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# The Wear of Acrylic Resin and Composite Resin Teeth against Polished and Glazed Zirconia

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The Wear of Acrylic Resin and Composite Resin Teeth against Polished and Glazed Zirconia

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree
Master of Science in Prosthodontics

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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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ABBREVIATIONS

| | |
|---|---|
| IPN | Interpenetrating Polymer Network |
| DCL | Cross-Linked |
| PMMA | Poly Methyl methacrylate |
| PZ | Polished zirconia |
| GZ | Glazed zirconia |

ABSTRACT OF THE THESIS

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by

Dr. Abdulkareem Alshehri

Master of Science, Graduate Program in Prosthodontics
Loma Linda University, August 2018
Dr. Mathew T Kattadiyil, Chairperson

**Background:** Excessive wear for the occlusal surfaces of teeth results in decreased masticatory efficiency, poor esthetics and leads to reduced the occlusal vertical dimension which could lead to the development of temporomandibular disorders, consequently, further compromise function. Very few studies have been performed on the wear resistance of zirconia against artificial denture teeth and human enamel.

**Aim**: The purpose of this study was to investigate the influence of polished zirconia (PZ) and glazed zirconia (GZ) on the 2-body wear resistance (vertical substance loss) of seven commercially available denture teeth made of different resins.

**Material and Method:** Eight groups (n=10) of denture teeth and one control group (natural teeth) were selected. Two sets of each group were prepared along with two groups of natural molars as control groups (n=10). Two sets of 90 antagonist surfaces made from PZ and GZ. Each group of teeth and its respective zirconia antagonists were mounted on the Alabama wear device and loaded for 400,000 cycles. The vertical substance loss was measured by using a laser scanner (3Shape A/S Copenhagen K Denmark) and 3D software (Geomagic Software).

# CHAPTER ONE

# INTRODUCTION

In prosthodontics treatment with complete and removable partial dentures, overdenture and fixed complete dentures the wear-resistance of denture teeth is an important factor to be considered in the rehabilitation. Excessive wear for the occlusal surfaces of teeth results in decreased masticatory efficiency, poor esthetics and leads to reduced the occlusal vertical dimension which could lead to the development of temporomandibular disorders, consequently, further compromise function.[1,2] Fixed implant-supported prostheses in the mandible have been shown to increase maximum occlusal force by a factor of two or three compared with complete dentures.[3]

Only a limited number of studies have been performed on the wear resistance of zirconia against restorative dental materials and human enamel.[4, 5,6,7] Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is one of the strongest and toughest materials among the many available dental ceramic systems.[8, 9] Artificial resin teeth have been commonly used for removable dental prostheses due to their esthetic properties, chemical bond with the acrylic resin denture base, convenient handling, and good mechanical properties.[10,11]

Acrylic resin teeth are most commonly made from poly(methyl methacrylate) (PMMA) polymers. However, some manufacturers modify PMMA with small amounts of inorganic filler particles, such as silicon dioxide, to improve abrasion resistance.[12, 13] Likewise, artificial resin teeth can be made from a matrix of urethane dimethacrylate (UDMA) with added inorganic filler particles.[12] For additional improvement in wear resistance, cross-linked acrylic resin teeth have been introduced. These feature blended polymers, interpenetrating resin networks (IPN), and double cross-linking (DCL). [10,26,27] Moreover, microfilled as well as nanofilled composite resin teeth have been developed, and are purported by the manufacturers to demonstrate superior esthetic and mechanical properties. Composite resin artificial teeth were developed in the 1980s as an effort to achieve greater wear resistance than acrylic resin teeth, [14] and considered less abrasive to human enamel antagonists than ceramic teeth.[15]

Wear has been defined as the slow removal of material because of the interaction between surfaces moving in contact. Tribology, the science of wear and friction, describes the wear phenomenon as a combination of abrasion, attrition, fatigue wear, and erosion.[16, 17] In the oral cavity, many wear processes may occur because of the contact of mechanical forces and other factors, such as pH, temperature, dietary habits, and occlusal force. Tooth wear is a multifactorial process and varies from person to person in clinical conditions.[18]

## Wear Stimulation Devices

There are many wear testing devices that have been developed with different level of complexity. The International Standards Organization (ISO) in 1999 published a technical specification on "Wear by tooth brushing"[19], followed by another technical specification in 2001 called "Wear by two- and/or three-body contact".[20] This specification defines eight wear testing methods including: DIN, Zurich, Alabama, ACTA, Minnesota, Freiburg, OHSU, and Newcastle. The main difference between the wear stimulator devices is the way the force is delivered. In addition, there are many methods of load release are available in the wear devices, including springs, weights, and electric or hydraulic actuators. The use of third body abrasive mediums between two antagonist cause scattering of the results and can effect on the reproducibility, since it is hard to standardize the testing chamber and difficult to maintain the same viscosity and composition during the whole wear testing process.[21] The Alabama wear test was ranked as the first method with the highest citation literature.[21] The Alabama wear device has four assemblies and uses springs to produce an appropriate force.

### ***Objective and Aim of the Study***

The objective of this study was to investigate the influence of glazed zirconia and polished zirconia on the 2-body wear resistance (vertical substance and volume loss) of eight commercially available denture teeth made of different resins.

### **Statement of Problem**

Wear resistance is one of the most important physical properties of artificial resin teeth, and wear resistance of zirconia against artificial acrylic and composite resin denture teeth has not been clearly established.

### ***Hypotheses***

The null hypothesis is:

1. There will be no difference in the wear of resin denture teeth with or without inorganic fillers and composite resin teeth against glazed zirconia.
2. There will be no difference in the wear of resin denture teeth with or

(without inorganic fillers), composite resin teeth, and against polished zirconia.

# CHAPTER TWO

## MATERIALS AND METHODS

The study included 8 groups (n=10) of denture teeth and one natural teeth control group (Table 1). Two sets of each group were prepared using mandibular first molar denture teeth (Fig 1). A natural molar was included as control group. The teeth were embedded in chemically-polymerizing acrylic resin. The acrylic resin was mixed and poured into custom-made holders, and the teeth placed into the mixture using a surveyor, to ensure that the buccal and palatal cusps were positioned at the same level. The cusp of each tooth was wet abraded and wet polished using a series of silicon carbide grinding papers (CarbiMet 2 -120 grit, 320 grit, 600 grit; Buehler Ltd, Lake Bluff, IL) to a depth of 0.5 mm. As a result, a flat area of approximately 2.0 x 3.0 $mm^2$ was formed on the buccal cusp. The sample then was polished using Deagglomerated Alpha Aluminum (Micropolish II; Buehler Ltd). This flat area was used for sample loading during the wear tests.

Two sets of 90 antagonist surfaces were made from PZ and GZ. They were fabricated in the form of the palatal cusp of a maxillary first premolar artificial tooth. The palatal cusp of a maxillary first premolar denture tooth (BlueLine Ivoclar) was scanned using a TRIOS®. 3D Dental Scanner (3Shape A/S Copenhagen K Denmark) to produce identical antagonists made of zirconia (Vericore Zirconia HT Disc, item #72803,).
All zirconia samples (Monolithic Zirconia; Ivoclarivadent) were airborne-particle abraded with alumina at 0.34 MPa and steam cleaned. The zirconia samples were randomly distributed to 2 groups.

**Table 1.** Tested resin denture teeth.

| Material | Manufacture | Composition |
|---|---|---|
| BlueLine DCL | Ivoclar-Vivadent, Liechtenstein | DCL-PMMA |
| Trubyte Portrait | Dentsply Int., York, USA | IPN-PMMA |
| Orthotyp DCL | Ivoclar-Vivadent, Liechtenstein | DCL-PMMA |
| Vertex Complete D | Vertex-Dental, The Netherlands | PMMA |
| Vertex Complete A | Vertex-Dental, The Netherlands | DCL-PMMA |
| IPN Enamel | Dentsply Int., York, USA | IPN- PMMA |
| IPN Body | Dentsply Int., York, USA | IPN- PMMA |
| Natural Tooth | Natural Tooth | Enamel |
| Phonares II | Ivoclar-Vivadent, Liechtenstein | Nanohybrid composite |

For the PZ group, the samples were polished using Dialite ZR medium and fine grit abrasive instruments (Brasseler, Savannah, GA). The same calibrated operator performed all polishing processes following the manufacture's instructions.

Samples were polished at 10,000 RPM with a slow-speed handpiece without lubrication. The polishing was performed using Dialite ZR green medium polishing points (H2MZR) and Dialite ZR orange fine polishing point (H2FZR). The polishing process of each cusp was carefully performed for standardization and reproducibility. This procedure was executed for one minute for each specific tip. A total polishing time for each sample was two minutes.

For the GZ group, the samples were polished in the area of the cusp by using Zenostar® polishing paste then cleaned with a steam jet. The cleaned samples were dried and prepared for the glazing process. A glaze paste (IPS Ivocolor glaze paste, Ivoclar Vivadent) was mixed to a creamy consistency and painted onto each sample.


