



Surface Treatment of Indirect Restorations

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Abstract

Background: All ceramic CAD/CAM materials require surface treatment protocols varying from one type to another according to their chemical composition, including hydrofluoric acid etching, sandblasting, silica coating, laser etching, and non-thermal plasma treatment. This review's objective to analyze and bring up-to-date data about the surface treatment of ceramics.

Data: The review just searched electronic publications of papers. Websites "Google Scholar" and "PubMed" were utilized as sources for performing data searches using the following keywords: Surface modification, plasma surface treatment, indirect restoration, ceramics The original papers and clinical investigations that were published between the years 2006 to March 2023 that were the most relevant to the subject at hand were chosen.

Conclusion: A variety of surface treatment methods have been proposed to enhance the bonding of restorative materials to resin cement and provide micromechanical retention by altering the restoration's surface mechanically by increasing the degree of roughness or physico/chemically by activating the surface. Hydrophloric acid etch is a golden standard for the surface treatment of feldspathic and lithium disilicate ceramics, the APC concept for zirconia, and hydrofluoric acid or sandblast surface treatment for resin nano-ceramic. A new approach used for surface treatment is plasma treatment, which is really promising in dentistry.

Introduction:

The surface treatment of the ceramics prior to cementation has an important effect on the effectiveness and longevity of ceramic restorations. For ceramic restorations to be successful clinically, cementation is essential. Ceramic materials can be generally categorized into three main groups depending on their formulation: polycrystalline ceramics, glass-matrix ceramics and resin-matrix ceramics (1). The majority of knowledge concerning adhesion has come from laboratory research, and the findings from these studies may be helpful in directing randomized clinical trials (RCTs) (2). Establishing a durable bond between zirconia and material is questionable (3). Hydrofluoric acid etching (HF) which creates micromechanical locks for resin bonding, destroys the glassy matrix of glass-ceramics. Zirconia cannot be effectively etched because it lacks a glassy phase (4). Conventional surface treatments to ceramics are utilised in order to improve the bond strength as HF acid etching or sandblasting (5). There are also alternatives like, silica coating (6), laser (7) Recently, non-thermal plasma has been used in dentistry for surface treatment. Micromechanical and chemical retention have been suggested for roughening the surface of ceramic, which results in better bond strength of CAM/CAM restorative materials to resin cement (8). Plasma produces carboxyl groups, which promote wettability and increase adhesion. The surface also becomes hydrophilic (9, 10). The kind of gas used, the duration of exposure, and the kind of material used to make the surface that the plasma is applied to have a significant effect on how the plasma interacts with material. Peizobrush is a novel handheld device that has applications in dentistry (11). The conventional pretreatment for glass ceramics is HF acid etching followed by silane application. Sandblasting is recommended for composite materials, followed by the application of primer (3). It is advised for hybrid to apply silane after hydrofluoric etching or CoJet/Al₂O₃ sandblasting. However, no reliable long-term bonding concept to resins exists for

zirconia restorations as of yet (12). Sandblasting the bonding surface of zirconium, followed by primer, is usually used for surface treatment (13, 14). However, hydrofluoric acid is a hazardous chemical with strong corrosive properties (15). Though, sandblasting could produce microcracks that limit the prognosis (16). Studies show that plasma treatment is a very promising dental treatment. To determine the most effective technique for cementing ceramic with adhesive resin, more studies involving various combinations of surface treatments, other cement types may be necessary, and thermal aging.

Methods\Search Strategy:

On the following websites, a thorough electronic search was done, the PubMed database and Google Scholar. The search was limited to manuscripts available in the English language from 2006 to 2023 in dental journals by using the following keywords: Ceramics, Surface treatment, plasma surface treatment, indirect restoration. A manual search of the reference list of the relevant papers was also done. The following types of articles were excluded: studies unrelated to the topic, personal opinions, editorials, and social media sources.

