-including resin cement was unsuccessful for elevating the bonding among the resin and zirconia. By comparing the findings of 60 days of incubation at 37°C in weekly-changed deionized water accompanied by 5,000 cycles of thermocycling at 5°–55°C with a dwell period of 30 s to the findings of 72 hours of post-cutting storage, it was revealed that the resin-zirconia bonding was decreased²¹².

It was determined that using MDP including monomer alone will not improve the long-term efficiency of the resin-zirconia bonding²⁸³. Thermocycling, it was also discovered, would drastically reduce the required strong bond among resin and zirconia, even when an MDP- including monomer was used²⁸⁴. It has already been proven that primers including either as the phosphonic acid monomer or even the phosphate ester monomer, such as 6-MHPA and MDP, can improve the resin-zirconia bonding under varied aging conditions^{134,285}. Another research found that utilizing of MDP-including primer and VBATDT monomer were shown to elevate resin-zirconia bonding following three days of water storage or 60 days of water storage and 5,000 cycles of 5-55°C thermocycling at 5-55°C²¹². According to Chen et al, the effect of MDP concentration in zirconia primers on the chemical bonding potency of a chemical adherent of methacrylate resins to Y-TZP was investigated. Novel primers with 5, 10, 15, 20, or 30 weight % MDP were evaluated to bonding with a

standard MDP-including primer and bonding without MDP as a negative control to assess whether or not MDP-containing primers are advantageous in strengthening the strength of composite-zirconia bonds. The results show that MDP enhances the resin bonding of zirconia as a result of the formation of Zr-O-P bonds with zirconia. To prepare zirconia primers for resin bonding, MDP at a concentration of 10% seems to become the most appropriate option.

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In our investigation, we employed air blasting with a size 50 μ m to roughen the surface two translucent monolithic zirconia Ceramill and Zenostar using a primer containing MDP (Z-Prime Plus). After 5000 thermocycling, the bond strength was much greater than the control and sandblasting groups. In accordance with our findings, Carrera, et al. analyze the adhesive capacity of conventional and high-translucent zirconia following surface roughening using 50 μ m Al₂O₃ sized particles accompanied by primer containing MDP. They find that the zirconia bonds well to resin cement ²⁸⁷. The effect of two variant 3Y-TZP samples and one 5Y-TZP sample was studied by Chen et al,²⁸⁸ they prepared and treated the samples with sandblasting and a self-adhesive resin cement including 10-methacryloyloxydecyl dihydrogen, they utilized the same parameter in our study and they found that alumina blasting with MDP including primer very effective method for bonding the three types of zirconia ²⁸⁸. According to the findings of Yi et al., the influence of zirconia primer, air abrasion, and bonding procedures on the shearing bond strength among Y-TZP ceramic and self-adhesive resin cement was explored. They employed sandblasting at 50 μ m for Lava Frame separately, blasting accompanied with MDP-including primer (Z-Prime Plus), and Z-Prime Plus separately, they determined that sandblasting accompanied with Z-Prime Plus produced in much greater bond strength than either the blasting group or the Z-Prime Plus group on their guideline of concrete ²⁸⁹. Shinet al, ²⁹⁰ evaluated the impact of numerous surface treatments on the shear bond strength of Y-TZP (Yttria-Tetragonal Zirconia Polycrystal) with zirconia primers and 2 distinct resin types of cement, according to their findings. The specimens were made of zirconia blocks (LAVA, 3M ESPE, St. Paul, MN) and were treated to a total of 5,000 thermal cycles. Irrespective of the resin cement utilized, a combination of 50 μ m Al₂O₃ particles sandblasting and application of zirconia

primers as that the surface treatment resulted in the strongest shear bond strength.²⁹⁰ Another agreement from our investigation was the testing and study of the combined usage of MDP-containing resin cement and air abrasion on highly sintered zirconia surfaces, these investigations have shown that when both MDP-including composite resin and air abrasion were applied, the bonding between resin composite and zirconia was enhanced^{106,291}. If an MDP-containing primer is not employed, the MDP monomer can be included in the resin cement to improve resin-zirconia bonding¹³⁴. However, MDP-including resin cement had a weaker bonding effect than MDP-including agent²¹². In our study we used MDP free self adhesive resin cement.