***Figure 1.*** Schematic Diagram of study groups

A thin glaze layer was applied onto the zirconia surface following the manufacturer's guidelines. For that process, the paste was mixed with distilled water until an adequate consistency was obtained, and then applied into the cusp surface with a specific brush, and fired in the Ivoclar 300MP furnace (Ivoclar-Vivadent, Liechtenstein) according to the following parameters; drying temperature 403 °C, furnace closing time 6 min, heating rate 45 °C/min, final temperature 710 °C, maintained at 1 min, with vacuum at 450 °C and at 709 °C.

One at a time, each group of teeth and its respective group of antagonists were mounted on the Alabama wear device and loaded for 400,000 cycles (Figure 2). The parameters of the wear test are listed in (Table 2). The load weight of each antagonist was 5 kg, which is equivalent to an effective loading force of 49 N. Samples were irrigated with distilled water at 37°C during the wear test during the entire testing process.

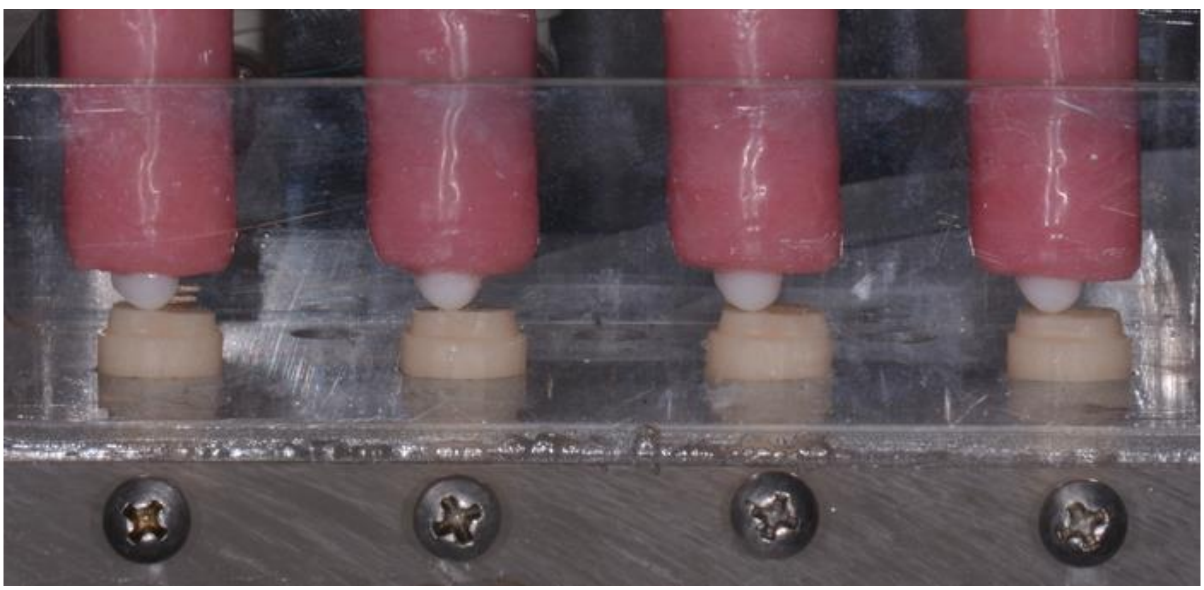

***Figure 2***. Alabama wear device with zirconia samples mounted against denture teeth

Samples were scanned using a TRIOS®. 3D Dental Scanner (3Shape A/S Copenhagen K Denmark) (Fig 3). A study reported the trueness value of this scanner as (6.9 ± 0.9 µm) and the precision value as (4.5 ± 0.9 µm). [22] The STL file of each samples before and after the wear test were superimposed by using a surface matching software (Geomagic Control 2014; 3D Systems). Superimposition was made using the global registration function by finding 50,000 points in common between the pre- and post-wear files. This software created color-mapped models of each sample and then aligned the two samples before and after the wear test to detect the geometric alterations that demonstrate the wear caused by the antagonist specimen (Fig 4). . The vertical substance loss of the sample was measured by recording the deepest area of wear.

**Table 2.** Test parameters

| | |
|---|---|
| Irrigation temperature | 25°C |
| Vertical movement | 6 mm |
| Rising speed | 55 mm/s |
| Descending speed | 30 mm/s |
| Weight per specimen | 5 kg |
| Kinetic energy | 2250 x 10-6 J |
| Dwell time | 60 s |
| Horizontal movement | 0.3 mm |
| Forward speed | 30 mm/s |
| Backward speed | 55 mm/s |
| Cycle frequency | 1.3 Hz |

One investigator recorded all the data. To test the reliability of data collection, ten random samples were collected twice with one week interval. Interclass correlation and paired t-test were used to analyze the reliability and agreement.

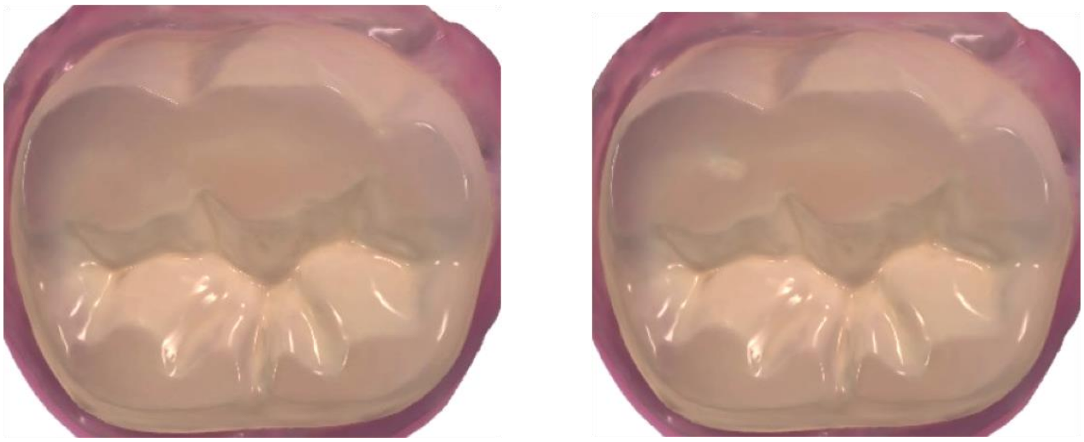

***Figure 3***. Example of scanned sample before and after the wear test

**Statistical Analysis**

Descriptive statistics in the form of mean -/+ Sd used to summarize the two-body wear for the different groups were assessed. A two-way analysis of variance (ANOVA) was used for statistical analysis of the main effects of polished and glazed zirconia and different groups, as well as their interaction. Pairwise comparison was used with Boneferroni correction. Data was statistically analyzed using statistical software (SPSS for Windows, 24.0; SPSS, Inc, Chicago, Ill). Alpha was set at a level of 0.05.

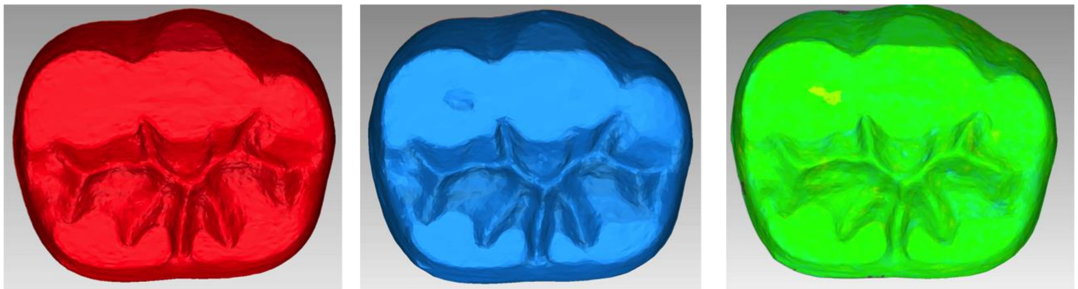

***Figure 4***. Example of sample superimposition by using a surface matching software

## CHAPTER THREE

## RESULTS

Reliability of the data collection was tested using interclass correlation showed excellent agreement (99%). There was no statistical difference between the two sets of data of 10 randomly selected samples with a mean difference of 0.001 mm ± 0.003 mm. The mean and standard deviation of vertical substance loss of different PZ group are shown in (Table 3), (Figure 5). For the BlueLine DCL group, the vertical substance loss was 0.067 ± 0.033 mm, followed by 0.076 ± 0.037 mm for Trubyte Portrait teeth, 0.059 ± 0.042 mm for Orthotyp DCL teeth, 0.069 ± 0.033 mm for Vertex complete D resin, 0.049 ± 0.030mm for Vertex complete A resin, 0.062 ± 0.015 mm for IPN Enamel resin, 0.094 ± 0.056 mm for IPN Body resin, 0.083 ± 0.022 mm for natural teeth, and 0.102 ± 0.053 mm for Phonares II teeth.

