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Fracture resistance and shear bond strength properties assessment of nano-crystalline monolithic high translucent zirconia by applying different surface modifications

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Abstract:

Objective: To have a more beautiful smile, the use of ceramic veneers has become very popular. However, surface defects can affect the strength of ceramic veneers and lead to fracture and separation of the veneer from the tooth surface. This study examines the use of several different methods of surface restoration of ceramic core materials to increase the strength of the coating.

Methods: In order to investigate different methods of surface treatment on the physical and mechanical properties of monolithic Ultra-translucent zirconia (ZrO2), 24 human maxillary premolar teeth were used for loading test. In this regard, the teeth prepared for veneers and after scanning 24 veneers from ultra-transparent zirconia (ZrO2) were made. A combination of 48% hydrofluoric acid solution and 69% nitric acid, Sandblasting and Nitric acid-hydrofluoric acid Zircos E etching system (ZSAT) were used to modify the surface of prepared ultra-translucent zirconia. The physical and mechanical characteristics of veneer were investigated in different experimental groups, including 48% HF and 69% HN combined group, Nitric acid-hydroflouric acid Zircos E etching system (ZSAT), and Sandblasted group as experimental groups. The results were analyzed using one-way ANOVA and Tukey's post-test.

Results: The flexural strength of different samples of monolithic zirconia surface treatment showed that in mixture 48% HF and 69% HN group the loading resistance was 821.4±90.45 N. Regarding the monolithic zirconia surface modification with sandblasting method and ZSAT groups, loading resistance was 685.7±115.3 and 756.7±119.3 N. In each experimental group, veneer was de-deboned and fractured after applying these loading stress. The result of high fracture strength more than 930, 1320 and 1410 N, was tooth fractured vertically between buccal and central groove as like as veneer in mixture 48% HF and 69% HN, sandblasted and ZSAT groups, respectively. According to these results, sandblasted surface treatment increased flexural strength compared to other groups. Based on the results, none of the group show any significant difference and wad same resistance to flexural strength.

Conclusion: mixture 48% HF and 69% HN, sandblasted and Zircos E etching system in monolithic zirconia surface treatment could increase its shear bond strength. These chemical agents could increase the strength of the coating, although clinical application should be further evaluated.

Keywords: Zirconia, Hydrofluoric Acid-Nitric acid compound, Surface treatment, Loading resistance.

1. Introduction:

Today, many people seek to use dental crowns in order to have a beautiful face with a pleasant smile. In addition to creating a beautiful appearance, dental veneers lead to strengthening and hiding the color of the teeth (1). Veneers are a popular cosmetic dentistry option for patients who want to improve the appearance of their smile (2). There are two main types of veneers: ceramic and porcelain (3, 4). Both types of veneers can provide a beautiful, natural-looking result. Ceramic veneers are made from a durable, high-quality porcelain material. They are less likely to stain than other types of veneers, and they can be custom-matched to the color of your natural teeth. Ceramic veneers are also less costly than porcelain veneers (4).

zirconium dioxide (ZrO_2) is a Ceramic veneer that is formed by combining oxygen and zirconium at high temperatures. Zirconia that is used in dental implants and veneers is called partially stabilized zirconia that also contains traces of yttrium oxide (5). Zirconia has been rightly termed "ceramic steel" as it's the strongest ceramic material around. 10 times stronger than your tooth enamel and can last anywhere between 10 to 30 years with proper care. Zirconia is the most biocompatible dental material around, after gold. This means zirconia will not react to any chemicals in your mouth. Due to the lack of metal sub-structures, Zirconia veneers don't cause allergies such as gingival recession, swelling, bleeding, etc., that porcelain veneers could cause at times (6).

Different types of zirconia have been developed due to the need for enhancing some of its properties due to the requirements of various parts and components. The most common types of zirconia consist of different oxides applied to this advanced ceramic material with the purpose of stabilizing and toughening it further (7).

Zirconia are non-silicate ceramics and therefore, due to their chemical structure, they cannot be etched with traditional acids. Therefore, other efficient methods can be used to increase the zirconia bonding surface. A micro-mechanical structure and different types of chemical bonds are required to create a stable connection between the dental crown and zirconia. Based on this, a series of advanced adhesive systems, various surface modifications, improve the dental bonding surface to zirconia ceramics. Until now, various surface treatment methods have been used to improve the bonding with zirconia. The use of aluminum oxide particles, various main compounds and surface treatment methods with hot chemical compounds have been reported in previous studies (8).