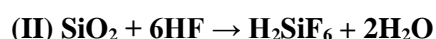
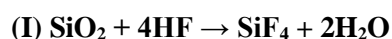
Surface treatment

Surface treatment can be well-defined as a process of surface conditioning that increases the surface energy, resulting in better wetting for bonding (15). Surface conditioning procedures have a significant impact on the bonding procedure, which also have an effect on the microstructures of the material surfaces (17). Chemical surface treatment techniques like acid etching and silane as well as mechanical ones like sandblasting, tribochemical and pyrochemical silica coating, and laser irradiation (18), and plasma surface treatment.

Chemical surface treatment methods**-Acid etching**

Hydrofluoric (HF) acid: is “an aqueous solution of hydrogen fluoride”. Because the HF bond is comparatively stronger

than the bonds formed by other strong acids such as (HCl), it is a weak acid and the function of the free hydronium ion (H_3O^+) is weak (19). HF has the ability to dissolve the glass phase of ceramic surface through the reaction with silicon dioxide (SiO_2). This process will increase the roughness of ceramic surface and subsequently creates micromechanical interlocking that improves the bonding strength between resin and ceramic material (3). The reaction process is demonstrated as:



It is important to know that the dissolution process of the glassy phase does not depend on the “acidic” property of hydrofluoric acid, yet because SiF glass has a high electronegativity, it depends on substituting fluoride for oxygen. Accordingly, the term “acid etch” is misleading and thus “HF etching” is preferred (3). However, HF has dangerous effects and it is highly corrosive material. When it is used intraorally, direct contact with enamel and dentin must be avoided. Calcium fluoride (CaF_2) precipitation, which develops on enamel and dentin and prevents the adhesive resin from penetrating into the dentinal tubuli, is the cause of weak adhesion with composite resin (20). (21) demonstrated that exposure to HF acid through contact or inhalation can cause severe eye, lung, and throat irritation as well as nail and/or skin burns. Following the manufacturer's recommendations is crucial when manipulating HF acid because different dosage forms (gel vs. liquid), acid concentrations, and formulation elements may have an effect on the final result (22). With the luting resin substance, which is typically hydrophobic in nature, this treatment process offers the potential for improved micromechanical retention and/or greater physical interactions and wettability. HF etching of feldspathic and lithium disilicate ceramics, has been considered as the golden standard for the treatment of the silica-based ceramic (23). The glassy phase of e.max CAD ceramic was destroyed by HF acid because the

lithium disilicate crystals were maintained, leaving a silica-rich active surface behind. 20 seconds of 5% hydrofluoric acid etching was performed, following the recommendations of the manufacturer. In several studies of the lithium disilicate etching procedure, it was discovered that increasing the etching time had an adverse effect on the material's flexure strength, and increasing the etching time or concentration did not significantly enhance the bond strength (24). The chemical etching period for feldspathic ceramics should be between 2 and 2.5 minutes with a concentration of 8 to 10% hydrofluoric acid (25). This causes a morphologic change in the ceramic surface, resulting in a honeycomb-like topography suitable for micromechanical bonding (26). In this process, hydrofluoric acid preferentially chemically interacts with the feldspathic ceramic's silica phase to produce the salt hexafluorosilicate, which is then washed away with water spray (27). For hybrid-ceramic (Vita Enamic), HF etching performed better surface treatment (28). IPS Ceramic Etching Gel (Ivoclar Vivadent, Schaan/Liechtenstein) is a gel-like aqueous solution of 5% HF (29), unlike VITA ceramic etching. It is a gel-like alcoholic solution of 5% HF and 10% sulfuric acid (30). Porcelain Etch, According to the manufacturer's instructions, Ultradent, a 9% hydrofluoric acid gel, can be utilized due to its high viscosity; it is ideal for intraoral repairs of broken porcelain in porcelain fused to metal or all-ceramic restorations (31). For intra or extra oral use, PORCELAIN ETCHANT, Bisco, is available in two different concentrations, 4% and 9.5% HF acid gel (32). Illusion offers of surface treatment two different Porcelain Etchants : 9.6% HF acid gel and 4% gel of acidulated phosphate fluoride (33). The etching time, hydrofluoric acid, that is micromorphological alterations and microroughness of the ceramic surface: Increasing the depth of the pores by prolonging the etching time (34). Longer than 60 sec of acid activity caused by etching results in a rougher ceramic surface the prevalence of cohesive failures in ceramic materials is increasing.

