Pharmacogn J. 2024; 16(1): 204-210
A Multifaceted Journal in the field of Natural Products and Pharmacognosy
www.phcogj.com

Research Article

Effect of Plasma Treatment on Tensile Bond Strength of (5) Yttrium Zirconia Coping Fixed on Titanium Implant Abutment

Amani Abduljabar Altaie *, Emad Farhan Alkhalidi

Amani Abduljabar Altaie *, Emad Farhan Alkhalidi

Department of conservative dentistry, College of Dentistry, University of Mosul, Mosul, IRAQ.

Correspondence

Amani Abduljabar Altaie

College of Dentistry, University of Mosul, Mosul, IRAQ.

E-mail: amani.abduljabar@uomosul.edu.iq

History

- Submission Date: 13-12-2023;
- Review completed: 14-01-2024;
- Accepted Date: 17-01-2024.

DOI : 10.5530/pj.2024.16.29

Article Available online

http://www.phcogj.com/v16/i1

ABSTRACT

Objective: The goal of this research is to investigate the effect of plasma surface treatment on retentive strength (RS) between the (5)Yttrium Zirconia coping and the titanium implant abutment (Dentium system) using self-adhesive resin cement. **Methods:** forty standard titanium implant abutments of 5.5 mm height and 4.5 mm in diameter were screwed with implant laboratory analogs embedded vertically in autopolymerizing acrylic resin blocks, forty Zirconia copings with a hole on the occlusal surface were fabricated using CAD/CAM system. Samples were divided into four groups (n 10 for each group); Group (1) no plasma surface treatment for implant abutment and coping (act as control). Group (2) plasma surface treatment for implant abutment only. Group (3) plasma surface treatment for coping only. Group (4)plasma surface treatment for implant abutment and coping. Coping of all groups were cemented with implant abutment by Allcem dual cure resin cement. All cemented samples were (5000) cycles of thermocycling process and then tensile bond strength evaluated by Universal testing machine, Following the tensile bond strength test, each debonded surface was examined by stereomicroscope at a 20x magnification. The one-way analysis of variance and Duncan test were used to statistically examine the experimental results. **Results:** Plasma surface treatment had observed effect that increase tensile bond strength between titanium implant abutment and (5) yttrium Zirconia coping, plasma surface treatment for abutment and coping (Group 4) was the highest value of tensile strength followed by abutment plasma surface treatment (Group 2), while lowest value of tensile bond strength in control group (Group 1) and coping plasma surface treatment (Group 3). **Conclusion:** Plasma surface treatment increase tensile bond strength between implant abutment and zirconia coping. Plasma surface treatment for both abutment and coping provided higher tensile bond strength. Mode of failure was adhesive failure occurs in abutment surface.

Keywords: Plasma, Titanium abutment, (5)Y Zirconia. Tensile bond strength.

INTRODUCTION

Dental implant is the finest alternative available in modern dentistry to replace missing tooth or teeth. They provide an remarkably effective durable, and aesthetically pleasing alternative. Most patients discover that they are steady and secure and good suitable substitute for their natural teeth.[1] Implant abutments are parts that attach to implant fixtures in order to hold and/or support a prosthesis. Titanium are the most popular material for abutments, because it has a great mechanical strength and excellent biocompatibility, making it a popular material for implant abutments.[2]

Nowadays, cement retained prostheses supported by implants are more common due to a number of advantages, including loading along a linear axis, better passivity fit, a small occlusal table because of the lack of an accessibility hole, and a lower risk of porcelain fracture. The only significant benefit of a screw-retained prosthesis is its retrieval.[3]

Cementation of indirect restorations is an important part of the treatment regimen in reconstructive dentistry and typically indicates the end of dental rehabilitation[4]. Adhesive resin cements are non-acidic, have a high tensile strength, and exhibit high micromechanical bonding to alloy and ceramic surfaces. However, their primary drawback can be attributed to polymerization shrinkage, but in modern types have modification in its composition to reduce polymerization shrinkage such as addition of filler particles.[5,6]

The discipline of dentistry has been using more and more cosmetic materials in recent years, This could be the result of the necessity to fulfill patient requests and the advancement of new fabrication techniques. With the state of restoration systems today, computer-aided design and computer-aided manufacture (CAD/CAM) guarantees tooth-colored restorations made of ceramic and resin materials in a timely manner.[7]