**Table 3.** Vertical substance loss of denture teeth against PZ

| Groups | N | Mean (mm) | SD |
|---|---|---|---|
| BlueLine DCL | 10 | .067 | .033 |
| Trubyte Portrait | 10 | .076 | .037 |
| Orthotyp DCL | 10 | .059 | .042 |
| Vertex Complete D | 10 | .069 | .033 |
| Vertex Complete A | 10 | .049 | .030 |
| IPN Enamel | 10 | .062 | .015 |
| IPN Body | 10 | .094 | .056 |
| Natural teeth | 10 | .083 | .022 |
| Phonares II | 10 | .102 | .053 |

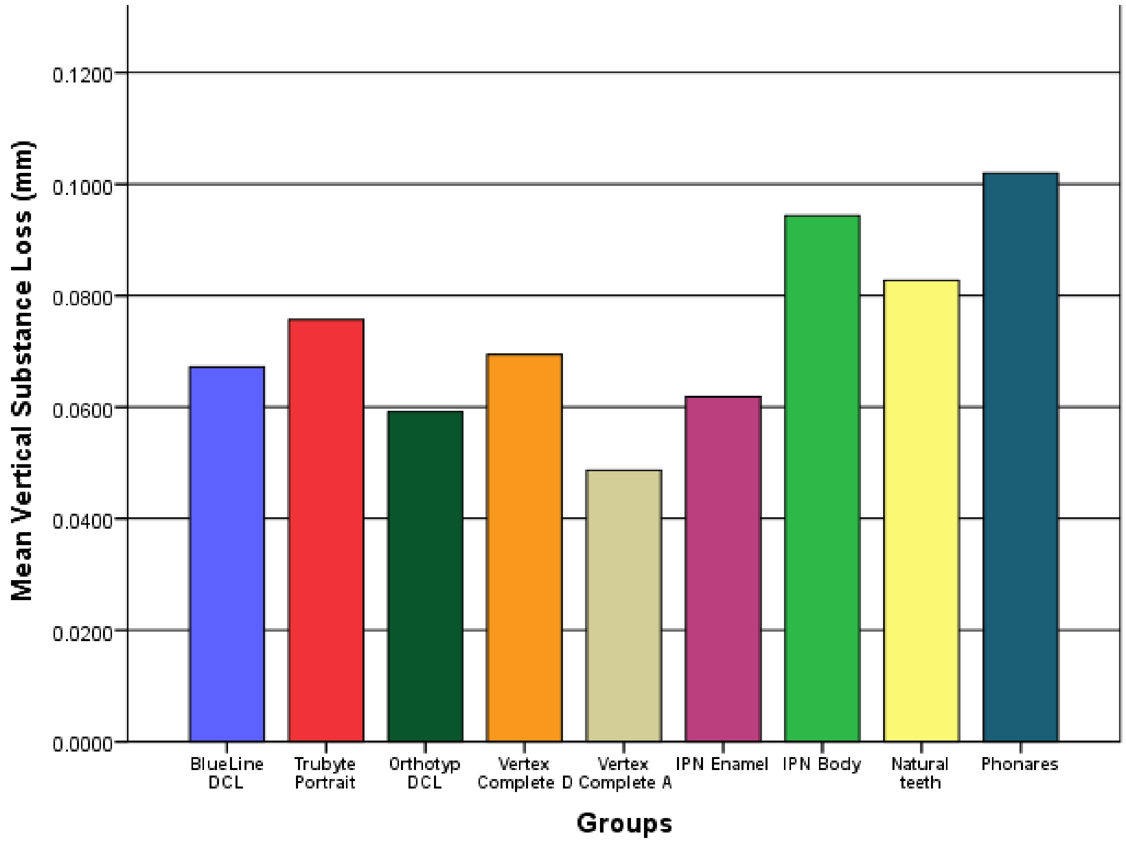


***Figure 5***. Mean vertical substance loss of denture teeth against PZ

The mean and standard deviation of vertical substance loss of different groups across GZ group are shown in (Table 4), (Figure 6). For the BlueLine DCL group vertical substance loss was 0.08 ± 0.025mm, 0.111 ± 0.0.038 mm for Trubyte Portrait teeth, 0.081 ± 0.023 mm for Orthotyp DCL teeth, 0.120 ± 0.048 mm for Vertex complete D resin, 0.08 ± 0.038 mm for Vertex complete A resin, 0.047 ± 0.028 mm for IPN Enamel resin, 0.064 ± 0.033 mm for IPN Body resin, 0.231 ± 0.093 mm for natural teeth, and 0.187 ± 0.066 mm for Phonares II teeth.

**Table 4.** Vertical substance loss (mm) of denture teeth against GZ

| Groups | N | Mean (mm) | SD |
|---|---|---|---|
| BlueLine DCL | 10 | .080 | .025 |
| Trubyte Portrait | 10 | .111 | .038 |
| Orthotyp DCL | 10 | .081 | .023 |
| Vertex Complete D | 10 | .120 | .048 |
| Vertex Complete A | 10 | .080 | .038 |
| IPN Enamel | 10 | .047 | .028 |
| IPN Body | 10 | .064 | .033 |
| Natural teeth | 10 | .231 | .093 |
| Phonares II | 10 | .188 | .066 |

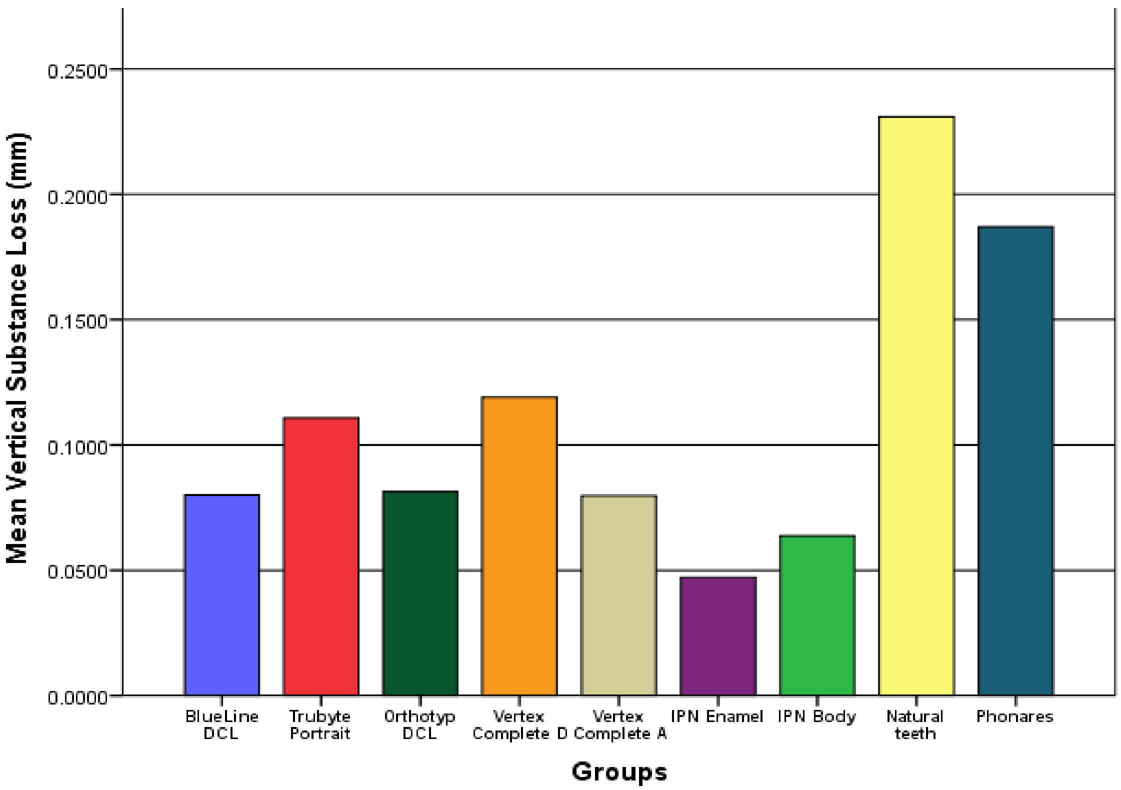


***Figure 6***. Mean vertical substance loss of denture teeth against GZ

Two-way ANOVA showed a significant difference between the zirconia groups ($p<0.001$), significant effect of groups ($p<0.001$), and significant interaction between zirconia groups and different test groups ($p<0.001$) (Table 5). (Table 6) shows *p-values* of pairwise comparison of different groups within PZ group. (Table 7) shows *p*-values pairwise comparison of different groups within GZ.