Another type of micromechanical adhesive is linked to silica particles, which are commonly utilized in sandblasting operations, in order to facilitate the deposition of silica in acid-resistant ceramic material such as zirconia by interlocking silica particles on the ceramic surfaces. So, the silane can operate on the treated surface, promoting adhesion chemistry while also improving the micromechanical bond¹¹³. Furthermore, silanes are expected to aid in surface wetting, cement^{163,292}. Due to non-polar TZP's surface, greater chemical stability than that of silica-containing ceramics, and inability to be easily hydrolyzed, conventional silane chemistry is not fully efficacious with it.

To compensate for the lack of silica in Y-TZP, various ways of coating with silica have been investigated to take advantage of the chemical interaction produced by silanization. Using a tribochemical silica coating is a common approach for covering metal alloys and also alumina- or zirconia-based dental ceramics using silica, and the Cojet and Rocatec systems are two examples of such technologies in practice^{269,293}. Alumina particles that have been covered with silica are air-abraded into the ceramic surface via the tribochemical process, which embeds or coats the surface with silica as a result²⁹⁴. There are several applications for it, including the preparation of surfaces for silanization as well as the development of micromechanical retention. A tribochemical coating applied before silanization has been shown to significantly improve the adhesive strength among a treated substrate and resin cement^{116,269,293}. Traditional organo-silane monomer primers react favorably with the coated silica particles, but the residual bond strengths are generally less

than those found on traditional dental porcelain surfaces¹¹⁶. Additionally, when typical resin cement is used for the cementation of silica-based ceramics, a considerable reduction in binding strength might occur over time. Because of elevated the hardness of Y-TZP¹¹³, particle abrasion may be problematic, leading to a low concentration of silica on the surface. Prior to silanization and resin bonding, ultrasonic washing of tribochemically coated Y-TZP for 2 -5 minutes results in a substantial drop in bond strength, to levels that are substantially equal to those produced by air abrasion alone prior to bonding²⁹⁵. It has been established that ultrasonic cleaning reduces the amount of silica present on the surface. It is hypothesized that this decrease in bond strength, together with surface morphological changes, is what causes the loss of bonding strength. When a tribochemical coating is used, it has also been established that air pressure has an impact on bond strength. As reported by Heikkinen et al.¹¹⁸, raising the air pressure used during the application of a tribochemical coating has a considerable impact on the bond strength of Y-TZP with resin cement¹¹⁸.

Furthermore, it was revealed that higher pressure increased the levels of silica on the Y-TZP surface. Increased air pressure, which enhances the kinetic energy of particles, is estimated to raise the roughness of the surface and the number of silica particles in interface with it. As a result, additional silica is mechanically maintained, increasing the amount of silica available for chemical bonding. Although it may raise the amount of degradation to the Y-TZP surface (tetragonal to monoclinic phase change), it is not recommended¹¹⁸.

In our research, we used the Cojet system to apply a tribochemical silica coating perpendicularly to the sample surface for 20 seconds at a working distance of approximately 10mm and a pressure of 2.8 bar to both types of highly translucent monolithic zirconia Ceramill and Zenostar with application silane. After 5000 thermocycling, the bond strength for both groups were significantly greater than the control and sandblasting. SEM pictures of materials sandblasted by 30 μm Cojet reveal that impurities were eliminated, surface roughness and irregularities were enhanced, exposing zirconia granules and inter-granular gaps, however, the exposure of granules and sharpness of edges is less than that of alumina blasting groups (Figure 4.29-4.34).

In accordance with our research, two different brands of 3Y-TZP specimens and one 5Y-TZP specimen were manufactured and abraded with tribochemical silica coating followed by silanization. The adhesive strength of 5Y-TZP is identical to that of 3Y-TZP when the same bonding techniques are used. Long-lasting may be obtained with both 3Y-TZPs and 5Y-TZP by tribochemical silica coating followed by silanization ²⁸⁸. Additionally, Altan et al.²⁹⁶ studied the effectiveness of several surface treatments on monolithic zirconia and found that by utilizing Cojet, the adhesive strength was greatly enhanced of three types of monolithic zirconia (Vita YZ HT, Sirona inCoris TZI, and IPS e.max ZirCAD) after 5000 thermocycling, compared to the control and sandblasting groups ²⁹⁶. Elsaka⁹ investigates the effectiveness of the Cojet surface treatment on the microtensile bond strength (TBS) of resin cement to two different kinds of monolithic zirconia. After 10,000 thermocycling, the adhesive strength of Zenostar T ZT and Prettau Anterior PA was considerably greater than that of the control and sandblasting groups ⁹. Dantas et al.²⁹⁷ evaluated the effectiveness of surface modification on the adhesive strength of a zirconia-based ceramic and two resin cement and they observed that irrespective of the type of cement employed, air-particle abrasion using alumina coated with silica particles Cojet enhanced the bond ²⁹⁷.

