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EFFECT OF MONOLITHIC ZIRCONIA VS. GOLD ALLOY ON THE WEAR OF HUMAN ENAMEL: AN IN VITRO STUDY

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ABSTRACT

The purpose of this study was to evaluate the effect of monolithic zirconia vs. gold alloy type IV on the wear of human enamel under different occlusal loads. **Materials and Methods:** Forty square plate specimens, 6×6×2 mm, were prepared from monolithic zirconia (Bruxzir, n=20) and type IV gold (Begostar, n=20) and divided into two groups. Forty freshly extracted premolar teeth for orthodontic purpose were sectioned mesio-distally and only the cusp tips of the buccal halves were used as antagonists in the testing procedures. All of the specimens were mounted to chewing simulator with the cusp antagonists, half of them were subjected to(50000 chewing cycles under 50N load), the other were subjected to (50000 chewing cycles under 150N load) cyclic loading (50 N load, 3700 cycles). Data were submitted to two-way ANOVA, and statistical significance was set at $p < 0.05$. **Results:** Type IV gold alloy based restorations had significantly little wear effect on human enamel than that of monolithic zirconia (Bruxzir) based restorations in high load. However in low load it was non-significant.

INTRODUCTION

Tooth enamel is a unique natural substance which cannot be substituted effectively by artificial restorative materials. The most important feature of enamel is its good wear resistance. [1] Tooth wear is multifactorial process based either on physiologic or pathologic mechanisms that finally lead to the noncarious loss of tooth surface substance with subsequent alterations in the tooth anatomy[2]. In physiologic wear, gradual tooth surface deterioration normally takes place following abrasion, when a third body is present during mastication[2, 3]. Pathologic wear is frequently associated with bruxism and clenching characterized by massive attrition and subsequent unacceptable tooth damage and alteration of the functional path of masticatory movements. Anterior teeth may, also, be involved; impairing both esthetics and the anterior guidance function, that increase the stress on the masticatory system with subsequent temporo-mandibular joint dysfunction[2,4]. Ideally, a restoration should present wear properties similar to those of human enamel[5]. The proper selection of restorative materials is important to preserve normal function as well as occlusal harmony. Except for their esthetic limitations, gold based casting alloys are considered the most ideal. restorative material, because they are wear resistant and cause minimal wear of opposing enamel. Ceramics are used as an alternative to gold-based casting alloys, because of their greater esthetic potential. However, the main shortcoming of ceramics is their abrasiveness to enamel[6]. Improvements to dental ceramics include the reinforcement of crystalline phases and ceramics with different compositions. Examples include glass infiltrated zirconia toughened alumina, lithium disilicate-based glass ceramic, and zirconia based materials[7,8]. The use of non-veneered, anatomic contour zirconia, which is more resistant to fracture than conventional dental porcelain[7, 9], is a simple way of reducing the cracking or chipping caused by mastication, clenching, and moisture wear[7]. Metal or metal–ceramic restorations seem to be the safest choice in cases of high load conditions. However,

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under extreme conditions, there is no material that will last for too long[(10)*]. The surface wear characteristics of dental ceramic materials have been demonstrated to be quite different from those of metals. Metals are known to exhibit some ductile behavior. When metallic crowns slide against an opposing enamel surface, as during mastication, wear to the metal usually occurs by plastic deformation. Softer gold-based crowns have been shown to result in less wear to opposing tooth structure than harder metal based crowns[(11)]. Tooth wear phenomenon may be described as a complex, multifactorial phenomenon involving the interplay of biological, mechanical, and chemical factors[(12)**]. It is caused by complex masticatory movements as the jaw moves in different directions. Wear patterns vary depending upon joint pathology, occlusion, muscle tone, lubricants, individual dietary habits, and the type of restorative material used[(12, 13)***]. Accordingly, this study is being conducted to evaluate the effect of monolithic zirconia vs. gold alloy on the wear of human enamel under different occlusal loads.