Zirconia restorations have been well-established in conservative dentistry during the past few years, enabling excellent mechanical properties and appropriate biocompatibility, CAD/CAM systems were used in prosthodontics to realize zirconia restorations.[8]

To improve the translucency of zirconia, 5 mol.% yttria-partially stabilized zirconia (5Y-PSZ) or ultra-translucent zirconia.[9,10] Increasing the concentra tions of yttria increases the amount of the optically isotropic cubic phase,[11] In addition, cubic grains are typically larger than tetragonal grains, resulting in fewer grain boundaries. Because the light transmission through polycrystal ceramic is strongly affected by the two-sidedness at the grain boundary, the smaller number of grain boundaries in 5YZ increases its translucency.[12,13]

Cite this article: Younis AA, Altaie AA, Alkhalidi EF. Effect of Plasma Treatment on Tensile Bond Strength of (5) Yttrium Zirconia Coping Fixed on Titanium Implant Abutment. Pharmacog J. 2024;16(1): 204-210.

Plasma surface treatment is technique for altering a material's surface that has been utilized for a long time in many industrial and medicinal domains.[14] highly reactive species such as electrons, free radicals, ions, and electronically excited neutrons are found in plasma.[15] With little alteration to the materials' inherent qualities, these plasma species increase surface reactivity.[16,17] Specifically, of the several forms of plasma, non-thermal atmospheric pressure plasma (NTP) doesn't need the vacuum apparatus needed for vacuum plasma, Furthermore, NTP generation equipment has low maintenance expenses in addition to being affordable.[16]

In dentistry, NTP processing has been developed, and it may be a useful technique for raising the zirconia coping's retentive strength,[18] and The titanium surface of implant abutment forms an oxide layer after being treated with NTP. As a result, the surface turns hydrophilic, potentially changing the adhesion qualities.[19]

Hence, this study was to evaluate tensile bond strength and mode of failure between (5) Y zirconia coping and titanium implant abutment after plasma surface treatment. Null hypothesis of this study is no difference in tensile bond strength between (5) Y zirconia coping and implant abutment before and after plasma surface treatment of them.

MATERIALS AND METHODS

Specimens Preparations

Forty prefabricated titanium abutments (abutment- Hex type) from Dentium System, Korea; with (5.5mm) height, (4.5mm) in diameter, (1.5mm) of gingival height and (8°) tapering per side were used in the research, Each titanium abutment constructed with a screw which was used for fixation of the abutment to its fixture or laboratory analog, Then, forty laboratory analogs (with 12mm height and 4.5mm in diameter) were prepared to be used in this study.

Each titanium abutment was mounted onto its laboratory analog with titanium abutment screw and torqued to (35 N/cm) using a torque-controlled ratchet, and then adapted into acrylic mold (Figure 1).[20]

Surface treatment of specimens

The forty specimens (which include the Dentium titanium abutments adapted to the analogs in the acrylic mold) were randomly divided into four main groups according to the type of surface treatment:

Group 1: n=10 where the titanium abutments no surface treatment.

Group 2: n=10 where the titanium abutments treated by plasma with CORE plasma activator.

Group 3: n=10, where the inner surface of zirconia coping treated with plasma by non-thermal plasma for 80 sec, 100% plasma power and 5cm2/s treatment speed using a non-thermal plasma device (PiezoBrush® PZ3 Handheld Device, Relyon Plasma, Regensburg, Germany), The device was a handheld unit that generated a plume of plasma jet at atmospheric pressure.[21]

Figure 1. Implant analog with abutment seated in an acrylic resin mold.

Group 4: n=10, where the titanium abutments treated with plasma by plasma CORE activator and inner surface of zirconia coping treated with plasma by non-thermal plasma for 80 sec, 100% plasma power and 5cm2/s treatment speed using a non-thermal plasma device (PiezoBrush® PZ3 Handheld Device, Relyon Plasma, Regensburg, Germany), The device was a handheld unit that generated a plume of plasma jet at atmospheric pressure.

Zirconia Copings Construction

Type of zirconia used in this study was (5) Yttria tetragonal zirconia polycrystalline high translucent (5Y-TZP/VITA YZ® HT, shade white, VITA Zahnfabrik , Germany), we need forty coping copings were fabricated in CAD/CAM system in following steps:

1. Computer surface digitization: Scanning of implant abutment is done with LED based scanners. Autoscan DS500 is perfect for module scanning.