Sandblasting of zirconia with Al_2O_3 or SiO_2 particles causes limitations in morphological aspects and contamination with remnant abrasive particles. The method of surface abrasion with aluminum oxide particles is considered as one of the simple and common methods to increase the hydrophilicity and roughness of the surface as a technique for micromechanical interconnection. There is a possibility that the wear method of surface suspended particles leads to structural changes and the induction of sharp cracks, which can increase the performance of the surface coating of the tooth (9).

Acid etching creates a homogeneous surface roughness regardless of the size and shape of the material used in it. Recently, various studies have shown the beneficial effectiveness of HF to treat the surface of zirconia and thus improve the adhesion of zirconia resin. HF reacts with the silica phase in a ceramic veneer and form hexafluorosilicates, that make rough surface of the zirconia ceramic. Concentrations between 4 and 10% of HF acid are usually used in the dental laboratory. Using higher concentrations of etchant can change the morphology of the zirconia surface by creating a very uneven surface (10).

Short-term treatment with 48% HF resulted in more uniform deep micro retentions on the surface of treated zirconia compared to untreated zirconia. The mixed solution of HF and nitric acid has been shown to be able to create surface irregularities. This combination of HNO_3/HF etching on zirconia samples significantly roughens the surface of zirconia compared to samples treated only with sandblasting (11).

Fixed restorations have different durability due to variables such as the type of tooth preparation, the way the restoration is attached to the tooth, and the type of cement. For this purpose, it is necessary for different parts of the tooth to establish a strong connection with the structure and restoration of the tooth, and therefore, with this connection, they will be able to show high strength against tensile forces. Durability of restorative coatings is due to increased friction level, micro-mechanical or chemical bonding or a combination (12).
Based on the reports of previous studies, it was determined that conventional etching-silane treatment for zirconia has not been effective. Due to the lack of a glass matrix and the absence of SiO_2, the conventional acid etching method of the zirconia surface has not been successful without an apparent improvement in bond strength, so the zirconia surface must be modified using other micromechanical or chemical methods (13). There is no universal way to achieve a high bonding zirconia surface. So, achieving a zirconia surface with high bonding ability requires a series of alternative bonding methods for zirconia ceramics. This study aims to use acid etching to modify the surface of nano-modifier samples in order to increase silanization using modern techniques compared to sandblasting method. The results of this study can be used in the development and evaluation of a practical method to modify the chemical surface of dental ceramics with high strength (for example, zirconia) to facilitate stable adhesive bonding using silanes and resin cements available in the market. In order to evaluate the strength of adhesion and stability against the pressure on the dental veneer against failure, the maximum loading strength test was used. The coating durability test has been used in many researches, where cement restorations are subjected to axial displacement forces until failure.

2. Study design and Methodology

2.1. Type of study

This study is a randomized experimental study with three different experimental groups. To compare two types of chemical adhesive preparation and a sandblasting method for bonded Monolithic nanocrystalline Ulta-translucent zirconia veneer. During this experiment, different treatment groups have been randomly selected, so the comparison of these groups has been ensured.

2.2. Tooth collection and preparation

24 sound freshly extracted maxillary premolars were used in the study. Dental calculus was removed with periodontal curettes and teeth were cleaned and stored in distilled water at room temperature. The research was approved by the Ethics Committee of the Hawler medical university.

2.3. Technique for making dental preparations

Teeth were marked with a Titanium periodontal probe 2 mm below the cement-enamel junction to simulate the periodontal ligament. Then, they were placed in a container with heated utility wax, forming a thin layer of 0.3 mm, and its thickness was verified with an adapted periodontal probe (Figure 1).

Figure 1. Insertion of tooth in polyvinyl chloride cylindrical device close to periodontal ligament junction, below the cement-enamel border to simulate the alveolar bone.

After that, they were positioned along their long axis in PVC (Polyvinyl Chloride) cylindrical devices and embedded in self-cure acrylic resin, to simulate the alveolar bone. Once the acrylic resin was completely cured, the teeth were removed, leaving an alveolus-like space due to melting of the 0.3mm wax that represented the periodontal ligament (Figure 2). A polyether adhesive (Universal Adhesive, 3M ESPE) was applied over the roots and 15 min was allowed to pass. Then, they were covered with a 0.3 mm layer of a polyether impression material (Variotime light body, KULZER) to simulate the periodontal ligament. The teeth were then returned to the acrylic resin mold. After 6 mins, the polyether excess was removed, completing the periodontal ligament simulation.