Between 20 and 60 seconds of acid etching the ceramic surface resulted in only slight structural alterations, according to a SEM examination. Between 90 and 180 seconds of acid etching produced a more noticeable morphology of surface with protruding lithium disilicate crystals (35). The etching pattern became more obvious when the time was increased from 20 to 120 seconds. When the acid etching period was increased from 20 to 30 seconds, a variation in micromorphology was not seen; however, prolonged etching up to 90 and 120 seconds induced a noticeable alteration in the surface micromorphology (36). Due to the increased dissolution of the surrounding silica matrix, Ceramics with leucite reinforcement and feldspar as a base developed deeper holes and grooves, and lithium disilicate crystals protruded more. The ceramic network material significantly disintegrated as a result of the prolonged etching of polymer-infiltrated ceramic network material (36). Nagayassu et al. (37) the long-term (4 min) HF etching of the resin ceramic bond has a negative effect. According to Zogheib et al. (35) increases the average roughness due to delaying the etching time of the treated surface, but reduces the flexural strength of the lithium disilicate at the same time slightly. However, The flexure strength values of feldspathic porcelain were not significantly different when 5% HF acid was used, when the etching time was increased from 45 to 90 and 180 s (34). When acid etched in the exact same conditions, different ceramics displayed varied surface patterns. For example, 5 minutes of surface etching feldspar-based ceramic results in pores with a depth of 5 to 7 μm , but 5 minutes of surface etching glass ceramic results in pores with a depth of up to 10 μm (38). As previously Kim et al.(39) The effectiveness of the surface treatment is dependent on the chemical composition of the ceramic; for a lithium disilicate ceramic, HF etching is the most appropriate procedure. Zirconia is a non-silica-based ceramic, hence HF cannot etch it at normal temperature. However, It is feasible to etch a zirconia surface by prolonged high temperature exposure in a high concentration HF solution (40).

According to Casucci et al., (41) zirconia that was hot-etched with a low acid concentration has a surface roughness that is similar to that of zirconia that had been room-temperature etched with a high acid concentration. When working with HF, an isolated workplace with suitable ventilation is necessary. Although HF is not a very strong acid, it diffuses into cells and destroys them by interfering with their metabolism. When HF is spilled on the skin, there may be no immediate burn since the effects can take up to 48 hours to manifest, including very deep tissue necrosis (41). A Zirconia Etchant Cloud System (Medifive Co., Incheon, Korea), which offered a triple-locking secure shell, an HF neutralizer, and a heat-generating pack, was utilized. It contained 9% HF gel (42).

Strongly acidic solution

Zirconia was pretreatment with etching solution, etched for 15 or 30 min, and sonicated at room temperature with a power of (100 W/cm^2) at a frequency of 30 kHz. The strongly acidic solution was created by combining (48%) HF acid and 70% nitric acid, followed by the adding of hydrogen peroxide to reach a 10% mixed of solution. After the zirconia was thoroughly washed with running distilled water, the furnace heated to (1150°C for 1 h) to completely eliminate the etchant and to reduce the residual stress that was acquired during the sintering process. Recently, it was revealed that zirconia's surface treatment might be altered using strong acid (43). Based on the findings of previous studies looking into the etching of zirconia, strong acids were created and useful in this investigation. The etching procedure, which uses a strong acid to chemically dissolve particles on the zirconia surface, may be advantageous since it allows for a more objective application and produces more consistent results than sandblasting. Previous research, (SEM) images showed Although morphological changes occurred on the surface of zirconia after etching with a strongly acidic solution, the defects of acid-etched surfaces were more homogeneous and detailed (44).

Acidulated phosphate fluoride (APF)

The APF contains (1.23%) fluoride ions originated from sodium fluoride and HF acid, acidified with 0.1 M phosphoric acid (45). Similar to how HF acid affects ceramic surfaces, APF also has this effect. It disrupts the silica network by selectively releasing Na ions to damage the glassy phase(46).