2. Computer-aided designing (CAD): A three-dimensional image of the abutment is produced over the screen and can be rotated for observation from any angle. Once the 3-D image is captured through any of the computer surface digitization techniques, 3-D image processing is done and the digitized data is entered in the computer. Designing of the Zirconia copings is done using CAD software in its dimensions are (height of coping 9.3mm, diameter of coping 3.8mm, diameter of hole 0.6mm and cement cap 0.5 micrometer), which in turn sends commands to the CAM unit, for fabricating the restoration.[22]

3. Computer-aided manufacturing (CAM):Third stage is Computer-aided manufacturing (CAM) by Subtractive technique from a Solid Block, Cut the zirconia disc to the specific dimensions with a milling machine (Zircon Zahn) by IMS 303 UL & IMS 302 UL (1- 0.6 mm) cutting burs and IMS 301 UL (0.3 mm) finishing bur and prepare it for sintering (firing).

4. Firing: the prepared samples of zirconia has been sintered (fired) in an NHT oven, ZirCAD Prime was used in accordance with manufacturer instructions for 9 hours and 50 minutes (heating phase starting temperature 20°C, heating until temperature reach 900°C by heating rate 10°C/min and holding in 900°C for 30 min, then heating until 1500°C by heating rate 3.3°C/min and holding in 1500°C for 120 min, after which cooling phase start cooling from 1500°C to 900°C by cooling After sintering, verify all dimensions with an electronic digital caliper. The specimens were then ultrasonically cleaned following polishing with 1200-grit silicon carbide paper (Figure 2).

Cementation and Thermocyclin

Specimens Cemented with the Dual-cured Resin Cement (Allcem cimento dual, FGM shade A2) Each coping coping was filled with the luting agent by an examiner and the explorer was used to distribute the luting agent over the entire inner surface of the coping coping, then the coping was hand-seated over its selected abutment. In order to achieve a standardized seating pressure over the coping during the cementation process and to eliminate the excess that may appear when different seating pressures over the coping were applied, a special device (AS-Standardized Cementation Load) was locally manufactured.

Then, the bonding material was cured using a light curing machine (Eighteeth, China) of (1180 mW/cm2) intensity and (450 nm) wave length for about (1minute), the thermocycler (100 SD Mevhatronic, Germany) was used in this experiment. All samples underwent (5000) cycles of thermocycling in deionized water between 5 and 55 degrees Celsius having a 10 second transfer time and a 30 second dwell time.

Figure 2. Final adjustments and shape of coping.

Tensile Bond Strength Measurement

Each coping was pulled with a crosshead speed of (0.5 cm/min). The force at which the bond failure between the coping and the abutment appeared on the meter which was already connected to the tensile machine, then the record was transferred to the computer and saved by Universal testing machine (Gester, China).

Mode of Failure

After testing of tensile bond strength , every debonded surface was examined under stereomicroscope using 20x magnification (Optika, Italy) to determine the mode of failure. The mode of failure was classified as below:

1. Adhesive failure at: A) interface of adhesive and abutment B) interface of adhesive and Zirconia coping.

2. Cohesive failure: Failure within the resin cement (adhesive).

3. Mixed failure which is combination of Adhesive and Cohesive failure.

RESULTS

Evaluation of The Tensile Bond Strength Between Zirconia Copings and Implant Abutments

Upon completion of the experimental technique. The forces needed to separate the titanium abutments from the coping copings were measured in Newton in each group. These results were statistical descriptive analysis was performed on these data (Table 1).

The results show that the greatest retentive mean value of bond strength obtained in plasma surface treatment for abutment and coping (group 4) (163 N) followed by plasma surface treatment for abutment only (group 2) (143 N). Whereas the least retentive mean value was recorded in control group (51 N) followed by plasma sutface treatment for coping only (group 3) (70 N).

The analysis of variance (One way ANOVA) was made to show if there is a significant differences among the groups (Table 2).

The One way ANOVA test results indicated that there is a significant differences between the groups at (p-value < 0.01). This mean that one or all of groups are different from each other.

In order to know which of group are significant different from the other group, Duncan's multiple range test was made. The Duncan's Test revealed that all groups are different from each other as shown in Table (3):

Mode of Failure Evaluation

All samples had adhesive type failure in abutment surface (Figure 3).