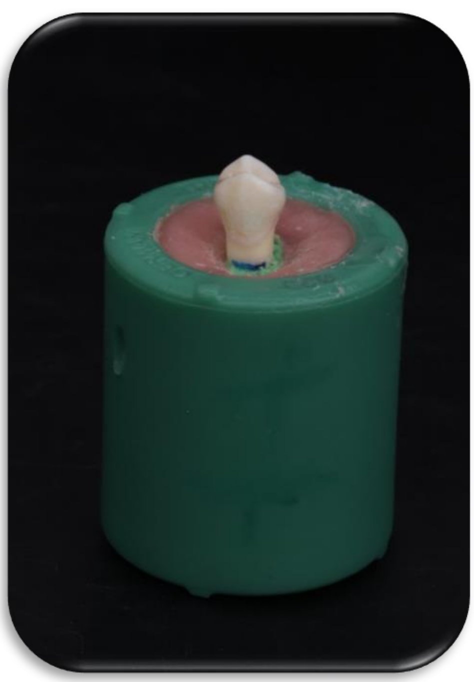

Figure 2. Positioned tooth along their long axis in PVC cylindrical devices and embedded in self-cure acrylic resin. Making an alveolus-like space due to melting of the wax that represented the periodontal ligament.

2.4. Tooth preparation and digital impression recoding

After fixing the teeth in a semi like periodontal system, the preparation started in buccal surface with 0,3 mm depth, controlled by depth guiding cutter diamond bur (kit 1443 Efficient veneer prep kit, Jota) with only 0.3 mm cutting efficiency, and extended across the buccal surface involves 1mm in occlusal surface of buccal cusp.

Tapered diamond burs were used for the completion of dental preparation in buccal and occlusal surfaces, according to each group depth, aided by adapted customized-periodontal probe, and verified with a digital caliper. Dental preparations finishing steps were performed with fine and extra-fine granulation stone tapered diamond burs (Jota). A high-speed handpiece turbine (~200,000 rpm) (T3 LINE E 200, Dentsply Sirona) was used with constant water refrigeration and all the procedure done under microscope (MediWorks's dental microscope 620 pro). After preparation finished, impressions were obtained digitally (3SHAPE IOS trios 3) from all teeth, and then all the scans were sent to lab.

Before touching the teeth, an impression with Polyvinyl siloxane (silagum Putty, DMG) and intraoral scans (3SHAPE IOS trios 3) were taken from the teeth figure 3, 4 &5. The polyvinyl siloxane impression to fabricate horizontal and vertical matrix guides to be used in the assessment tooth preparations depth, aiming to standardize the preparations' depth figure 6. As for the digital scans later after preparation we scanned the samples again then overlapping both scans for the exact accurate measuring the amount of tooth structure that been removed by treatment stimulation feature comparing scans, comparing tooth and visualize the differences figure 7 &8. Typical buccal veneers were designed on tooth prepared scans using finishing lines that did not extend beyond the cemento-enamel junction or interproximally, and had a minimum thickness of 1 mm. The design done with exocad, and monolithic Ultra-Translucnet zirconia (VITA-Zahnfabrik VITA) were used to fabricate veneers, then milling has been proceeded by Milling machine (Imes-icore, CORiTEC 350 PRO) according to the manufacturer's recommendations at sintering temperatures of 1500 °C, holding time for 2 hours, then their surfaces had been cleaned with ethanol to get rid of any debris then washed with distilled water. Again, veneers were examined under a microscope (Mediwork microscope 620 pro) to ensure accuracy, detection of cracks and fitness, and the whole procedure is done by one operator.

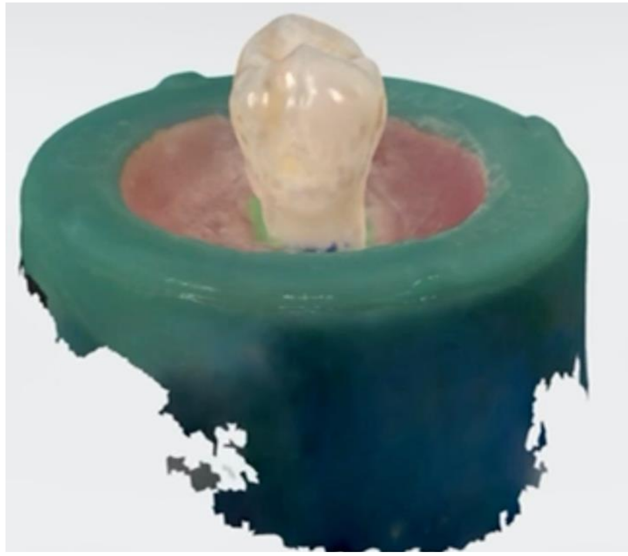

Figure 3. Scan of tooth before preparation.