In a recent study, the efficiency of a multi-mode adhesive as a replacement for silica coating and silane implementation on the bonding of three types of zirconia ceramic (Lava / 3M ESPE, Ceramill Zirconia / Amann Girrbach, and Zirkonzahn / Zirkonzahn) to resin cement was evaluated, and all specimens were preserved in distilled water (37 °C) in sealed containers for 30 days in a bacteriological media, as a consequence of the Cojet accompanied by silanization, higher bond strength of resin cement and zirconia was achieved, irrespective of zirconia ceramic type ²⁹⁸.

We employed a Siljet system in our research (Danville Engineering, San Ramon, CA), which was applied perpendicularly to the surface of the zirconia sample for 20 seconds, at a working distance of 10mm and a pressure of 2.8 bar to monolithic zirconia (Ceramill and Zenostar) with application silane, and the bond strength for both groups was significantly higher after 5000 thermocycling than controls and sandblasting. Compared to samples sandblasted with 30 µm Siljet. The SEM image demonstrates that impurities have been

removed, surface roughness and irregularity have been minimized, and the image reveals grooves and less sharp edges with narrow inter-granular space, as well as grooves and less sharp edges. (Figure 4.35- 4.40).

In accordance with our findings, Vincent Bielen et al.²⁹⁹ analyze the influences of various mechanical surface modifications on the adhesive strength to dental zirconia they come to the conclusion that mechanical surface pre-treatment of zirconia using tribochemical silica coating (Cojet, Siljet) resulted in the most favorable bond durability of resin cement to dental zirconia before and after aging when compared to the other treatments ²⁹⁹. Özcan, Yetkiner ³⁰⁰, study the effect of using 30 µm Siljet surface treatment on Emax ZirCAD, and resin cement they conclude that the shear bond strength after 6000 thermocycling was significantly higher than control. Pilo et al³⁰¹. evaluated the adhesive strength of a resin composite's bond to zirconia via Cojet and Siljet, as well as two commercially available silane primers and they found that Siljet and Cojet with two types of silane significantly increased bond strength in comparison to control groups ³⁰¹.

Zirconia surfaces have been subjected to controlled and definitive microtopographic changes utilizing lasers including such CO₂ lasers, Nd: YAG laser, Er: YAG laser, Er, Cr: YSGG laser, and femtosecond laser are used in a variety of applications ^{131,147,302,303}. The CO₂ laser is often used for soft tissue procedures, like periodontal surgery, and it is quite effective, as a consequence, ceramic materials absorb the wavelength that the laser emits, forming micromechanical retentions to facilitate the adhesive process ³⁰⁴. Accurate removal of oxide ceramic particles can be achieved when the Er: YAG laser is placed on the surface, it goes through a process called ablation ^{305,306}. The Er, Cr: YSGG laser, which develops a roughness equivalent to that of sandblasting, has excellent adhesion outcomes ³⁰⁷. Zirconia samples have been shown to transmit Er: YAG laser light at high transmission rates (up to 62% in the 0.5mm thickness range and 47% in the 1mm thickness range) ³⁰⁸.

Consequently, Because Er: YAG laser energy has a restricted absorption capacity in zirconia materials, it is inadequate to promote the production of efficient micromechanical retention on the zirconia surface throughout laser processing. The Nd: YAG laser is used for a variety of procedures, including tooth sensitivity reduction, caries removal, and dental

bleaching³⁰⁹. Due to the limited thermal conductivity of zirconia, this laser promotes the formation of interesting surface roughness¹⁶⁶. In comparison, the use of the above-mentioned lasers increases local temperature, which may lead to internal tensions capable of inflicting destruction to the ceramic material³¹⁰. Lately, the femtosecond laser was used to limit the level of destruction. Due to the fact that this laser creates optical pulses and it is capable of producing a smooth finish while also significantly reducing the number of phase transformations³¹⁰. The literature has argued whether the elements inherent in the equipment configuration have an effect on the outcome. Ahrari et al.³¹¹ examined adhesive strength after use of CO₂ laser, they concluded that greater energy settings 10 W/14 MJ or 20 W/10 MJ obtained lower adhesive strength, while reduced energy settings 10 W/10 MJ resulted in adhesive strength that was identical to those gained by sandblasting application. The CO₂ laser can create roughness on the ceramic surface, Kasraei et al.³¹² claim that when a greater energy density (about 265 J/cm²) is employed, even at smaller power levels can produce surface roughness.