**Table 5.** Two-way ANOVA

| Source | Mean Square | F | Sig. |
|---|---|---|---|
| Intercept | 1.493 | 776.659 | .000 |
| ZG | .062 | 32.259 | .000 |
| Groups | .024 | 12.523 | .000 |
| ZG * Groups | .013 | 6.999 | .000 |
| Error | .002 | | |

**Table 6.** *P*-value of pairwise comparisons between different denture teeth with PZ

| Group | Blue Line DCL | Trubyte Portrait | Orthotyp DCL | Vertex Complete D | Vertex Complete A | IPN Enamel | IPN Body | Natural teeth | Phonares II |
|---|---|---|---|---|---|---|---|---|---|
| BlueLine DCL | X | .672 | .697 | .913 | .355 | .790 | .175 | .086 | .083 |
| Trubyte Portrait | .672 | X | .423 | .762 | .178 | .490 | .350 | .195 | .189 |
| Orthotyp DCL | .697 | .423 | X | .627 | .609 | .896 | .088 | .040 | .038 |
| Vertex Complete D | .913 | .762 | .627 | X | .313 | .713 | .226 | .118 | .114 |
| Vertex Complete A | .355 | .178 | .609 | .313 | X | .510 | .023 | .009 | .008 |
| IPN Enamel | .790 | .490 | .896 | .713 | .510 | X | .105 | .048 | .046 |
| IPN Body | .175 | .350 | .088 | .226 | .023 | .105 | X | .716 | .703 |
| Natural teeth | .086 | .195 | .040 | .118 | .009 | .048 | .716 | X | .986 |
| Phonares II | .083 | .189 | .038 | .114 | .008 | .046 | .703 | .986 | X |

**Table 7.** *P*-value of pairwise Comparisons between different denture teeth with GZ

| Group | BlueLine DCL | Trubyte Portrait | Orthotyp DCL | Vertex Complete D | Vertex Complete A | IPN Enamel | IPN Body | Natural teeth | Phonares II |
|---|---|---|---|---|---|---|---|---|---|
| BlueLine DCL | X | .125 | .948 | .051 | .988 | .101 | .417 | .000 | .000 |
| Trubyte Portrait | .125 | X | .142 | .674 | .122 | .002 | .020 | .000 | .000 |
| Orthotyp DCL | .948 | .142 | X | .059 | .937 | .089 | .381 | .000 | .000 |
| Vertex Complete D | .051 | .674 | .059 | X | .050 | .000 | .006 | .000 | .001 |
| Vertex Complete A | .988 | .122 | .937 | .050 | X | .104 | .426 | .000 | .000 |
| IPN Enamel | .101 | .002 | .089 | .000 | .104 | X | .405 | .000 | .000 |
| IPN Body | .417 | .020 | .381 | .006 | .426 | .405 | X | .000 | .000 |
| Natural teeth | .000 | .000 | .000 | .000 | .000 | .000 | .000 | X | .000 |
| Phonares II | .000 | .000 | .000 | .001 | .000 | .000 | .000 | .000 | X |

The mean and *p*-value of vertical substance loss within groups between PZ and GZ group are shown in (Table 8), (Figure 7-16). The average vertical substance loss for

BlueLine DCL group loss was -0.013 mm (p=0.516), -0.035 mm (p=0.076) for Trubyte Portrait group, -0.022 mm (p=0.275) for Orthotyp DCL group, -0.05 mm (p=0.015) for Vertex complete D group, -0.031 mm (p=0.116) for Vertex complete A group, 0.015 mm (p=0.543) for IPN Enamel group, 0.031 mm (p=0.121) for IPN Body group, -0.184 mm (p<0.001) for natural teeth, and -0.085 mm, (p<0.001) for Phonares II group.

**Table 8.** Pairwise Comparisons of mean difference in vertical substance loss between groups

| Groups | (I) Zirconia | (J) Zirconia | Mean Difference (I-J) | *P*-Value | 95% Confidence Interval |
|---|---|---|---|---|---|
| BlueLine DCL | PZ | GZ | -.013 | .516 | (-.052, .026) |
| Trubyte Portrait | PZ | GZ | -.035 | .076 | (-.074, .004) |
| Orthotyp DCL | PZ | GZ | -.022 | .275 | (-.062, .018) |
| Vertex Complete D | PZ | GZ | -.050 | .015 | (-.089, -.010) |
| Vertex Complete A | PZ | GZ | -.031 | .116 | (-.070, .008) |
| IPN Enamel | PZ | GZ | .015 | .453 | (-.024, .053) |
| IPN Body | PZ | GZ | .031 | .121 | (-.008, .69) |
| Natural teeth | PZ | GZ | -.184 | .000 | (-.189, -.107) |
| Phonares II | PZ | GZ | -.085 | .000 | (-.124, -.046) |

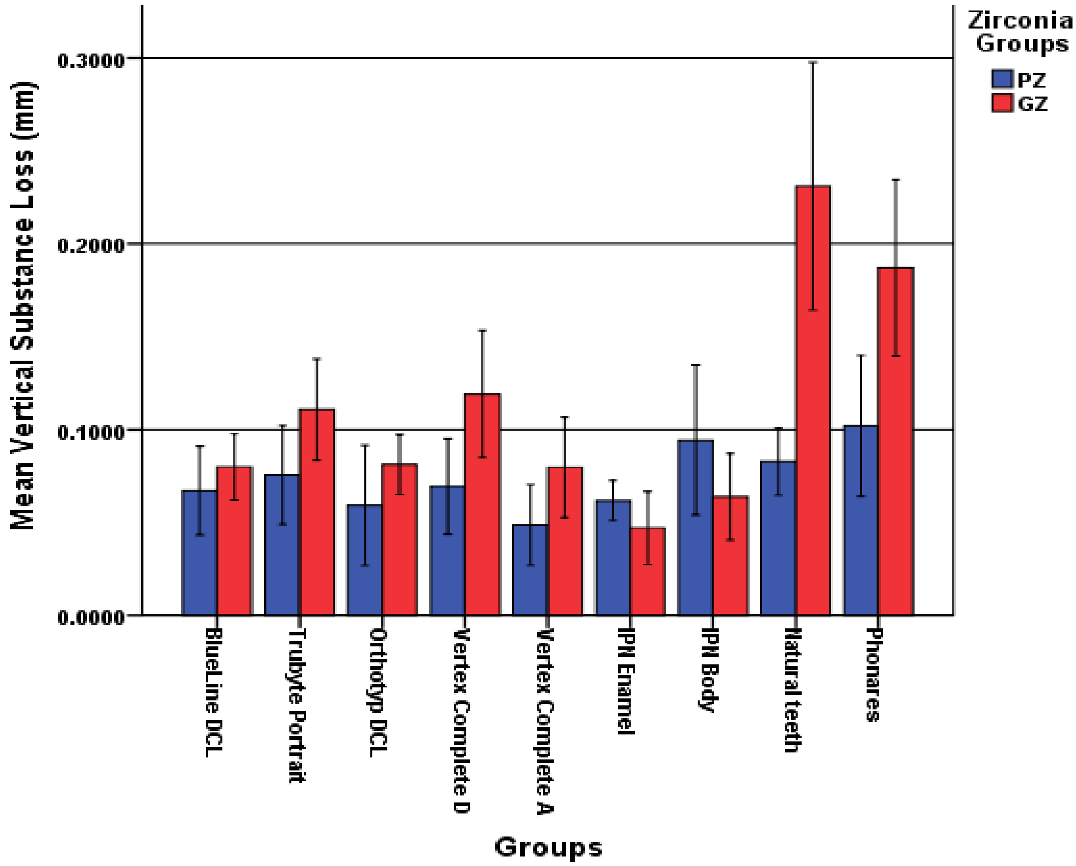


*Figure 7*. Mean vertical substance loss of denture teeth against PZ and GZ

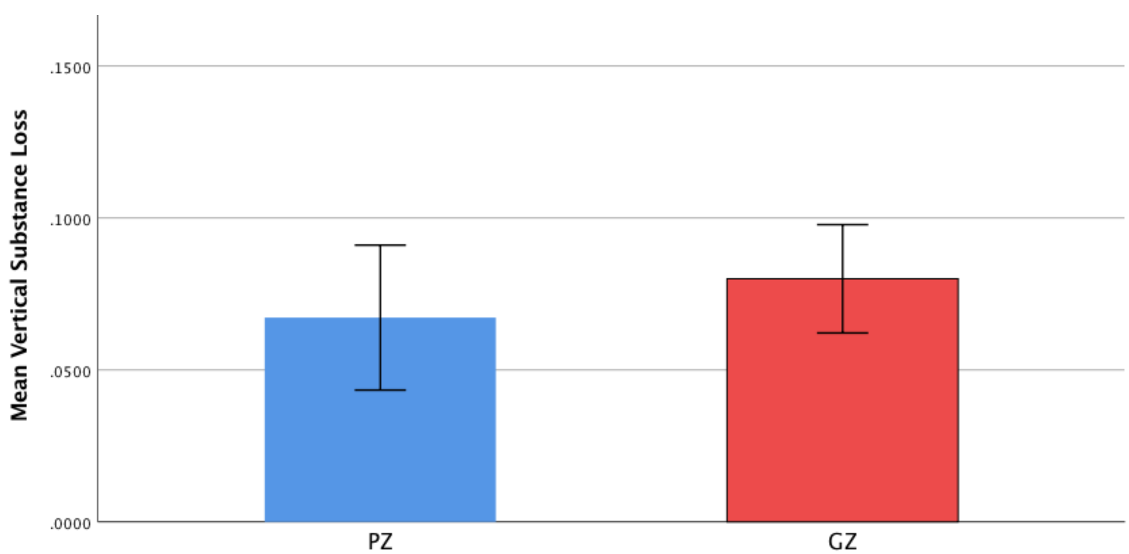


*Figure 8*. Mean vertical substance loss (mm) of BlueLine DCL denture teeth against PZ and GZ