Phosphoric acid

In dentistry, orthophosphoric acid, an inorganic acid having the molecular formula (H_3PO_4), is used as a phosphoric acid (3). On enamel and dentin, phosphoric acid works well, but it has no direct effect on the surface properties of ceramics, metals, or composites. The degreasing and cleaning actions of phosphoric acid etching on these surfaces, however, have a beneficial effect on retention rates following the repair process. Evidently, acidity has no significant impact on the etching process, but fluoride's participation in the atomic displacement of silicon dioxide is more significant (3).

Silane treatment

In dentistry, 3-methacryloxy propyltrimethoxysilane (or γ -methacryloxypropyl-trimethoxysilane) is the silane that is most usually used to attach resin to ceramics. It is a bifunctional molecule, and its abbreviations are MPS, MTS, or MPT (15). MPS silanes consist of a reactive silanol group on one side, which can create siloxane bonds with the silica and/or alumina present on the substrate surfaces, and a methacrylate group on the other side, which reacts with the intermediate adhesive resin and composites (47). Ceramic surfaces have been discovered to be more wettable and have a smaller contact angle when silane coupling agents are used (48). Silane is often placed in thin layers that range in thickness from 10 to 50 nm. It has been found that if silane is applied on ceramic surface in a successive number of layers, a cohesive destruction of layers will be occurred (49). In order to achieve adequate bonding, it is advised that ceramic surfaces be coated with a thin coating of

silane (3). There are two types of silanes: hydrolyzed and nonhydrolyzed. The hydrolyzed silanes are used directly and must be applied previous to the adhesive resin as a separate step. Nonhydrolyzed silane needs to be activated first by mixing with an acid which is an acidic monomer that is present in the primer or adhesive resin depending on the used adhesive system (47). Silanes can be used extremely successfully to promote adhesion in silica-based materials like porcelain. However, utilizing silanes alone has poor adhesion performance for non-silica-based substrates like zirconia, metals, or metal alloys. The silica-coated layer is adhered to the surface of the substrate, enabling the silane to form long-lasting connections with substrates made of non-silica materials throughout this coating. Additionally, the enhanced surface roughness of this layer enhances micromechanical interlocking (15). Monobond Etch & Prime is a recently introduced one-bottle system that combines silane with ammonium polyfluoride without the use of hydrofluoric acid. Ceramic primer that is self-etching should be washed with water after application. By etching and priming glass-ceramics in a single step with this technology, the bonding process is made simpler while maintaining the ceramic material's ability to adhere to the luting cement (50). A silane coupling agent Clearfil Ceramic Primer Plus (Kuraray Noritake Dental Inc., Tokyo, Japan) contain a phosphate monomer in their chemical composition (28). G-Multi PRIMER (GC Corporation, Tokyo, Japan) ensuring optimal adhesion in every situation by containing three separate chemical agents. The stability of the adhesion is ensured by adding silane to primer rather than a bonding agent. Silane will offer adherence to glass ceramics, lithium disilicate, hybrid ceramics, and composites. MDP will ensure adhesion to precious metal and zirconia, and MDTP will ensure adhesion to precious metal, respectively. Light air flow was supplied for 5 s, allowing the solvent (ethanol) to evaporate (51).

Universal primer (Monobond Plus; Ivoclar Vivadent AG) provided high bond strength (52), like the (Clearfil Ceramic Primer, Kuraray). A new zirconia primer containing organophosphate monomers and carboxylic monomers (Z-Prime Plus; Bisco Inc) was suitable for various resin cements and improved resin cement bonding after sandblasting (53). The AZ Primer (Shofu, Dental Corp) containing phosphonic acid monomers provided a better bond than other silane primers. The other primer that contains the adhesive monomer thiophosphoric methacrylate and provides a more effective and durable bond than ceramic primer (GC Corp) is Metalprimer II. (GC Corporation, Tokyo, Japan) (54). Non-precious alloys easily create a layer of oxide on their surface that chemically binds to the phosphate ester groups of MDP. Therefore, after surface treatment, it is possible to create predictable adhesive bonding by employing an MDP containing primer or cement. Manufacturers were quick to incorporate sulphate monomers and MDP into single-bottle metal primers. This has greatly simplified the alloy bonding process because the same processes can be used for each type of material, though the benefit of these combination primers for non-precious alloys over MDP alone is questionable (55).