Because that hand-operated device can result in an inhomogeneous irradiation pattern, studies have emphasized the need of using fractional CO₂ lasers for surface treatment³¹³. According to the employment of shorter and controllable pulse durations (50 ls) in pulse-controlled devices, the peak laser power and the incidence of laser energy on the interface of zirconia can be enhanced³¹⁴. For surface treatment, ultrashort-pulsed lasers are much more feasible than long-pulsed lasers due to their precision and lack of thermal adverse effect³¹⁵.

Ultra-fast fiber lasers are mostly employed in the field of dentistry to change the surface of implant³¹⁶. The influence and alteration of surface microstructure caused by laser settings suggest that lasers may be an alternate way for surface treatment to improve the bonding between different materials³¹⁶. When compared to other lasers, fiber lasers can touch surfaces swiftly and powerfully while inflicting less mechanical and thermal damage³¹⁶. Based on the results of one investigation, the adhesive strength among ceramic and metal brackets was strengthened by the use of a femtosecond laser application³¹⁶. In their study, Korkmaz et al.³¹⁶ found that utilizing ultrafast fiber laser leads to elevating the

bond strength among resin cement and titanium and that ultrafast fiber lasers are a viable substitute approach for modification of metal surfaces ³¹⁶.

While numerous investigators have studied several research on improving the bonding among zirconia and resin cement, there have been relatively few investigations on the usage of fiber lasers in this field ³¹⁷. Ytterbium-doped fiber laser (YbPL) was tested on zirconia by Mutluay Unal et al. According to the power of the laser irradiation, the zirconia discs were separated into four groups (5, 12, 17, and 20 W). According to the frequency, these groupings were subdivided into five categories (25, 40, 60, 80, and 100 kHz). It was found that all groups' Ra values were higher than the control group's using a noncontact profilometer to measure surface roughness. At 20W and 100 kHz, the surface roughness value was ³¹⁷.

Yb-doped fiber-based nanosecond pulsed lasers were used to irradiate the two types of monolithic zirconia Ceramill and Zenostar disk surfaces in our experiment (Vision, Neukirchen, Germany). At 1064 nm and 100 kHz, the YbPL irradiation was carried out at a working distance of 0 mm perpendicular to the surface of the, and the working period was 20 seconds. Speed was 350mm/s.t for each specimen. For Zenostar and Ceramil, the fiber laser surface treatment resulted in shear bond strengths of 17,814 MPa and 21.7 MPa, respectively, which is a substantial improvement above all other groups, including Cojet and Siljet. Images from the SEM for Zenostar and Cermaill indicate surface alteration with organized parallel grooves on the surface (Figure 4.41,4.43) and a hole on the surface of zirconia (Figure 4.45), as well as an area where the zirconia has been burned (Figure 4.47). stereomicroscope image demonstrates color changes for both zirconia type Figure (4.7,4.8).

The fiber laser's average shear bond strength Ceramill has a greatly higher shear bond strength than the average fiber laser shear bond strength Zenostar. Because Zenostar is non pigmented while Ceramill is prestained. Laser application results in the rapid deposition of large amounts of radiation energy on the ceramic surface. As a result, the radiation energy is converted to heat, while the temperature of a thin surface layer increases. The most critical connection among the laser and the substrate occurs when the laser energy is absorbed by the

substrate. The pigmentation and water content of the surface, as well as other surface properties, all contribute to the amount of energy absorbed by the irradiated surface ³¹⁷.

In line with our findings, they used a variety of laser parameters in their research. The goal of Unal et al.³¹⁸ research was to compare the influence of a Yb-doped fiber laser and other surface modification procedures, such as sandblasting with 110 m particle size aluminum oxide or 30 m silica-covered alumina, on the (SBS) among zirconia and the tooth surface, by utilizing CAD/CAM technique to develop an overall of 128 zirconium oxide disks. The disk surfaces were blasted using Al₂O₃ or silica-coated alumina or irradiated with such a Yb-doped fiber-based nanosecond pulsed laser with just an output power of 85W at 25 kHz. Disks were subsequently luted to dentin utilizing 2 distinct resin cement. The SBS of each specimen was determined. Independent of the resin cement utilized, the strongest bond is obtained when the zirconia surface is prepared using a Yb-doped fiber-based nanosecond pulsed laser.