DISCUSSION

Due to excellent mechanical qualities, high corrosion resistance, low density, and exceptional biocompatibility, titanium (Ti) and its alloys are frequently utilized as dental materials in prosthodontics and implantology.[23]

Zirconia's superior mechanical qualities, chemical stability, and biocompatibility make it a desirable core material for all-ceramic restorative construction.[24] However, zirconia ceramic demands different methods for a long-lasting, resilient resin bond. Thus, a variety of surface treatments are applied to enhance bonding to zirconia ceramic including alumina coating,[25] plasma surface treatment, tribochemical silica coating,[26,27] or airborne-particle etching.[28]

The growth of dental computer-aided manufacturing (CAM) and computer-aided design (CAD) technologies has led to a rise in the

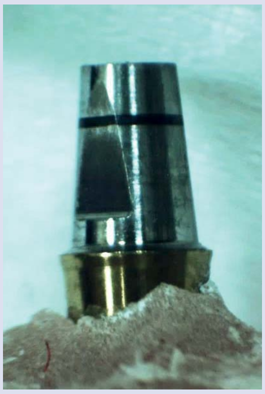

Figure 3. Adhesive failure in abutment surface.

Table 1. **Descriptive statistical analysis of the studied parameters.**

	N	Minimum	Maximum	Mean±SD
Group 1(no treatment)	10	40	60	51±6.6
Group 2 (plasma treatment for abutment)	10	127	150	143.2±6.5
Group 3 (plasma treatment for coping)	10	55	80	70.5±7.2
Group 4 (plasma treatment for abutment and coping)	10	150	175	163.5±8.2
Valid N (listwise)	10			

Table 2. **One way anova analysis of the studied parameters.**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	89709.3	3	29903.1	583.602	0.0001
Within Groups	1844.6	36	51.239		
Total	91553.9	39			

Table 3. **Duncan test analysis of the studied parameters.**

Codes	N	1	2	3	4
Group 1 (no treatment)	10	51			
Group 2(plasma treatment for abutment)	10		70.5		
Group 3 (plasma treatment for coping)	10			143.2	
Group 4 (plasma treatment for abutment and coping)	10				163.5
Sig.		1	1	1	1

demand for dental prosthesis made of 3 mol.% tetragonal zirconia polycrystals stabilized by yttria.[29,30] Subsequent technological advancements have made it possible to fabricate monolithic restorations without veneering porcelain, such as the development of 3YZ with a tooth-like hue and improvements in translucency.[31,32] However, the practical applications of monolithic 3YZ prostheses are restricted to the molar region due to their inferior esthetics (particularly their translucency) compared to dental feldspathic porcelain and lithium disilicate.[33]

The application of partially stabilized zirconia (PSZ), which is stabilized with roughly 5 mol% of yttria (5Y), in dentistry. Because 5Y has a higher translucency due to a higher fraction of the cubic phase and a lower fraction of the tetragonal phase of zirconia, it is mostly employed as a monolithic zirconia anterior coping.[34] However, because there is less tetragonal zirconia in 5Y than in 3Y, the mechanical strength of 5Y is nearly half that of 3Y.[35] Excellent mechanical qualities characterize the 3 mol% yttria-stabilized tetragonal zirconia polycrystal (3Y-TZP), notwithstanding its considerable opaqueness. Improved translucency is provided by the 5 mol% yttria-stabilized zirconia polycrystal (5Y-ZP), yet many of its clinical characteristics have not been compared to those of 3Y-TZP.[36]

In order for titanium to withstand the different obstacles present in the oral environment, a strong and long-lasting cement bond is necessary when using titanium as the superstructure of a prosthetic.[37] A luting cement's ability to stick to a surface is dependent on both physical and chemical bonding, there are several surface modification methods that have been suggested to improve binding; they include chemical bonding, micromechanical retention, and micromechanical retention combined with chemical bonding.[38]

For fixed restorations to be successful, coping retention is crucial. The geometry of the abutment preparation, surface area, abutment height, surface roughness, and cement type are related to the need for retention and resistance of cement-retained restorations. The doctor has control over two factors: surface roughness and luting chemicals.[39]