Mechanical surface treatment methods

Sandblasting with aluminum oxide

Al₂O₃ particles (30–250 µm in diameter) are typically used for the grit-blasting treatment of surfaces, which is delivered in an airstream (2–3 bar) and applied for about 15 seconds. The hand-piece nozzle must be directed perpendicularly at (1cm) distance away from the ceramic surface, and this instruction differs according to the ceramic material used. This procedure cleans the surface, specifically increases surface roughness, and enhances micromechanical bonding (56). A thin layer of alumina may be applied to the substrate's surface after sandblasting. Additionally, the blasting pressure directly correlates with the amount of alumina deposit (57). The mechanical strength at the surface layer may be compromised by

this method's potential for subsurface damage and the development of surface microcracks during the impaction of the powder particles (58). Strasser et al. (12) discovered that the zirconia surface treatment used small or medium grain size and low pressure, the resin-infiltrated ceramic surface treatment used Hf etching or small grain size and low pressure, and the surface treatment for composites used sandblasting. Şişmanoğlu *et al.* (28) sandblasting was more effective for resin nano-ceramics (CeraSmart, Lava Ultimate, and Shofu HC). Mahrous et al. (59) applied primers comprising phosphate ester monomers, such as 10-methacryloyloxydecyl dihydrogen phosphate, to the surface of zirconia after applying a 50 µm Al₂O₃ particle at a distance of 10 mm for 10 seconds under 0.3 MPa pressure. Chintapalli et al. (58) indicated that the sandblasting conditions (abrasive particle size and pressure) had an effect on the degree of subsurface t-m change and substrate damage. The sandblasting pressure and alumina particle size has an effect on the zirconia specimens' surface roughness values, Kwon et al. (60) found that the bonding strength of the adhesive resin cement was unaffected by increased surface roughness and stress. To achieve strong and long-lasting durable bond strengths to zirconia, the APC concept for zirconia bonding has been established, which is based on decades of study. There are three practice steps in it.: (A) air-particle abrasion, (P) zirconia primer, and (C) adhesive composite resin. (APC-Step A) after cleaning for restoration, zirconia should be subjected to air-particle abrasion with alumina or silica-coated alumina particles; some refer to this process as microetching or sandblasting. (APC-Step P) The next step is covering the zirconia bonding surfaces with a specific ceramic primer that often contains specialized adhesive phosphate monomers. (APC-Step C) dual or self cure composites should be used to confirm adequate polymerization beneath the zirconia restoration, which decreases light transmission (61).

Silica-coating

The pyrochemical silica-coating is based on the principle of chemical reactions of silane at high temperature to form silica (62). The Silicoater system was the previous thermal silica-coating method utilized in dentistry labs (HeraeusKulzer, Wehrheim, Germany). This method can be used to cover porcelain, noble metal alloys, and base metal alloys as substrates (63). The silane solution is injected while the substrate is passed through a flame. As a result, at temperatures between 150 and 200, a sequence of pyrochemical reactions take place, and an intermediate layer of siliconoxide is created above the substrate surface. ThenAfter allowing the ceramic to cool at room temperature, a silane coupling agent is applied to the freshly produced silicon oxide layer (49). Tribiochemical In 1989, this method was developed to enhance the pyrochemical silica coating. Rocatec System (3M-ESPE, Seefeld, Germany) tribochemical silica-coating and silanization were combined to provide a marketable product for excellent surface preparation (64). It was indicated to condition many dental substrates surfaces like: metals, metal alloys, and ceramics. The surface of the substrate is subjected to grit-blasting via silica-coated alumina powder under compressed air. The alumina particles will transfer the kinetic energy and the absorbed energy will cause microscopic melting of substrate surface and rise the surface temperature to 1200 momentarily. The melting zone on substrate surface is depended on the kinetic energy of the powder particles (65). Alumina powder has the ability to embed itself onto the surface of the substrate in addition to changing the surface topography. The silica-coated surface is then silanized as a primer and then bonded using flowable composite resin. The blasting pressure used in this procedure affects the bond strength that is attained (66). Also, The grit blasting angle was discovered to alter resin bonding, although modifying the sand blasting distance had no apparent effect (67). The CoJet® system is a chair-side version of the Rocatec® System and it is used at dental offices for intraoral