A study by Fornaini et al.¹⁴³, in contrast to our findings, checked the influence of utilizing 1070 nm fiber nanosecond pulse laser on zirconia specimen. Apart from the fact that laser irradiation with a 1070 nm fiber laser and suitable processing parameters resulted in acceptable results in form of greater surface roughness and low thermal serious harm, a correlation of irradiated and unirradiated samples revealed no statistically significant discrepancies in bonding strength. This result can be attributed to the fact that they used a different laser parameter in their experiment than we utilized ¹⁴³.

In our investigation, the (Yb)-doped fiber laser causes color changes in both forms of monolithic zirconia. This could be related to the laser parameter we utilized in our experiment including use of laser without water and direct contact of laser to zirconia surface. However, laser irradiation has caused damage such as material loss ³²⁰, voids and a plaque-like scaly structure ³²⁰, fractures, microcracks, and micro-fissures ³²⁰, melted areas; grooves ³²⁰, and blister-like spheres and bubbles. Roughness on the surface facilitates cement infiltration, resulting in a better bond to zirconia surfaces³²⁰. Unfortunately, high power setups can permanently damage the surface, and particulate from micro-explosions could adhere to the molten ceramic's surface, leading to poor adhesion ³²⁰. Additionally, it is necessary to keep

in mind that when particular lasers are utilized, current temperature changes occur, and the resulting stress may result in phase transition³²⁰. While multiple investigations have revealed that superficial changes caused by laser irradiation result in a phase transition, just one research by Usemez et al.^{320,321}, utilized X-ray diffraction to determine the impacts of multiple surface modification on the monoclinic phase conversion of zirconia³²⁰. The research showed that Nd: YAG laser treatment leads to a phase shift from tetragonal to monoclinic zirconia and that the proportional percentages of monoclinic zirconia in the specimens varied from 13 and 30.5%. In terms of monoclinic content, the polishing control group had the least (13%) value; glazed and acid-etched groups both resulted in a small increase (15.7%), whereas alumina blasting resulting in a 16.2 % higher, according to X-ray diffraction. It was discovered that the monoclinic percentage of zirconia increased by 26.5% after Nd: YAG laser irradiation with lengthy pulse duration as well as a 30.5 % monoclinic percentage after Nd: YAG laser irradiation with short pulse duration, revealing that Nd: YAG laser treatment initiates the phase transition of zirconia from tetragonal to monoclinic³²⁰. It was possible to get an improvement in peak power from 625 to 1.110 W by reducing the pulse length, which was accomplished by reducing the pulse duration. The surface roughness of the samples is enhanced by the addition of this modification, and as a consequence, the amount of phase transformation is elevated as well.³²⁰. Because phase shift has been shown to be detrimental to mechanical performance criteria such as strength and toughness, additional research should be estimated future, utilizing the multiple lasers and customizable parameters that are already accessible.

In accordance with our investigation show that after 5000 thermocycling, there is no statistically significant difference between (Siljet, Cojet) plus silane and sandblasting plus MDP containing prime (Z Prime plus) when it comes to bond strength. As a result of our research, Thammajaruk et al. concluded that, when particularly in comparison to certain other mechanical and chemical treatments, tribochemical silica coating as well as alumina air abrasion combined with MDP-containing primer groups generally tend to produce the extras mean bond strength in an intermediate-aged situation²⁵³. In accordance with our research, another systemic review by Scainaci Rus proved that sandblasting with silica-coated particles

(which permits the connection of silane primers) and regular alumina sandblasting combined with the use of chemical promoters such as 10-MDP-based products are two protocols that have more proof in the literature³²².

In order to demonstrate the quality of the bond to be addressed in our experiment, it is necessary to evaluate the manner of failure of specimens. The adhesiveness of HF groups and air blasting groups was 100% adhesive. Low bond strength values were found to be the most often related to adhesive failures in the current experiment. It is possible to explain this by the fact that neither procedure was accompanied by a chemical connection. There is no statistically significant difference between the failure modes of the Siljet, Cojet, and blasting MDP groups for both zirconia materials, which are predominantly mixed due to the use of chemical bond between zirconia and resin cement after roughness the chemical bond resists the hydrolytic effect of thermocycling were translated as intermediate bond strength values for both zirconia materials. The fiber laser groups for both zirconia materials were cohesive, indicating a good grade of bond; nevertheless, the laser pretreatment caused discoloration of the zirconia material.