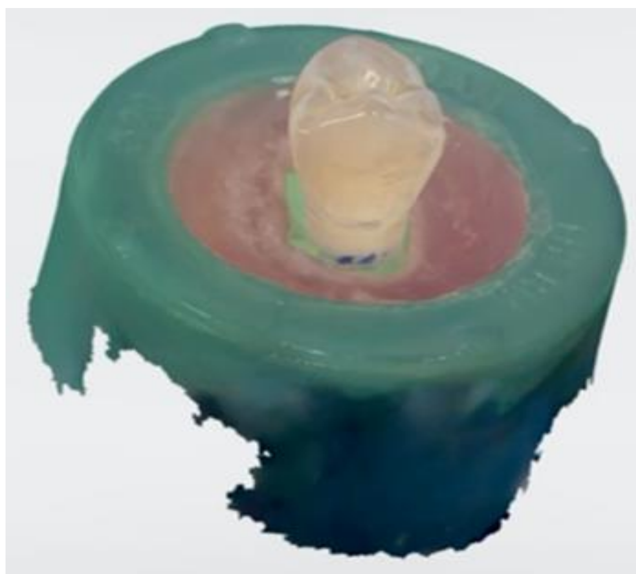

Figure 4. Scan of tooth after preparation.

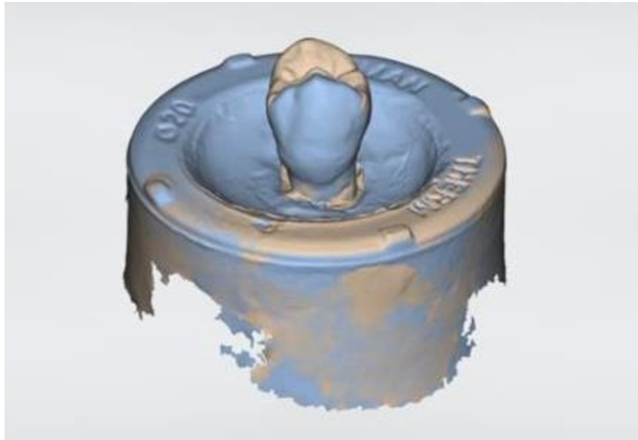

Figure 5. Scan of tooth after preparation technique (blue color shows the areas were touched and prepared).

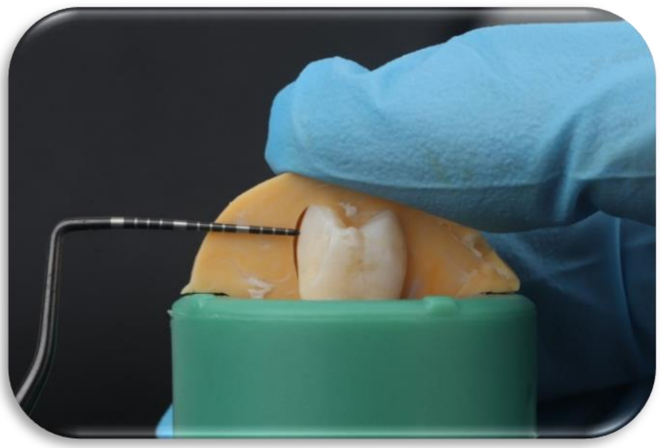

Figure 6. Polyvinyl siloxane impression to fabricate horizontal and vertical guides to be used in the bur preparations steps, aiming to standardize the preparations' depth.

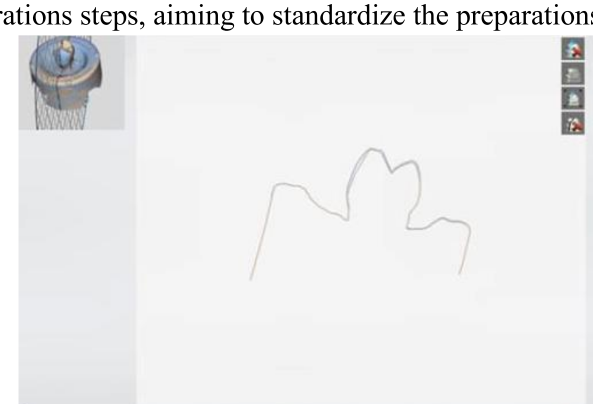

Figure 7. Sagittal cross section of tooth after preparation

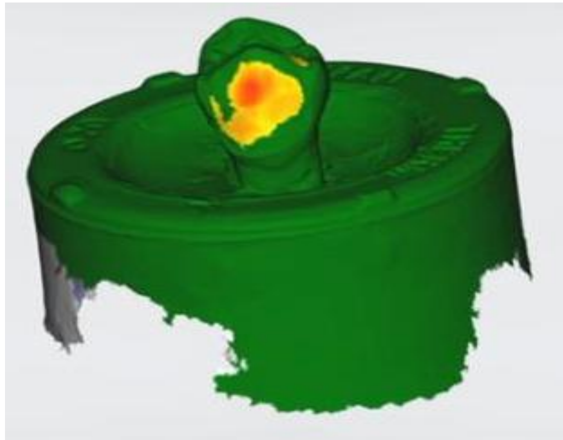

Figure 8. Overlapping before and after scans comparing to detect the exact amount of tooth that has been removed.