repairs using 30µm silica coated alumina powder. Silica coating and silane application with the Rocatec System (3M ESPE Dental Products, St. Paul, MN, USA) seems to give bisphenol A glycidyl methacrylate (BIS-GMA) composite cements a reliable resin binding to glass-infiltrated aluminum oxide ceramic. Bisphenol A glycidyl methacrylate (BIS-GMA) composite cements appear to have a uniform resin bonding to glass-infiltrated aluminum oxide ceramic (68). The Procut CoSiLab 110 micron silica highly coated aluminum oxide, which is specially packaged in cartridges for Aquacare Air Abrasion machines, is ideal for: chrome cobalt, titanium, gold, and ceramic high performance polymers. Tribochemical coating and a silane coupling agent are employed to treat the metal alloy's surface. used for surface treatment of metal alloy (69).

Laser surface modification

The term LASER is an abbreviation of "light amplification by stimulated emission of radiation". In dentistry, Laser irradiation is a well-known and often used method for dental therapy. Nowadays, Lasers can be utilized as an additional tool that sometimes complements or replaces conventional dental treatments (70). The effectiveness of laser treatments and their present applications depends on a number of factors, including the laser's power, frequency, treatment time, distance from the surface, and kind of bonding system (71). The laser energy will be absorbed and converted into heat energy when it is applied to a substrate surface. The substrate surface melts as a result of this heat energy, which also causes surface irregularities (72). Thus, the modification of surface topography will occur and the adhesion will be enhanced. Recently, dental lasers can be used as an alternative conditioning technique in repairing processes of dental restorations made from ceramics, composite and resin ceramic materials in a relatively easy and safe manner. Laser irradiation causes micro and macro porosities on ceramic surfaces, which changes the surface and increases the dental ceramic's micromechanical adherence with resin materials (73). The

visible to far infrared regions of the electromagnetic spectrum (400 nm to 10.6 m) can be used for the clinical application of laser in dentistry (70); Table (1).

Nd:YAG laser: The neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers are a group of solid-state lasers that are broadly used in dentistry (74). The Nd:YAG laser's wavelength, 1064 nm, occurs in the invisible nonionizing infrared region of the spectrum. Soft tissues that contain colored chromophores effectively absorb emission in the pulsed mode. Therefore, Nd:YAG laser can be utilized successfully for numerous soft tissue applications, such as periodontal operations, requiring good hemostasis (75). Recently, After tooth extraction surgery, the Nd:YAG laser has been employed in photobiomodulation treatment to speed up wound healing (76). As well, Nd:YAG laser has many uses in dentistry, including lowering tooth sensitivity, removing tooth decay, whitening teeth, cleaning dental tissues, and acting as a promising therapy option for indirect restorations (77). The Nd:YAG laser is a technique for altering the surface of dental ceramic before bonding that has been used in various research (80). This technique involves melting and inducing random crystallization to create microporosities, increase surface roughness, increase surface energy, and improve wettability (78).