Several limitations were identified in this investigation. This investigation was carried out in a laboratory setting where there were no contaminated specimens or oral moisture conditions that might have an impact on the clinical applicability. Within the intraoral cavity, mechanical and chemical variables have a significant impact on the bonding strength of the resin cement. The medium employed for the storage procedure was distilled water; no saliva was used in the process. The findings of this investigation need to be confirmed in a clinical setting. Although further research with a larger number of samples, particularly those based on mechanical testing, would be required to corroborate these early findings. fiber laser irradiation appears to be an attractive technique for improving zirconia performance from an adhesion standpoint. Fiber laser parameter need more researches to overcome the damaging effect of laser on zirconia surface for example, utilized water media during using of laser to decrease heat generation and avoid direct contact laser with zirconia surface and utilized X-ray diffraction to determine the impacts of multiple surface modification on the monoclinic phase conversion of zirconia.

Regarding the null hypotheses proposed at the start of the research,

1) “Its bonding strength of the self-adhesive resin cement to both forms of highly translucent monolithic zirconia CAD/CAM material would be insignificant” was accepted.

2) “ Pre-stained highly translucent monolithic zirconia CAD/CAM material would be a significant difference in the shear bonding strength in term of modification of surface” was partially accepted only for fiber optic laser surface treatment and HF acid surface treatment methods.

3) “HF acid surface treatment for 1 hour would be improved the shear bonding strength of self-adhesive cement for both types of CAD/CAM highly translucent monolithic zirconia” was rejected.

4) “That fiber-optic laser surface treatment would improve the shear bonding strength of self-adhesive resin cement for both types of CAD/CAM highly translucent monolithic zirconia” partially was accepted du to discoloration of zirconia

6 CONCLUSION

The following conclusions can be obtained from this research,

1. The shear bond strength between monolithic zirconia and the resin cement was not significantly affected by the type of monolithic zirconia CAD/CAM blocks.
2. Surface treatments of two monolithic CAD/CAM zirconia with 50 μm alumina abrasion improve the bond strength to self-adhesive resin cement for both types of monolithic highly translucent zirconia.
3. Surface treatments of two monolithic zirconia with air abrasion together with MDP primer (Z Primer Plus) improve the shear bond strength to self-adhesive resin cement.
4. Fiber-optic laser surface treatment has the highest bond strength for both types of monolithic zirconia but leads to a change in color of zirconia. For this reason, it is not recommended to be the ideal surface treatment for monolithic zirconia and needs more research.
5. Fiber-optic laser surface treatment for pre-shaded Ceramill provided significantly higher mean shear bond strength than un-stained Zenostar translucent zirconia, because Ceramill having more pigmentation might led to better absorption of laser wave by zirconia surface.
6. Cojet and Siljet surface treatments of Ceramill and Zenostar together with their corresponding silane-coupling agent application improve the shear bond strength of two types of highly translucent monolithic zirconia to self-adhesive resin cement.
7. There is no significant difference between shear bond strength of Cojet, Siljet, and sandblasting with 50 μm alumina particles plus MDP containing primer. These were considered to be the most effective surface treatment for translucent monolithic zirconia.
8. Surface treatment with HF acid 9.5% for 1 hour is not an effective surface treatment for both types of highly translucent monolithic zirconia.

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8 CURRICULUM VITAE

Personal Information

Name	Sirageddin	Surname	Alhmadi
Place of Birth		Date of Birth	
Nationality		TR ID Number	
E-mail		Phone number	

Education

Degree	Department	The name of the Institution Graduated From	Graduation year
PHD	Prosthodontics	Yeditepe University	2022
Master	Prosthodontics	İstanbul Yeni Yüzyıl Üniversitesi	2016
University	Bachelor of Dental Surgery (BDS)	TRIPOLI Medical and Health Sciences University	2007
High school	Scientific Section	Alarab High School	2000

Languages	Grades
Arabic	Native Proficiency
English	IELTS 6.5
Turkish	Tomar C1

Computer Skills

Program	Level
Microsoft Office; Word, Power Point and Excel	Very Good