2.5. Surface treatment and experimental groups

The designed monolithic ultra-translucent zirconia veneers were categorized in to 3 groups; Treated hot chemical etching solution as a mixture of 69% nitric acid and 48% hydrofluoric acid group, sandblasted group and Treated with nitric acid-hydrofluoric acid Zircos E etching system (ZSAT) (equal Ratio) group. In mixture group, sample surface was treated with a combination of 69% nitric acid (from BIOCHEM Chemopharma) and 48% hydrofluoric acid (from scharlau) equal ratio inside a glass jar to prevent any further chemical reaction then applied for exact 25 min then rinsing and drying for 2 minutes (Figure 9).

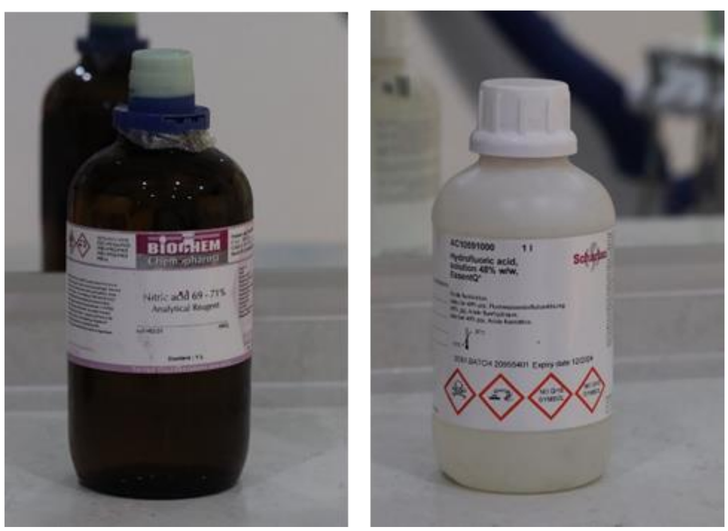

Figure 9. Nitric acid (from BIOCHEM Chemopharma) and hydrofluoric acid (from scharlau) to making a combination of 69% nitric acid and 48% hydrofluoric acid.

In sandblasted group, a sandblasting machine (Basic classic fine sand blasting unit, Renfert) was used. It was closed with a translucent plastic container with two holsters to allow you to work inside and keep the liquid and gases inside (Figure 10).

Figure 10. A sandblasting machine used for surface treatment of zirconia cuboid.

Samples were fixed on a hard surface to prevent any movement while sandblasting the airborne particle abrasion on the specimen using 29 Mm grain sized Al2O3 particles the performance made in circular movements at a standoff distance of 1 cm at angulation 45 degree with 2.8 bar pressure for 15s. The substrate surface was rinsed for 20s and air-dried for 5 s by using (AquaCare Velopex) tool (Figure 11).

Figure 11. The airborne particle abrasion on the specimen using 29 Mm grain sized Al2O3 particles the performance made in circular movements at a standoff distance of 1 cm at angulation 45 degree with 2.8 bar pressure for 15s.

Zircos E is another group that is a highly toxic liquid. All safety precautions were taken when applying the surface treatment, including wearing protective gloves and gowns. After preparing everything inside the working container we applied a layer of nitric acid-hydrofluoric acid Zircos E on a sample surface taking the sample carefully and put it inside the ultrasonic cleaner (Dental Ultrasonic Cleaning Machine | 2.5L | Stainless Steel, OXYAIDER) in a range of 20 KHz and 0.2W/cm2 for 30min. After time is up, we put the sample to rinse under running water for 30 seconds then apply steamer for 30 seconds (Figure 12).


Figure 12. Dental Ultrasonic Cleaning Machine.