MATERIAL AND METHODS

A total of forty 1[st]premolars was selected for this study. The selection criteria were based on teeth condition. All teeth were examined under 4x magnification loops[(1)] for any cracks, caries or old restorations. All defected teeth were excluded. The teeth were then splitted mesio-distally to use only the buccal half that was mounted to Jakub's chuck (of the chewing simulator) leaving only the buccal cusp exposed for testing procedure. All teeth were stored in distilled water at the room temperature until the tests were being carried out.

A total of 40 square-shaped 6×6×2mm specimens was prepared from monolithic zirconia (Bruxzir, n=20) and type IV gold (Begostar, n=20).

Preparation of gold specimens: (Wax pattern construction): Square plate specimens, 6×6×2 mm were prepared from CAD/Ivory disc[2] by using an electrical high-precision saw[3]under water cooling system with two anticorrosive agents rotating at a speed 2500 rpm and feeding rate 5mm/min. the diamond disc used is of 0.3 mm thickness. The plates were then assembled with modeling wax to form a single wax pattern that was ready for burnout and casting. The gold specimens were then constructed using the traditional lost wax technique: Spruing, Investing using phosphate bonded investmen[****], wax elimination in the burnout furnace, graphite crucible was used for melting of gold, casting was then accomplished in the casting machine Furnax compact high-frequency induction casting machine[*****] divesting. The casting was then sectioned using cutting disc[******] to separate the gold plates from each other. Finishing and polishing procedure was accomplished using gold polishing classic plastic kit[(7)] which used for finishing and super-polishing of cast gold and precious alloys: (Brown disc used for prepolishing, Green disc used for polishing. Super green disc used for super-polishing).

Preparation of the zirconia specimens:

Square plate specimens, 7.5×7.5×2.5 mm were prepared from Pre-sintered Bruxzir zirconia milling blanks by using an electrical high-precision saw[#] under water cooling system with two anticorrosive agents rotating at a speed 2500 rpm and feeding rate 5mm/min. the diamond disc used is of 0.3mm thick-

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****** Frank Dental GmbH, Germany
# Isomet 4000, micro saw, Buehler Ltd, USA

ness. The specimens were cut oversized by approximately 25% to compensate for the shrinkage occurred during sintering to full density specified by the enlargement factor on the product label, to give plates of final dimensions 6×6×2 mm approximately. The sintering process was proceeded in the Nabertherm Hightemperature bottom loading furnace LHT 02/17 LB speed with rapid cooling function* by using the preset program of Bruxzir as recommended by manufacturer. The finishing and polishing procedure was done according to manufacturer instructions using DIASYNT Zirconia finishing and polishing kit[9].

Wear testing: The two-body wear testing was performed using a programmable logic controlled equipment (Four stations multimodal ROBOTA chewing simulator {Figure,1} Integrated with thermo-cyclic protocol operated on servo-motor[10]. The chewing simulator has four chambers simulating the vertical and horizontal movements simultaneously in the thermodynamic condition. Each of the chambers consists of an upper Jacob's chuck as tooth antagonist holder that can be tightened with a screw and a lower plastic sample holder specially designed with a square depression having the same dimensions ofthe specimen to be tested. The plastic holder is fixed in plastic sink that holds any solutions to be used during testing procedures .

The whole specimens (teeth, bruxzir and gold) were weighed before wear testing using an electronic analytical balance ** with an accuracy of 0.0001 gr. Values of all specimen weightss were accurately measured and recorded. Each specimen was cleaned and dried with tissue paper before weighing was proceeded. To ensure accuracy, the balance was kept on a freestanding table at all times away from vibrations. The glass doors were closed to avoid the effect of air drafts. Each tooth specimen was mounted to a Jacob' chuck, the corresponding specimen was mounted to the plastic specimen holder and the sink was filled with distilled water, so any wear debris resulting from the testing procedure were spontaneously washed out.

The first groups of gold and bruxzir and corresponding teeth specimens were mounted and tested sequentially under the first set of load **(Low load)** which was **50 N** for a number of 50000 cycles under the wear testing parameters mentioned in table (1).