In the industrial sector, plasma treatment has been widely employed to alter product surfaces.[40,41] Under normal pressure conditions, plasma is an electrically neutral ionized gas that contains electrons, UV radiation, and free radicals.[41] This method has previously been utilized to effectively kill bacteria, even those found in bio-films on titanium surfaces.[41,42] Since plasma irradiation doesn't require chemical additives, it doesn't pollute the environment. Thirteen The input power and the distance from the plasma flame both affect the plasma's temperature. Because of its wide temperature range of 37ºC to 62ºC, it was classified as biocompatible.[43] According to reports, the surface can become hydrophilic and develop an oxide layer when plasma treatment is applied correctly. This could have an impact on the adhesive capabilities.[44]

The adequate mechanical properties,[45] low solubility,[46] biocompatibility,[47,48] and high adhesion to the tooth structure of resin cements have made them widely used for luting ceramic restorations.[49] Three ways are commonly available for curing resin cements: chemical, light, or a combination of both.[50] Dual-cured cements were developed in order to attain superior mechanical properties and a high degree of conversion in the presence or absence of light.[51]

In clinical situations, a reduced inter-arch space leads to a cemented prosthesis retention issue. Because implant-supported cement-retained restorations can improve esthetics, maximize occlusal interdigitation, and offer a passive fit, their adoption has surged. In certain sorts of clinical conditions, it becomes important to employ a cement-retained prosthesis instead of a screw-retained one. Applying airborne particle abrasion, bur adjustments, plasma surface treatment, retentive groove addition, and minimal angle of convergencenc are recommended to promote retention.[52]

According to the results of this study, null hypothesis was rejected because there was statistical significance effect of plasma surface treatment on tensile bond strength of (5)Y Zirconia coping fixed on titanium implant abutment, that effect was increase tensile bond strength after plasma surface treatment .

According to the results of our study, arrangement of all groups from high to low value of tensile bond strength was: Group 4 < Group 2 < Group 3 < Group 1. Śmielak et al. (2015)[53] found that titanium without surface treatment results in low tensile bonding strength between zirconia and titanium, the control group 1(which did not apply any surface treatment to titanium) had the lowest bond strengths and tended to produce specimens with adhesive failure patterns between the resin cement and titanium abutment.[53] This result is consistent with the findings of our research.

Tensile bond strength was higher in group 2 (plasma treatment for abutment only) than in group 1 (control) and group 3 (plasma treatment for coping), but lower in groups 4(plasma for abutment and coping). These findings are consistent with those of Seker et al. (2015),[54] who found that bond strength increased slightly but significantly after an atmospheric plating treatment was applied to a titanium disc surface in comparison to a control group. Additionally, our findings in line with those of Ozyetim et al. (2023),[55] who discovered that atmospheric plasma treatment considerably raised the retention value between the coping and abutment in comparison to the control group (P <0.01). Cold atmospheric plasma's (CAP) capacity to alter the physico-chemical properties of titanium surfaces without affecting their microstructure, as well as how well it works to lower the treated surfaces' in vitro water contact angle (WCA) and enhance their hydrophilic surface characteristics.[56]

The impact of atmospheric plasma surface treatment on the adhesion of particular dental material types—polymers, more so than zirconia and titanium—has been the subject of numerous studies. Certain authors claim that procedures to alter the plasma surface help form stronger connections, make the surface more wettable, and give additional molecules chemically active sites to attach to it.[57]

Plasma surface treatment for zirconia coping (Group 3) increase tensile bond strength more than control group but this increased less than group 2 and group 4, because plasma treatment raises surface energy (SE) for zirconia coping. High energy electrons break down the moisture in the gas and environment during NTP treatment, producing OH radicals. The organic contaminants bonded to the zirconia surface are broken or eliminated.[58,59,60] As a result, this impact promotes the production of active peroxide radicals, which increase the Y-TZP surface's ability to combine functional groups like C-O and C-OH (these functional groups found in resin cement).[61] Surface wettability is enhanced by an increase in the polar portion of the surface that contains oxygen.[62] This is in line with the Kim et al. (2019)[63] study's findings, which show that the NTP therapy caused the contact angle to drop and the SE to increase.[63]

When we used plasma surface treatment for both titanium abutment and Zirconia coping (group 4) we got highest tensile bond strength among other groups, because there was combination of plasma effect on titanium abutment and plasma effect on (5Y-TZP) coping, mode of failure for all samples was adhesive failure in abutment surface.