2.6. Insertion of veneers on tooth

As for the tooth surface treatment, it was the usual steps for any indirect case insertion by phosphoric acid being applied for 15s, then rinse and dry, later apply adhesive bonding (Bisco universal bond) twice and air spray in between to thin the adhesive layer not to be so thick (Figure 13). OptracStick applicator (Ivoclar vivadent) is used to hold veneers, then adding light cure cement (BISCO choice 2) to inner surface of the veneers starting in one end and ending in another one, and putting on teeth gently, a sponge head of Ivoclar Optrasculpt Pad with a gentle pressure is used to enhance better sitting, then primary curing for few seconds, removing excess cement around it finishing line, finally final cure for 10 seconds, and apply glycerin gel then again 10 second for each surface (occlusal, insical third middle third and cervical third) light-cured with a LED unit (Translux Power Blue, Heraeus Kulzer) with a light intensity of 550 mW/cm2.

Figure 13. Veneer surface treatment.

2.7.Mechanical testing evaluation

The samples were fixed in a universal testing machine (Instron 4444, Instron Corporation) and subjected to the fracture resistance test under compression force. The test was performed with a speed of 0.5 mm/min using a 2 KN maximum load perpendicular to the buccal surface of direct or indirect veneers, until a complete or partial fracture of the samples. The force was applied through a zircon (VITA-Zahnfabrik VITA) sphere device with 7 mm diameter. adapted in the universal testing machine to simulate an antagonist tooth cusp.

Statistical analysis

SSPS 16 was used for statistical evaluation of the obtained data. First, descriptive analysis was performed. One-way ANOVA test was utilized to determine differences between groups. To visualize these differences, Tukey post hoc test was used. Significance level was set to P=0.05 with a confidence interval of 95%.

3.Results

3.1. Fracture Resistance

Table 1 shows the flexural strength of different samples of monolithic zirconia in mixture of 69% nitric acid and 48% hydrofluoric acid surface treatment group. In two samples, veneers crashed into multiple small pieces; tooth has a big crack from incisal tip in a frontal plane involving the whole enamel layer but did not separate completely after applying 930 Newton strength. Flexural strength between after using 880 N, Veneer fractured from tip of buccal cusp vertically into 2 pieces both parts had a tooth fragment mesial & distal part inside that fractured with them. The result of 830N & 740 N, veneers crashed into pieces and debonded, with sound tooth (Table 1&4; Figure 14). The other samples treated with mixture of 69% nitric acid and 48% hydrofluoric acid were summarized in table 1.

Table 1. Calculated maximum fracture strength loading resistance of veneer and tooth in mixture of 69% nitric acid and 48% hydrofluoric acid surface treatment

Number of samples	Fracture strength/Newton	Failure mode	Details
1	930	Veneer debond & crashing Tooth cracking	Veneer crashed into multiple small pieces; tooth has a big crack from incisal tip in a frontal plane involving the whole enamel layer but did not separate completely
2	900	Veneer debond & fracture	Veneer fractured into multiple pieces small part remained bonded to tooth on distal part, cervical part fractured sticking inside of veneer
3	450	Veneer debond & fracture	1/3 of veneer debonded and fractured into small pieces, the last third remained bonded to tooth surface
4	790	Veneer & tooth fracture	Veneer fractured from tip of buccal cusp vertically into 2 pieces both parts had a tooth fragment mesial & distal part inside that fractured with them
5	680	Veneer & tooth fracture	Veneer fracture into multiple pieces only small part remained on cervical part, tooth crown fractured in frontal plane from central groove toward buccal beyond cemento-enamel junction and separated completely
6	830	Veneer debond & crashing	veneer crashed into pieces and debonded, with sound tooth
7	740	Veneer & tooth fracture	veneer crashed into pieces and debonded, with sound tooth
8	880	Veneer debond & fracture	Veneer fractured from tip of buccal cusp vertically into 2 pieces both parts had a tooth fragment mesial & distal part inside that fractured with them

Table 2 reveals that an Sandblasted surface treatment of zirconia disk by Sandblasting method. The method had effect on the flexural strength and significantly increased the flexural strength resistance up to 1320 N (Table 2). Veneer de-deboned and fractured but tooth was sound after applying 550, 670, 600, 630 and 780 Newton strength. Veneers fractured into small pieces, cement remained on buccal surface of tooth. Tooth fractured in frontal plane completely and separated after applying 680, 890 and 1320 N flexural strength (Table 2&4; Figure 14).