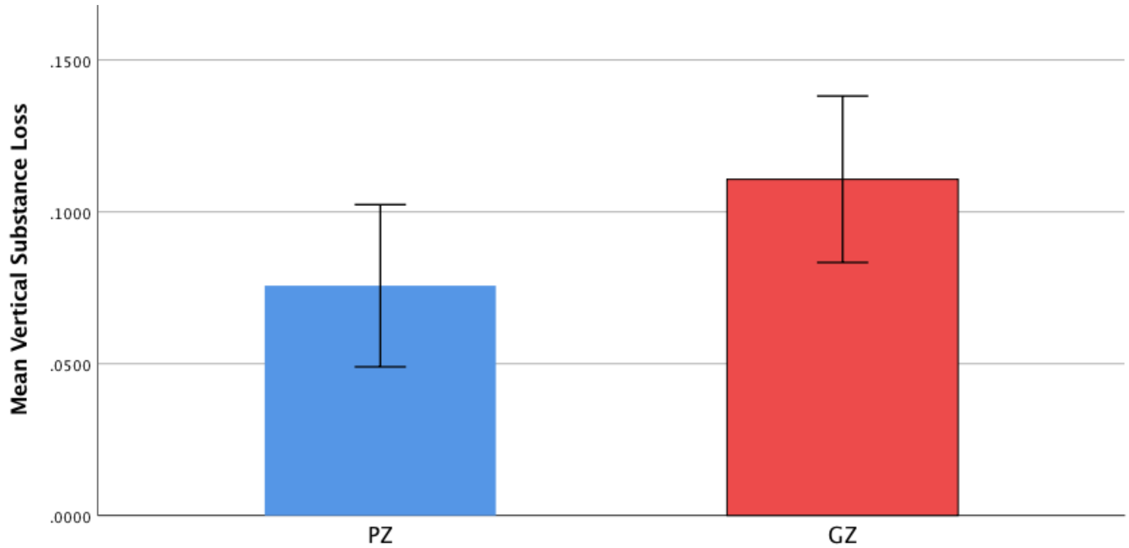


***Figure 9.*** Mean vertical substance loss (mm) of Trubyte Portrait denture teeth against PZ and GZ

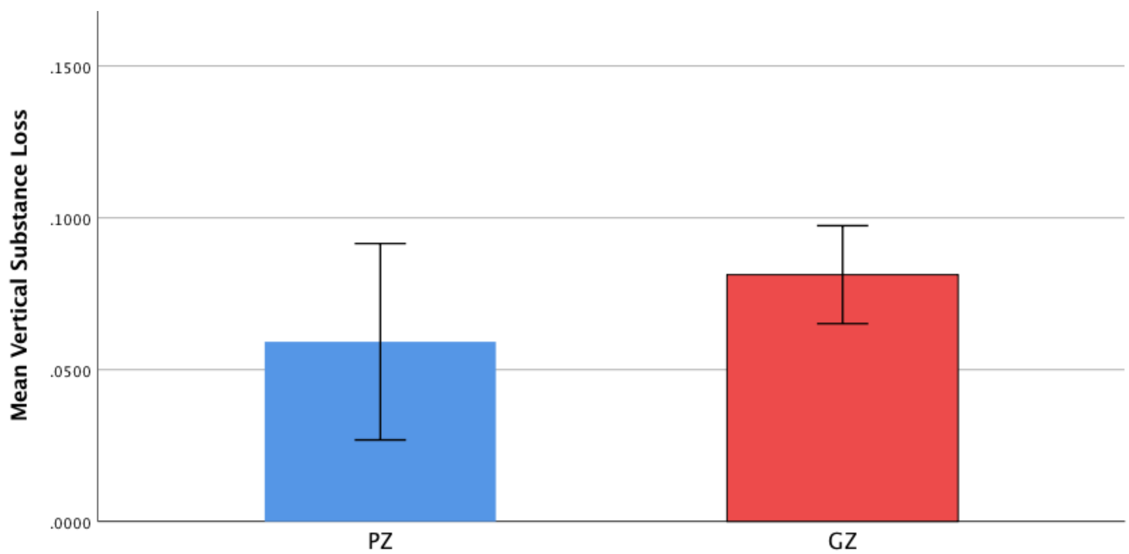


***Figure 10.*** Mean vertical substance loss (mm) of Orthotyp DCL denture teeth against PZ and GZ

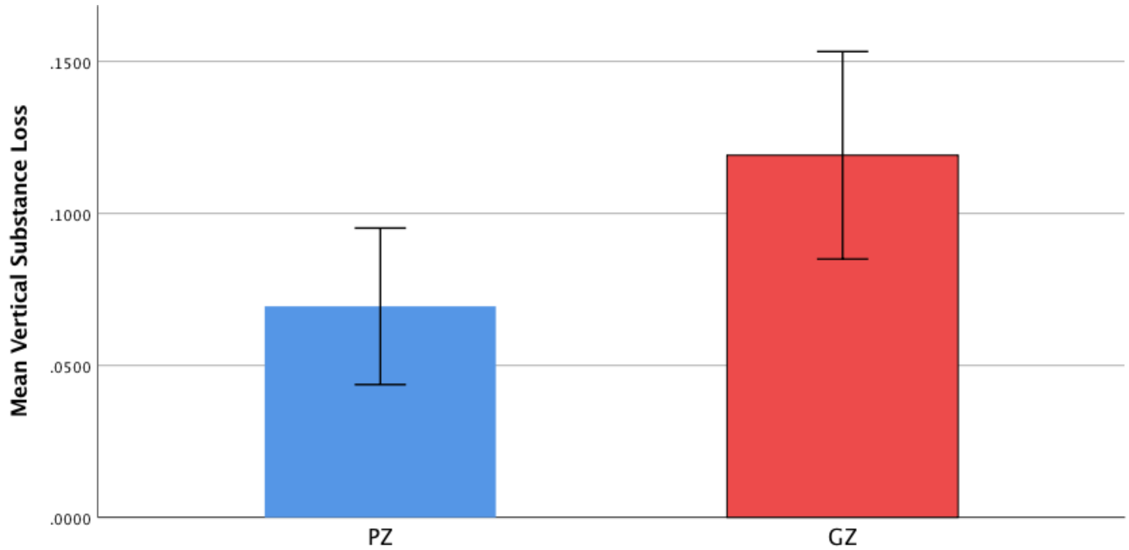


***Figure 11***. Mean vertical substance loss (mm) of Vertex Complete D denture teeth against PZ and GZ

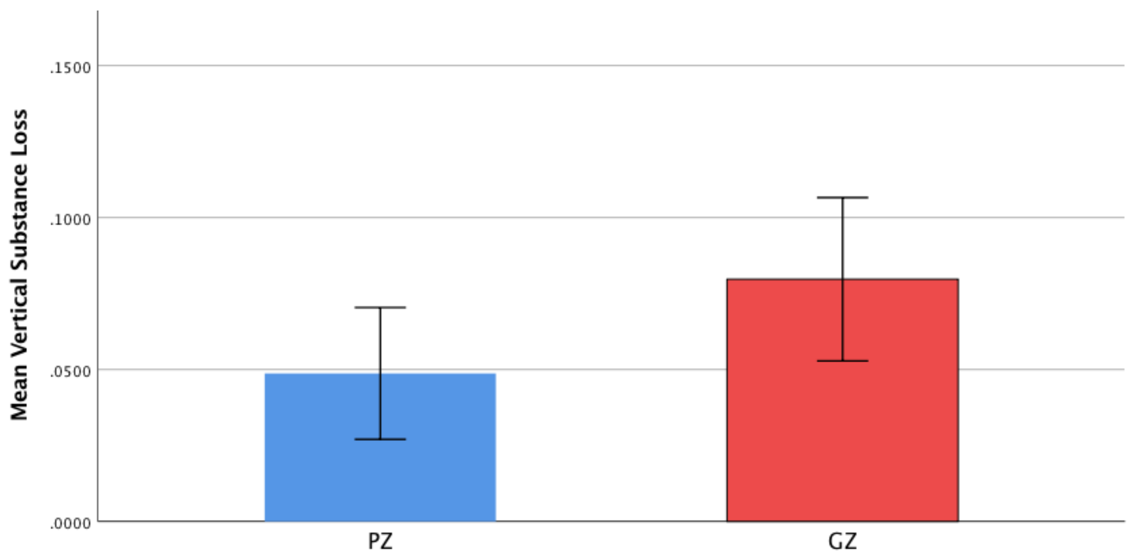


***Figure 12***. Mean vertical substance loss (mm) of Vertex Complete A denture teeth against PZ and GZ

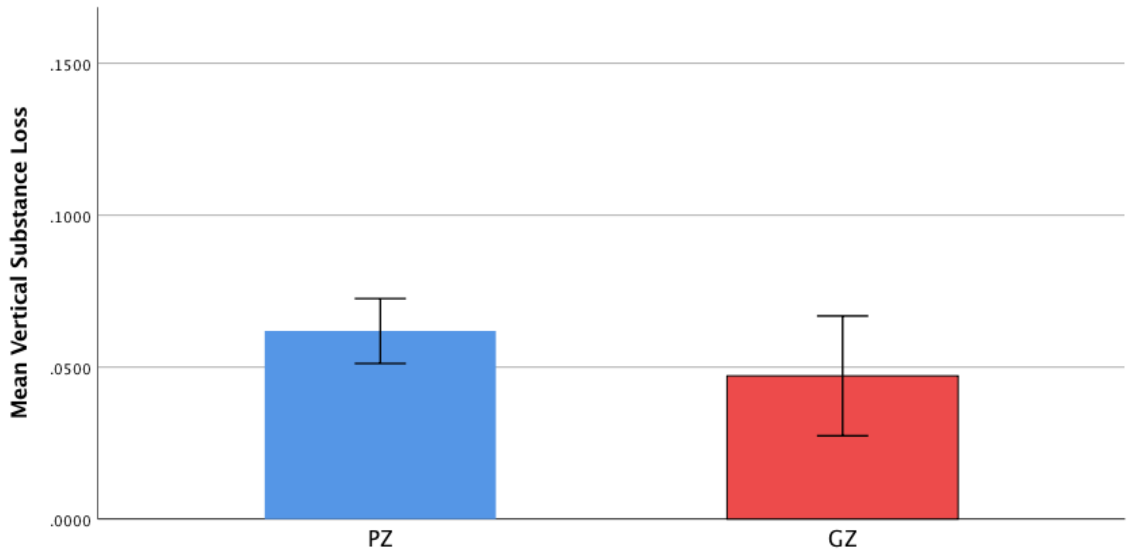


***Figure 13***. Mean vertical substance loss (mm) of IPN Enamel denture teeth against PZ and GZ

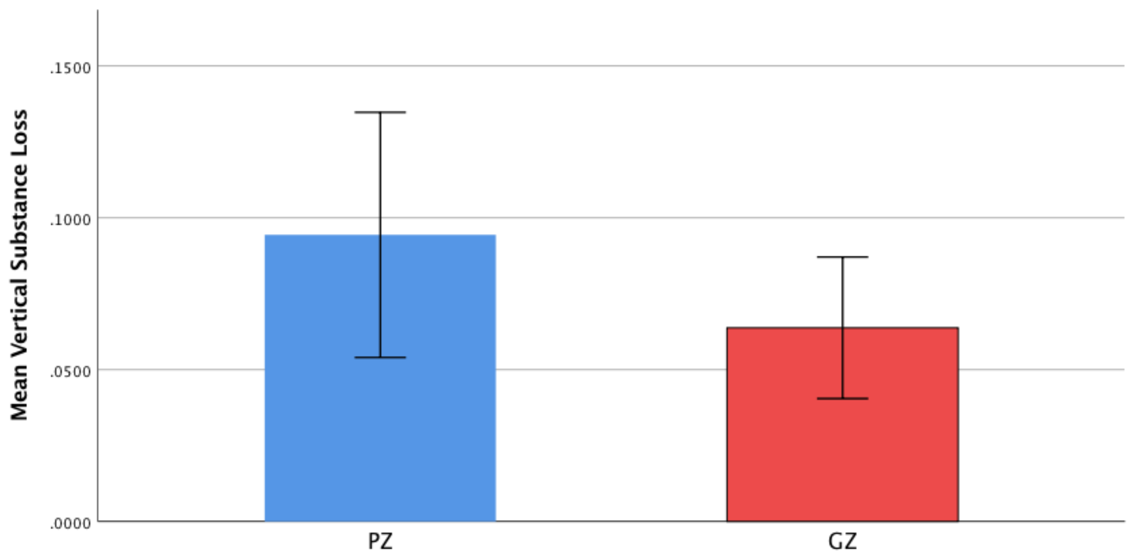


***Figure 14***. Mean vertical substance loss (mm) of IPN Body denture teeth against PZ and GZ

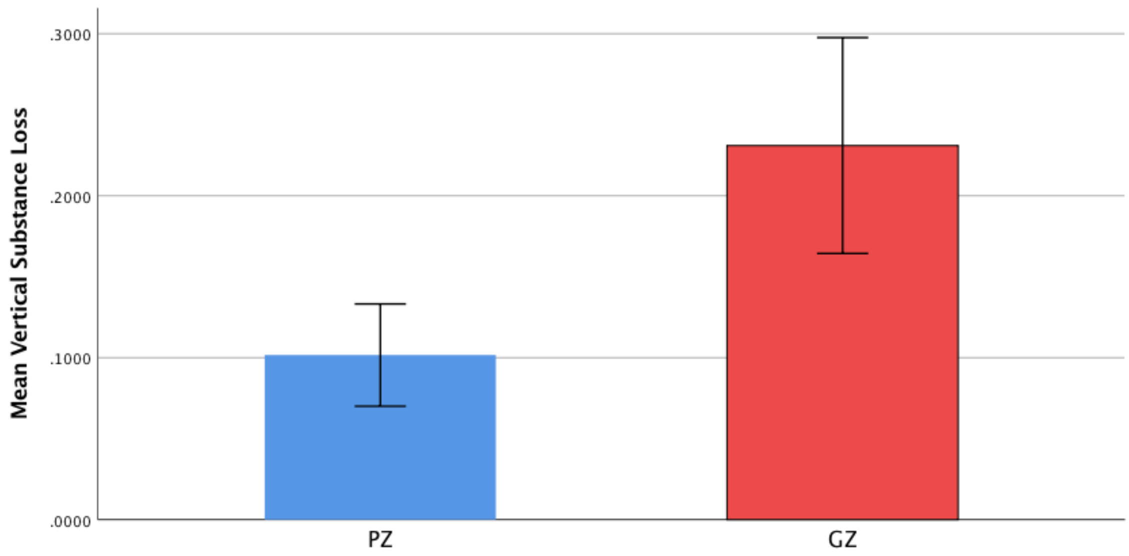


***Figure 15***. Mean vertical substance loss (mm) of natural teeth against PZ and GZ

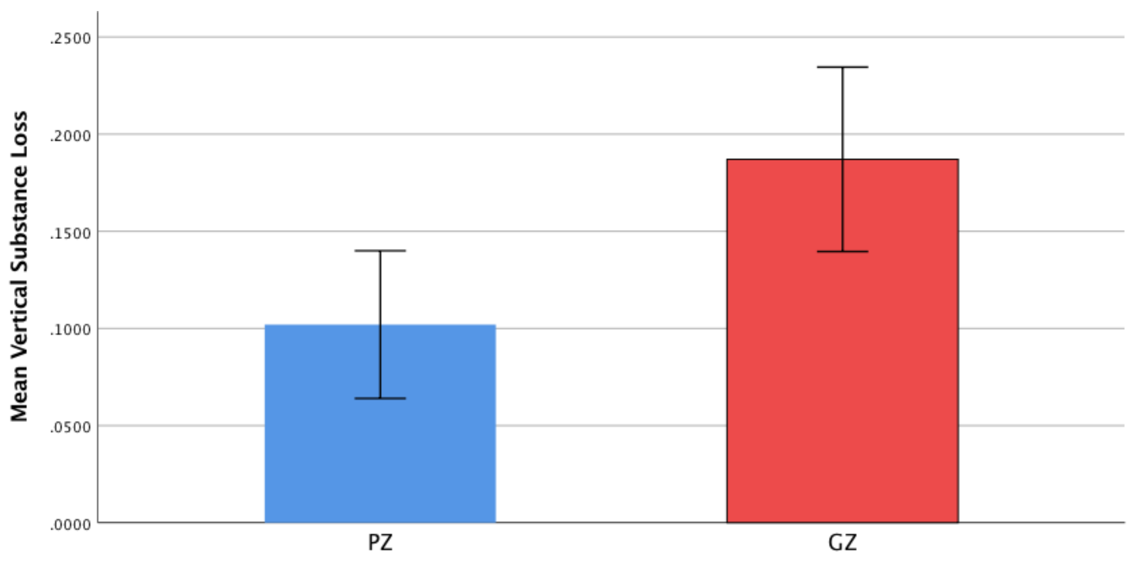


***Figure 16.*** Mean vertical substance loss (mm) of Phonares II composite teeth against PZ and GZ

## CHAPTER FOUR

## DISCUSSION

Within the limits of this study, the results support the rejection of the null hypothesis, and indicate that composition dose influences the wear resistance of artificial resin tooth materials against both PZ and GZ.

Within the PZ group, Vertex Complete A group showed the lowest wear. However, it was only significantly different when compared to the IPN Body material, natural teeth and Phonares II groups. Likewise, the Orthotype DCL group exhibited significantly less wear than natural teeth and the Phonares II group.

Within GZ group, natural teeth showed the highest wear between all groups followed by the Phonares II group. A significant wear difference was recorded between the natural teeth and all other groups. Likewise, the Phonares II teeth exhibited significant more wear when compared to the other groups except the natural teeth.

Interestingly, the wear of different acrylic resin groups did not exhibit significant differences between the PZ and GZ, except Vertex Complete D. Acrylic resin groups showed higher vertical substance loss with GZ more than PZ (not significant) except in two groups where more vertical substance loss occurred with PZ (not significant). Natural teeth and Phonares II group showed higher significant wear when opposed to GZ than PZ.

Significant interaction was shown in the analysis. All groups showed higher wear when opposed GZ except IPN Enamel and IPN Body groups show less wear against GZ. PZ demonstrated significantly less wears on natural teeth and Phonares II and Vertex complete D groups than GZ.