CONCLUSION

Plasma had a significant influence on the tensile bond strength between the titanium implant abutment and (5) yttria zirconia coping. Plasma treatment for titanium implant abutment had increased the tensile bond strength more than the Plasma treatment for (5Y-TZP) coping. From the result of this study, the combination of plasma surface treatment for both implant abutment and inner surface of zirconia coping were the most effective plasma surface treatment to improved bonding between titanium and zirconia, that may be recommended for clinical guideline of bonding between the zirconia coping and titanium implant abutment. Mode of failure for all samples was adhesive failure in abutment surface.

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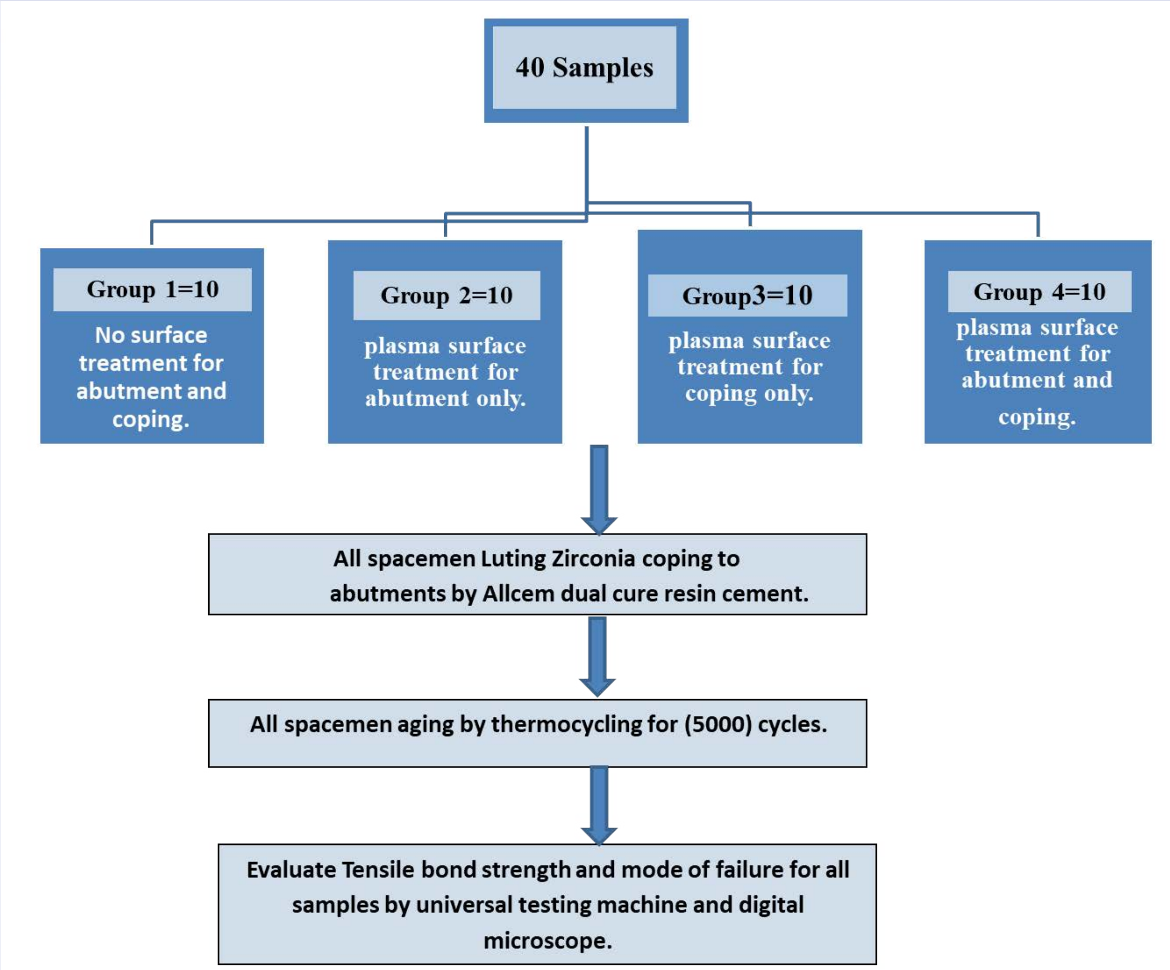
GRAPHICAL ABSTRACT



Cite this article: Younis AA, Altaie AA, Alkhalidi EF. Effect of Plasma Treatment on Tensile Bond Strength of (5) Yttrium Zirconia Coping Fixed on Titanium Implant Abutment. Pharmacog J. 2024;16(1): 204-210.