Table 2. Calculated maximum tensile stress of treated group with Sandblasting method

Sample No.	Fracture strength/Newton	Failure mode	Details
1	550	Veneer debond & fracture	Veneer fractured into multiple small pieces, cement remained inside of veneer, tooth remained sound
2	670	Veneer debond & fracture	Veneer fractured into two pieces, with sound tooth
3	1320	Veneer & tooth fracture	Veneer crashed heavily into numerous pieces, one side of tooth fractured too remained inside of veneer fragments

4	680	Veneer & tooth fracture	Fractured into small pieces, cement remained on buccal surface of tooth. Tooth fractured in frontal plane completely and separated
5	600	Veneer fracture & debond	Veneer fractured into 3 pieces; cement remained inside the fracture veneer piece with sound tooth
6	630	Veneer debond & fracture	Veneer fractured into 3 pieces; cement remained inside the fracture veneer piece with sound tooth
7	890	Veneer fracture & debond	Veneer fracture and debonded cement remained on cervical finishing line, tooth cracked from the tip of buccal cusp to middle of tooth
8	780	Veneer debond & fracture	Veneer fractured into 3 pieces; cement remained inside the fracture veneer piece with sound tooth

Table 3 reveals that an acid etching surface treatment of zirconia disk by Nitric acid-hydroflouric acid Zircos E etching system (ZSAT) treatment had effect on the flexural strength and increased the flexural strength after using 1410 N (Table 2). Veneers fractured into pieces; only a small thin part remained on mesial finishing line, tooth was sound except the buccal cusp tip is cracked after applying 630-690 Newton strength. Veneers fractured into pieces; only a small thin part remained on mesial finishing line, tooth was sound except the buccal cusp tip is cracked by using 700 N up to 730 N flexural strength (Table 3&4; Figure 14).

Table 3. Calculated maximum tensile stress of treated group with Nitric acid-hydroflouric acid Zircos E etching system (ZSAT) treatment

Sample No.	Fracture strength/Newton	Failure mode	Details
1	630	Veneer & tooth fracture	Veneer fractured into multiple small pieces; cement remained on tooth surface. Tooth fracture and separated completely in frontal plane
2	690	Tooth fracture,	Tooth fracture while the veneer still bonded to buccal surface of tooth, fracture line started from centric occlusal groove toward buccal side extending beyond the crown to root also
3	730	Veneer fracture & debond	Veneer fractured into pieces; with sound tooth
4	1410	Veneer & tooth fracture	Fractured into small pieces, cement remained on buccal surface of tooth. Tooth fractured in in thin layers not sticking to veneer
5	700	Veneer fracture & debond	Veneer fractured into pieces; only a small thin part remained on mesial finishing line, tooth was sound except the buccal cusp tip is cracked

6	830	Veneer debond & fracture	Veneer fracture and debonded cement remained on cervical finishing line, tooth cracked from the tip of buccal cusp to middle of tooth
7	960	E-max tip fracture	The device tip fractured. Tooth is safe and sound with the veneer bonded to it
8	760	Veneer fracture & debond	Veneer fracture and debonded cement remained on cervical finishing line

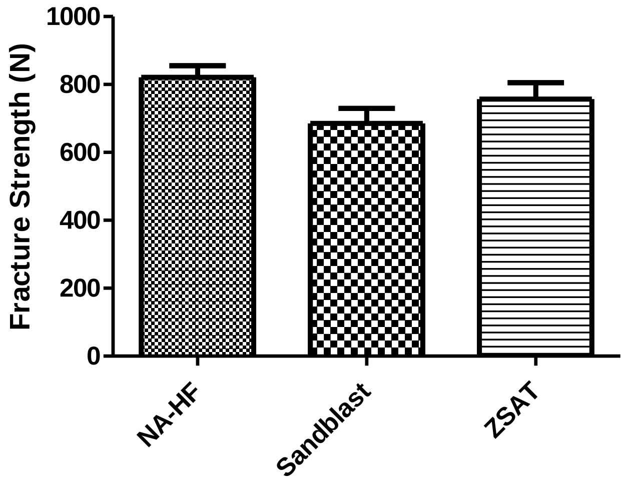

Figure 14. The effect of different surface modification of zirconia disk on fracture strength loading resistance.

Table 4. Mean value, Std. Deviation and Std. Error of Mean of different surface modification of zirconia disk

	NA-HF (Fracture strength/Newton)	Sandblast (Fracture strength/Newton)	ZSAT (Fracture strength/Newton)
Mean	**821.4**	**685.7**	**756.7**
Std. Deviation	**90.45**	**115.3**	**119.3**
Std. Error of Mean	**34.19**	**43.58**	**48.69**

4. Discussion

Due to the increasing demand for the use of dental ceramics, many researchers have considered trying to achieve changes in the properties of these dental veneers. These improved properties include increased aesthetics, chemical resistance, hardness, pressure resistance, and biocompatibility (14).