Zirconia finishing after adjustments and grinding is required to enhance the surface smoothness and to avoid a destructive effect on the mechanical performance and antagonist surface wear. There are different ways for zirconia post processing treatment including polishing, heat treatment and/or glazing.[23,24] The effects of grinding with diamond instruments on mechanical properties of zirconia were reported in many studies. Some studies documented a positive effect due to the phase transformation toughening mechanism where grinding initiates a t-m phase transformation[25, 26,27], which cause a volumetric expansion of 4% across the superficial defects, making compressive stress concentration and accordingly prevent crack propagation.[28] On the contrary, other studies showed that grinding induce significant superficial defects that result in reducing the mechanical properties and subsequent in higher risk of catastrophic failures.[29, 30,31]

Studies reported that when grinding is performed, a thin layer of compressive residual stress might be created. [32,33,34] Furthermore Deville et al.[35] found that the formation of this layer prevent the new phase transformation; so, the formation of this compressive residual stress layer may reduce the susceptibility of zirconia to low thermal degradation. However, grinding can initiates significant defects, increases roughness, and may permit water penetration to deeper spaces and result to increase susceptibility to low thermal degradation outcomes.[25] Zirconia surface roughness was significantly higher following the first polishing step. But after the second polishing step the roughness was further reduced. However, the outcome of surface roughness was not differing significantly between two-step and three-step polishing systems.[25] One study showed there was no significant relationship between polishing time and polishing outcomes.[36]

Therefore, the reuse of polishing instruments is possible without any significant changes in the final surface of zirconia.[37]

Glazing of zirconia surfaces that consists of applying a thin layer of glassy material intended to decrease the surface roughness, to improve the light reflection and aesthetic appearance as well as reduce the biofilm formation.[38] Preis et al. stated that GZ surfaces were as smooth as for polished surfaces but displayed increased wear depths. However, when glazing layer thickness was about 35 to 40 µm this consider weak layer was removed by wear because of its poorer mechanical properties.[25]

Chewing forces were set at 50 N during this test which complies with Bates et al. study that stated that chewing force during attrition has a range between 50 and 150 N.[39] Mean physiological biting forces were found to be 50 N for non-bruxing patient.[40, 41] The mastication simulation devise included the vertical application of masticatory force by direct contact between the test sample and its antagonist, together with lateral movement of the stylus. Therefore, both abrasive and fatigue wear were replicated in this device.[42, 16]

The number of cycles used in chewing simulation differs significantly in reported wear studies. One study used 400,000 cycles that represent a clinical service of 18 months.[46] DeLong and Douglas found that 250,000 cycles in the masticatory simulation devise equals 1 year in the human mouth for natural dentition.[47] Leinfelder et al.[48] used a more complex test method, and compared in vivo and in vitro wear data for eleven materials involving positive and negative controls. In their study they used PMMA bead slurry to offer three-body wear testing and a 75 N control force followed by lateral sliding. They reported a high correlation result between the 3 year in vivo and the 400,000 cycle when comparing in vivo wear depths to in vitro depths.

Quantifiable wear measurements with no contacting or contacting profilometers have been reported in several studies. Many researches have recorded the vertical substance loss dimensions of the various profiles tested, which then are averaged to get the mean 2-dimensional step height. With the improvement of surface metrology software, 3D wear measurements have been preferred to measure the wear loss (vertical loss and volume loss) of the wear surface. Both ways are available in the laboratory and have a important positive correlation. Though, 3D measurements are favored instead of 2-dimensional measurements because they specify a more accurate evaluation of wear loss.[43, 44,45]

Many PMMA materials are available for the manufacture of denture teeth. PMMA is one of the common materials used for the fabrication of denture teeth. In the manufacturing process, a noncrosslinked linear polymer is mixed with a monomer including a crosslinking agent and then polymerized. The mixture of monomer and crosslinking agent consists of a methyl methacrylate and a dimethacrylate, in most cases ethylene glycol dimethacrylate. Another type of denture teeth is a PMMA tooth that contain a inorganic fillers. Basically, it depends on polymethyl methacrylates, to which inorganic fillers have been added.

Highly crosslinked PMMA teeth are denture tooth material that is well known as Interpenetrating Polymer Network (IPN) material. IPN is produced by allowing polymers of different chemical and physical natures to penetrate each other and develop interlocking with each other. Highly crosslinked PMMA teeth (organically filled) are a modified product of poly(methyl methacrylate). They are homogeneously crosslinked between matrix and polymer filler. The outcome is a completely crosslinked material system that has significant advantages in terms of oral stability and wear resistance.

Nano hybrid composite teeth are another option for denture teeth. NHC teeth including inorganic fillers which are a composite material consisting of a urethane dimethacrylate matrix with inorganic fillers, isofillers (prepolymer) and PMMA clusters embedded in the structure. The NHC material is classified under the category of hybrid composites. Hybrid means that this composite is a mixture of different types and sizes of fillers; “hybrid” also means that the material is a combination of two types of material: composite and PMMA. The NHC material includes a range of fillers: highly crosslinked inorganically filled macrofillers, highly densified inorganic microfillers and silanized nanoscale fillers based on silicon dioxide. The macrofillers are generally responsible for the strength and color stability of the material, while the microfillers improve the wear resistance.

In the current study, human enamel was used as a reference material. Ideally, the wear resistance of denture teeth and natural enamel should be as similar as possible.[2] Commonly, wear of enamel is a very slow and gradual process with about 30–40 μm annual wear rate.[49]The disadvantage of using natural tooth structure, however, is the fact that one must expect high inter- and intraindividual variations in surface structure and wear behavior.

The low wear resistance of NHC teeth might be described by evaluating the composition and wear performance of the denture teeth. DCL PMMA teeth have organic fillers of PMMA clusters. As mentioned earlier, the organic fillers are highly crosslinked with the PMMA composition of the denture teeth that develop a homogenous structure. In contrast, IPN PMMA teeth, have a highly crosslinked structure without any fillers, which also provides the denture teeth with a homogenous structure. On the other hand, NHC denture teeth include inorganic silanized $SiO_2$ fillers, which are merged into the structure of the denture teeth to improve the hardness of the teeth; but, these fillers can be separated from the surface of the denture teeth throughout loading and can cause more wear.

In this study nano-hybrid composite denture teeth showed statistically significantly more wear than the IPN and double crosslinking PMMA denture teeth. This result agrees with a previous study that tested the wear resistance of NHC teeth in compared to IPN PMMA and DCL PMMA denture teeth using the same denture material of each group as antagonists.[50] Heintze et al also found that NHC teeth exhibited statistically significantly higher wear rate against two different ceramic antagonists.[51] However, our result does not agree with studies that tested the wear resistance of NHC teeth when using different wear devices and antagonists.[51,52] This could be explained due to use of different testing devices and samples preparation techniques. In addition, more wear of the NHC teeth may be predicted as result of the hardness of the zirconia because the brittleness of NHC is less wear-resistant than IPN PMMA and DCL PMMA denture teeth toward zirconia. Moreover, The high wear rate of NHC teeth may be justified by comparing the composition and wear patterns of the denture teeth. In DCL PMMA teeth and IPN PMMA the highly crosslinked structure create a homogenous structure of the denture teeth. NHC denture teeth include inorganic silanized $SiO_2$ fillers, which are embedded into the structure of the denture teeth that improve the teeth hardness. However, these fillers can be separated from the teeth surface during function leading to high wear rate.

# CHAPTER FIVE

## CONCLUSIONS

Within the limitations of this study, the following conclusions are drawn:

The Vertex Complete A group which is high cross-linked acrylic resin teeth found better wear resistance than IPN Body, natural teeth and Phonares II (nanohybrid composite) within polished zirconia group.

Within glazed zirconia natural teeth showed highest wear between all groups followed by Phonares II group (nanohybrid composite).

All groups showed higher wear when opposed glazed zirconia except IPN Enamel and IPN Body groups show less wear.

Careful material selection between denture teeth and zirconia could influence rate of wear.

## REFERENCES


1. Rammelsberg, P. (1996). Etiologic factors for disc displacement in the TMJ. Dtsch Zahnarztl Z, 51, 211-218.

2. Yip, K. H. K., Smales, R. J., & Kaidonis, J. A. (2004). Differential wear of teeth and restorative materials: clinical implications. International Journal of Prosthodontics, 17(3).

3. Lindquist, L. W., & Carlsson, G. E. (1985). Long-term effects on chewing with mandibular fixed prostheses on osseointegrated implants. Acta Odontologica Scandinavica, 43(1), 39-45.

4. Albashaireh, Z. S., Ghazal, M., & Kern, M. (2010). Two-body wear of different ceramic materials opposed to zirconia ceramic. Journal of Prosthetic Dentistry, 104(2), 105-113.

5. Ghazal, M., & Kern, M. (2009). The influence of antagonistic surface roughness on the wear of human enamel and nanofilled composite resin artificial teeth. Journal of Prosthetic Dentistry, 101(5), 342-349.

6. Janyavula, S., Lawson, N., Cakir, D., Beck, P., Ramp, L. C., & Burgess, J. O. (2013). The wear of polished and glazed zirconia against enamel. Journal of Prosthetic Dentistry, 109(1), 22-29.

7. Passos, S. P., Torrealba, Y., Major, P., Linke, B., Flores-Mir, C., & Nychka, J. A. (2014). In vitro wear behavior of zirconia opposing enamel: a systematic review. Journal of Prosthodontics, 23(8), 593-601.