Erbium laser: The erbium lasers family including Er:YAG (Erbium-Yttrium Aluminium Garnet), and Er,Cr:YSGG (Erbium, Chromium-Yttrium Scandium Gallium Garnet). The benefit of utilizing lasers with two different radiation wavelengths (2780 nm and 2940 nm), is that they are relatively moderate heating effects on adjacent (79). These lasers have a high affinity for hydroxyapatite crystals and the highest absorption of water and act by leveling the water content, resulting in micro-explosions of the surface. Therefore, erbium lasers can be practical for dental hard tissues treatment (80), also they can be employed for ablation of soft tissue. Although there are slight differences between the Er,Cr:YSGG and

Er:YAG lasers, such as laser wavelengths, pulse duration, and energy, they basically are similar in their properties. The Er,Cr:YSGG laser has been employed in different dental therapeutic applications including, caries removal, cavity preparations, tooth whitening gel activations, periodontal disinfection, and surface conditioning of teeth, hard and soft tissue therapies. The Er,Cr:YSGG laser uses the principle of micro explosion during tissue ablation to produce microscopic and macroscopic abnormalities (81). The Er:YAG laser removes surface particles by a process called "ablation", which involves micro-explosions and vaporization. In recent studies, it has been shown to be useful as a way of surface preparation that strengthens the bond between resin materials and ceramic restorations. When employed with the proper conditions, the Er:YAG laser can remove the glass phase from ceramic surfaces to form an irregularly rough surface and create micromechanical retention for resin material bonding (82). Furthermore, This laser has a high optical penetration depth that enables direct application to ceramic surfaces, making it a desirable alternative surface treatment approach (83).

CO₂ laser: Zirconia ceramic has a high capacity for CO₂ laser wavelength absorption. Porosity is created on the surface of the ceramic as a result of the laser's surface destruction and temperature increase, which increases the micromechanical retention of resin cement to zirconia ceramic (84). Previous experiments which examined how laser treatment affected the shear bond strength between zirconia and resin cement came to the conclusion that CO₂ laser has the capacity to improve shear bond strength (84). Zirconia ceramic has the capacity to absorb CO₂ laser wavelength fully. Heat induction caused by the laser's absorption causes a lot of shell-like porosities to form on the ceramic's surface. These porosities allow resin to enter and harden, creating a micromechanical connect with the ceramic (84). In contradiction with this research's results, Akin et al. (85) investigated the impact of

sandblasting and other lasers on the bond strength of resin cement to zirconia and found that CO₂ lasers reduce the bond between them. Due to the glass components in these ceramics, hydrofluoric acid and silane were utilized for evaluating their bonding strengths, although CO₂ laser irradiation of the ceramic surfaces revealed that this process had no apparent effect. Also, Combining CO₂ with sandblasting and silane to strengthen the shear bond (SBS) between resin cement and zirconia (86).

Flame treatment

Flame treatment oxidizes polymeric materials' surfaces to add polar reactive groups like hydroxyl and carboxyl, improving surface free energy and, as a result, the surfaces' wettability and adhesion. The use of this method for the treatment of ceramics is rather recent [31,32]. By applying surface treatments to ceramics made of silicate, aluminum oxide, and zirconium oxide, the PyrosilPen flame treatment technique was investigated. It produced good bonding to luting composites, it was discovered. However, Sandblasting the ceramic surfaces initially before flame treatment resulted in a stronger connection following surface treatment (87).

Plasma surface treatment

In recent years, the plasma surface treatment of ceramics, which is thought to have a novel use in dentistry, has attracted lots of interest. Atoms, molecules, and extremely excited radicals make up plasma, the fourth state of matter. At atmospheric pressure, there are two types: thermal and non-thermal (cold), with gas temperatures nearly equal to ambient temperature (88). Surface activation, which affects the topmost atomic layers of the surface, is accomplished using atmospheric plasma. A surface that hasn't been treated practically ever has polar end groups that could interact with the liquid, whereas plasma makes these end groups on the surface's molecule. With the most modern handheld tool, the piezobrush® PZ3, this is practically possible without having any heat effects on the surface. After the procedure, the surface still has

the same appearance and the surface roughness is unaffected, but it now has polar anchor groups that can create strong bondings with the adhesive. The surface's wettability is increased by plasma treatment that forms carboxyl groups, making it hydrophilic. Silva *et al.* (89), and Ye *et al.* (90), who all found plasma-treated zirconia. Dos Santos *et al.* (91) who found a higher surface energy of lithium disilicate after plasma. Zhu *et al.* (92) who found that plasma treatment of resin nanoceramic increased wettability.