A standardized and predictable cementation protocol is one of the most important factors contributing to the long-term clinical success of any restoration, including zirconium oxide. Adhesive cementation protocols for silica-based ceramics are widely known and accepted (15).

However, despite the high popularity of synthetic restorations made of traditional zirconium oxide and the development of a new generation of zirconia ceramics, the adhesive cementation technique still creates controversy.

In case of insufficient mechanical retention and in order to improve the marginal adaptation of the prosthetic restoration, adhesive bonding is recommended. Furthermore, in the case of fixed prostheses made of high-

performance zirconia ceramics with weaker mechanical properties compared to conventional zirconia ceramics, the aim is to increase fracture resistance (16).
It is important to use such restoration surface treatment in the vicinity of the abutment tooth that ensures the micromechanical and chemical bonding of the zirconium ceramics to the resin cement and at the same time does not negatively affect the mechanical properties of the material. Surface treatment may have a positive effect on the bonding quality of zirconium ceramics with resin cement, but it also has a negative effect on the mechanical properties of the material such as its bending strength, hardness and modulus of elasticity (17).
In some studies, bond strength and durability of different bonding methods to dental ceramics have been studied. Bonding to traditional silica-based ceramics has been done by mechanical methods (18).
Etching with hydrofluoric acid (HF) along with the application of methacryloxypropyltrimethoxysilane (MPS) is another method of increasing bond strength to dental ceramics, which is used by roughening the surface of silica-based ceramics and increasing their wettability, zirconia It is a non-etchable polycrystalline material. This dental ceramic creates a very weak and unstable resin bond (19).
Clinically, crown detachment is a common failure of zirconia-based restorations. Therefore, the search for surface treatments that improve the adhesion of resin to zirconia has greatly increased. Effective and durable bonding methods, i.e., new treatments such as nanofilm deposition of silicon oxides, glassing technique (application of a thin, low-melting glass porcelain layer rich in silicon oxides), thermal silane, and chemical etching have been used to improve bonding to zirconia (15).
Sarmento et al reported that when zirconia was air-abraded with aluminum oxide (Al_2O_3) (110 µm), it resulted in an increase in zirconia roughness. Air abrasion protocols were modified with silicon dioxide (SiO_2) (110 µm; Rocatec, 3M ESPE). Heat treatment of pretreated zirconia with silane primer led to an increase in bond strength and higher bond durability than the primers created using acidic primers (20).
Using an experimental hot etching solution (hydrofluoric acid and nitric acid at 100°C) changed the morphology of the zirconia surface and significantly improved the surface roughness. Casucci et al first reported that different surface treatments affect the micro-tensile bond strength of resin cement to zirconia ceramic. They reported that conditioning a high-strength ceramic surface with SIE and hot etching test solutions produced higher bond strength than either aerosol-worn or untreated samples (21).
Other options for increasing the bond to zirconia are not suitable for clinical applications, mainly due to hazardous substances such as Piranha solution (a mixture of sulfuric acid and hydrogen peroxide), which is able to improve the hydroxylation and bond strength of the adhesive monomers (22).
One study used load testing to separate zirconia veneers after thermal cycling supported by teeth or composite cores. The zirconia surfaces were subjected to silicate or glass of the inner surface and were cemented with various cements (23).
The results showed that the effectiveness of the surface treatment depends on the resin cement used, because glassing improves the staying power of 2-hydroxyethyl methacrylate-based cement.
Several studies have shown that some surface treatments can affect the mechanical strength of zirconia-based ceramics (23, 24). Albakry et al investigated the effect of sandblasting, grinding, grinding direction and finishing on the flexural strength of zirconia ceramics. They observed that sandblasting and grinding increased the strength of dental zirconia (25).
The increase in fracture toughness after air abrasion was attributed to the residual compressive stress layer, which increases the transformation from tetragonal phase to monoclinic phase (26).
Zircos E is a new system for etching zirconia ceramics at room temperature in laboratory conditions. It is a combination of nitric acid and hydrofluoric acid. It has been proven to be effective in increasing the surface

roughness of the material before treating the zirconia surface with the Zircos E system for 2 hours (27). In addition, it is an alternative to sandblasting and tribochemical siliconizing.
Monomer or tribochemical siliconization with Rocatec and Co-Jet systems using silane (28). However, it should be remembered that prosthetic materials science is one of the most dynamically developing fields in dentistry, and therefore the zirconium surface treatment methods that are most effective today may be subject to modification. Dentists specializing in prosthodontics have the difficult task of constantly updating this knowledge, which leads to professional development and patient satisfaction, and thus to the success of treatment, which is of fundamental importance in the treatment process for both the doctor and the patient.

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