8. Denry, I., & Kelly, J. R. (2008). State of the art of zirconia for dental applications. Dental materials, 24(3), 299-307.

9. McCabe JF, Walls A. (2009) Applied dental materials. 9th ed. Oxford: Wiley-Blackwell;. p. 133-52.

10. Hirano, S., May, K. B., Wagner, W. C., & Hacker, C. H. (1998). In vitro wear of resin denture teeth. Journal of Prosthetic Dentistry, 79(2), 152-155.

11. White, S. N., Miklus, V. G., McLaren, E. A., Lang, L. A., & Caputo, A. A. (2005). Flexural strength of a layered zirconia and porcelain dental all-ceramic system. Journal of Prosthetic Dentistry, 94(2), 125-131.

12. Stober, T., Lutz, T., Gilde, H., & Rammelsberg, P. (2006). Wear of resin denture teeth by two-body contact. Dental Materials, 22(3), 243-249.

13. Powers, J. M., & Sakaguchi, R. L. (2006). Craigs. Restorative dental materials. 12th ed. St. Louis: Mosby, 236-40.

14. Zeng, J., Sato, Y., Ohkubo, C., & Hosoi, T. (2005). In vitro wear resistance of three types of composite resin denture teeth. Journal of Prosthetic Dentistry, 94(5), 453-457.

15. Abe, Y., Sato, Y., Taji, T., Akagawa, Y., Lambrechts, P., & Vanherle, G. (2001). An in vitro wear study of posterior denture tooth materials on human enamel. Journal of oral rehabilitation, 28(5), 407-412.

16. Mair, L. H., Stolarski, T. A., Vowles, R. W., & Lloyd, C. H. (1996). Wear: mechanisms, manifestations and measurement. Report of a workshop. Journal of Dentistry, 24(1-2), 141-148.

17. Mair, L. H. (2000). Wear in the mouth: the tribological dimension. Tooth Wear and Sensitivity. London, Martin Dunitz, 181-188.

18. Kern, M., Strub, J. R., & Lü, X. Y. (1999). Wear of composite resin veneering materials in a dual-axis chewing simulator. Journal of oral rehabilitation, 26(5), 372-378.

19. International Organization for Standardization, & International Organization for Standardization. (1999). Technical Specification 14569-1. Dental Materials-Guidance on testing of wear resistance-Part 1: Wear by tooth brushing.

20. ISO, D. (2001). Guidance on testing of wear. Part 2: Wear by two-and/or three body contact.

21. Heintze, S. D. (2006). How to qualify and validate wear simulation devices and methods. Dental Materials, 22(8), 712-734.

22. Hack, G. D., & Patzelt, S. (2015). Evaluation of the accuracy of six intraoral scanning devices: an in-vitro investigation. ADA Prof Prod Rev, 10(4), 1-5.

23. Guazzato, M., Quach, L., Albakry, M., & Swain, M. V. (2005). Influence of surface and heat treatments on the flexural strength of Y-TZP dental ceramic. Journal of dentistry, 33(1), 9-18.

24. Pereira, G. K. R., Amaral, M., Simoneti, R., Rocha, G. C., Cesar, P. F., & Valandro, L. F. (2014). Effect of grinding with diamond-disc and-bur on the mechanical behavior of a Y-TZP ceramic. Journal of the mechanical behavior of biomedical materials, 37, 133-140.

25. Preis, V., Schmalzbauer, M., Bougeard, D., Schneider-Feyrer, S., & Rosentritt, M. (2015). Surface properties of monolithic zirconia after dental adjustment treatments and in vitro wear simulation. Journal of dentistry, 43(1), 133-139.

26. Ramos, G. F., PEREIRA, G. K. R., Amaral, M., Valandro, L. F., & Bottino, M. A. (2016). Effect of grinding and heat treatment on the mechanical behavior of zirconia ceramic. Brazilian oral research, 30(1).

27. Amaral, M., Valandro, L. F., Bottino, M. A., & Souza, R. O. (2013). Low-temperature degradation of a Y-TZP ceramic after surface treatments. Journal of Biomedical Materials Research Part B: Applied Biomaterials, 101(8), 1387-1392.

28. Garvie, R. C., & Nicholson, P. S. (1972). Phase analysis in zirconia systems. Journal of the American Ceramic Society, 55(6), 303-305.

29. Curtis, A. R., Wright, A. J., & Fleming, G. J. (2006). The influence of surface modification techniques on the performance of a Y-TZP dental ceramic. Journal of dentistry, 34(3), 195-206.

30. İşeri, U., Özkurt, Z., Yalnız, A., & Kazazoğlu, E. (2012). Comparison of different grinding procedures on the flexural strength of zirconia. Journal of Prosthetic Dentistry, 107(5), 309-315.

31. Kosmač, T. (2004). The effect of dental grinding and sandblasting on the biaxial flexural strength and Weibull modulus of tetragonal zirconia (Vol. 254, pp. 683-686). Trans Tech Publications.

32. Jing, Z., Ke, Z., Yihong, L., & Zhijian, S. (2014). Effect of Multistep Processing Technique on the Formation of Micro-defects and Residual Stresses in Zirconia Dental Restorations. Journal of Prosthodontics, 23(3), 206-212.

33. Ho, C. J., Liu, H. C., & Tuan, W. H. (2009). Effect of abrasive grinding on the strength of Y-TZP. Journal of the European Ceramic Society, 29(12), 2665-2669.

34. Sato, T., Besshi, T., & Tada, Y. (1996). Effects of surface-finishing condition and annealing on transformation sensitivity of a 3 mol.% Y2O3 stabilized tetragonal zirconia surface under interaction of lubricant. Wear, 194(1-2), 204-211.

35. Deville, S., Chevalier, J., & Gremillard, L. (2006). Influence of surface finish and residual stresses on the ageing sensitivity of biomedical grade zirconia. Biomaterials, 27(10), 2186-2192.

36. Polishing of Monolithic Zirconia Crowns—Results of Different Dental Practitioner Groups. Kozmacs C, Hollmann B, Arnold WH, Naumova E, Piwowarczyk A. Dent J (Basel). 2017 Nov 14;5(4)

37. Fischer, N. G., Tsujimoto, A., & Baruth, A. G. (2017). Effects of Polishing Bur

Application Force and Reuse on Sintered Zirconia Surface Topography. Operative dentistry.

38. Haralur, S. B. (2012). Evaluation of efficiency of manual polishing over autoglazed and overglazed porcelain and its effect on plaque accumulation. The journal of advanced prosthodontics, 4(4), 179-186.

39. Bates, J. F., Stafford, G. D., & Harrison, A. (1975). Masticatory function—a review of the literature. Journal of Oral Rehabilitation, 2(3), 281-301.

40. Gibbs, C. H., Mahan, P. E., Lundeen, H. C., Brehnan, K., Walsh, E. K., & Holbrook, W. B. (1981). Occlusal forces during chewing and swallowing as measured by sound transmission. Journal of Prosthetic Dentistry, 46(4), 443-449.

41. Heintze, S. D., Zappini, G., & Rousson, V. (2005). Wear of ten dental restorative materials in five wear simulators—results of a round robin test. Dental Materials, 21(4), 304-317.

42. Heintze, S. D. (2006). How to qualify and validate wear simulation devices and methods. Dental Materials, 22(8), 712-734.

43. Hahnel, S., Behr, M., Handel, G., & Rosentritt, M. (2009). Two-body wear of artificial acrylic and composite resin teeth in relation to antagonist material. Journal of prosthetic dentistry, 101(4), 269-278.

44. Rodriguez, J. M., & Bartlett, D. W. (2010). A comparison of two-dimensional and three-dimensional measurements of wear in a laboratory investigation. dental materials, 26(10), e221-e225.

45. Zeng, J., Sato, Y., Ohkubo, C., & Hosoi, T. (2005). In vitro wear resistance of three types of composite resin denture teeth. Journal of Prosthetic Dentistry, 94(5), 453-457.

46. Etman, M. K. (2009). Confocal examination of subsurface cracking in ceramic materials. Journal of Prosthodontics, 18(7), 550-559.

47. DeLong, R., & Douglas, W. H. (1991). An artificial oral environment for testing dental materials. IEEE Transactions on Biomedical Engineering, 38(4), 339-345.

48. Leinfelder, K. F., & Suzuki, S. (1999). In vitro wear device for determining posterior composite wear. The Journal of the American Dental Association, 130(9), 1347-1353.

49. Lambrechts, P., Braem, M., Vuylsteke-Wauters, M., & Vanherle, G. (1989). Quantitative in vivo wear of human enamel. Journal of Dental Research, 68(12), 1752-1754.

50. Munshi, N., Rosenblum, M., Jiang, S., & Flinton, R. (2017). In Vitro Wear Resistance of Nano-Hybrid Composite Denture Teeth. Journal of Prosthodontics, 26(3), 224-229.

51. Heintze, S. D., Zellweger, G., Grunert, I., Muñoz-Viveros, C. A., & Hagenbuch, K. (2012). Laboratory methods for evaluating the wear of denture teeth and their correlation with clinical results. Dental Materials, 28(3), 261-272.

52. Preis, V., Hahnel, S., Behr, M., & Rosentritt, M. (2017). Contact wear of artificial denture teeth. Journal of prosthodontic research.