Effect of Plasma on ceramic

a. Wettability: Following plasma surface application, the oxygen components were enhanced. Furthermore, plasma promoted the formation of active peroxide radicals and more functional groups (C-OH and C-O) on surfaces of inert ceramics such as zirconia, resulting in increased surface energy (93, 94). Surface energy is a concept that describes the intermolecular forces of a material's surface based on its polar and dispersion constituents (95). The surface energy of a surface and contact angle measurements of liquids have a relationship that is opposite (96).

b. Surface treatment: It occurs when a substrate is exposed to a gas that does not contain carbon, such as oxygen, ammonia, or nitrous oxide. The principal effect is the integration of various process gas moieties onto the surface of the substrate being treated. activation of surface and generation of anchor groups (90).

c. Cleaning: A clean material surface is well recognized to facilitate efficient bonding between heterostructures, and plasma cleaning can efficiently remove impurities and contaminants from surfaces (44). The excited particles in the plasma oxidize the surface layer of hydrocarbon and carbonate molecules, producing H₂O and CO₂, which are desorbed from the surface and pumped away(97).

Cleaning of the restoration

Ceramic bonding surfaces are frequently contaminated by silicone pastes, blood, saliva, rubber gloves, and residual gypsum. The surface layer has been removed using a variety of techniques, including as organic solvents, acids,

alumina with abrasive particles, water washing, and ultrasonics. Over the last few years, a few commercial zirconia cleaners have been released (98).

These cleaners include Ivoclean (Ivoclar Vivadent, Schaan, Liechtenstein), The most suggested technique for cleaning ceramic and metal pretreatment surfaces is Ivoclean, a solution of zirconia powder and sodium hydroxide.

ZirClean™ (Bisco Inc., Schaumburg, IL, USA), is an alkaline solution, which contains potassium hydroxide, and is a cleaning agent for zirconia ceramic and metal.

KATANA™ Cleaner (Kuraray Noritake Dental Inc., Tokyo, Japan) and AD gel (Kuraray Noritake Dental Inc). NaOCl and alumina make up 10-15% of the AD gel. Sodium hypochlorite works through non-selective oxidation and has a rather high pH.

Both Ivoclean and ZirClean™ are alkaline cleaners, a A gel containing potassium hydroxide. It is a powerful alkaline solution that can remove impurities from restorations while boosting adhesive strength and KATANA™ Cleaner decontaminates via the incorporation of surfactants (99). The damaging effects of intraoral contamination on surfaces appear

to be inhibited by the use of an ethyl cellulose protective lacquer.

Lee et al. (44) Discovered after sandblasting, the zirconia blocks were cleaned using ultrasonic for three minutes, Then thoroughly cleaned with running distilled water once more. Şişmanoğlu and Turunç-Oğuzman (28) the ceramic surface was cleaned with distilled water using an ultrasonic bath for 5 minutes, and then it was allowed to air dry.

Conclusion

Various surface treatment methods have been recommended to improve the bonding of restorative materials to resin cement. Hydrophloric acid is a golden standard for the surface treatment of feldspathic and lithium disilicate ceramics, the APC concept for zirconia, and hydrofluoric acid or sandblast surface treatment for resin nano-ceramic. A new approach used for surface treatment is plasma treatment, which is really promising in dentistry.

Conflict of interest: None

Table (1): Different lasers classifications(75)

Classification of Lasers		
Mode of Operation	Continuous	
	Pulsed	Q-switching mode-locking pulsed pumping (FS)
Lasing media	Gas	Argon laser (488-515 nm) CO2 laser (9.3, 9.6, 10.6 nm)
	Solid	Nd:YAG laser (1064 µm) Er: YAG laser (2790 nm -2940 nm) Er:CrYSGG laser (2780 nm) Ti: Sapphire laser (650 nm -1180 nm)
	Semiconductor	Crystals Diode laser (812 nm -1064 nm)
Tissue type	Hard	CO2, Er:YAG and Nd:YAG lasers
	Soft	Argon and Diode lasers

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