TABLE (1): Wear testing parameters:

Vertical movement	1 mm
Horizontal movement	3 mm
Rising speed	90 mm/s
Descending speed	40 mm/s
Forward speed	90 mm/s
Backward speed	40 mm/s
Cycle frequency	1.6 Hz (96 cycle/min)
Time of 50000 cycles	8.68 h
Torque	2.4 Nm
Weight per specimen	50 N and 150N

The second groups of gold and bruxzir and corresponding teeth specimens were mounted and tested sequentially under the second set of load **(High load)** which was **150 N** for a number of 50000

* Nabertherm GmbH, Germany9 EVE Ernst Vetter GmbH, Germany 10Model ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY.
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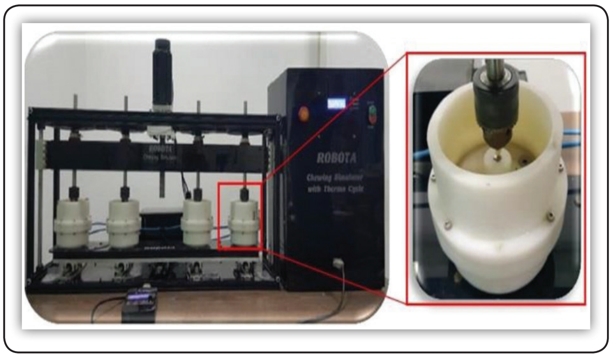

Fig. (1): ROBOTA chewing simulator with tooth specimen assembly in place

RESULTS

cycles "The same as shown in the first testing group" using the same wear testing parameters as shown in t**able (1)**. Each specimen was cleaned and dried with tissue paper. The whole specimens (teeth, bruxzir and gold) were then weighed after wear testing was proceeded using the same electronic analytical balance. Values of all specimen weights were accurately measured and recorded.

Data analysis was performed in several steps. Initially, descriptive statistics for each group results. Student t-test was performed between both materials and enamel cusp groups. Two way analysis of variance (ANOVA) test of significance was done for comparing variables affecting mean values (experimental material groups and load).Statistical analysis was performed using a sistat 7.6* statistics software for Windows. p values ≤0.05 are considered to be statistically significant in all tests.

Weight: the mean values and standard deviations (SD) for wear measured by weight loss (gram) recorded on both materials and enamel cusp antagonist as function of load application before and after 50000 wear simulation cycles summarized in t**able (2).**

After low load application (50 N):

a. In experimental groups: it was found that gold alloy group recorded higher weight loss mean value (0.00134±0.0012) than Bruxzir group mean value (0.00101±0.0005gr)The difference between groups was non-significant statistically as indicated by student t-test ($t=1.457$, $p=0.1594 > 0.05$).

b. In enamel cusp antagonist groups: it was found that enamel cusp antagonist of Bruxzir group recorded higher weight loss mean value (0.0030067±0.0013gr) than enamel cusp antagonist of gold alloy group mean value (0.002853±0.0055gr).The difference between groups was non-significant statistically as indicated by student t-test ($t=4.228$, $p=0.07> 0.05$).

TABLE (2): Weight results (Mean values ±SD) for experimental groups antagonist before and after wear simulation:

Variables		*Weight loss of Samples*	*Weight loss of Antagonist*
Low load (50 N)	*Bruxzir*	0.00101±0.0005	0.002853±0.000121
	Gold alloy	0.00134±0.00035	0.0030067±0.00041
High load 150 (N)	*Bruxzir*	0.00193±0.0002	0.0058433±0.00082
	Gold alloy	0.00298±0.00044	0.0043567±0.000123

After high load application (150 N):

a. In experimental groups: it was found that gold alloy group recorded higher weight loss mean value (0.00298±0.0008gr) than Bruxzir group mean value (0.00193±0.0018gr). The difference between groups was statistically significant as indicated by student t-test ($t=0.089$, $p=0.0381 < 0.05$).

b. In enamel cusp antagonist groups: It was found that enamel cusp antagonist of Bruxzir group recorded higher weight loss mean value (0.0058433±0.0026gr) than enamel cusp antagonist of gold alloy group mean value (0.0043567±0.0043gr). The difference between groups was statistically significant as indicated by student t-test ($t=0.926$, $p=0.0179 < 0.05$).

Regardless to load, totally it was found that:Gold alloy group recorded statistically significant higher weight loss mean value than *Bruxzir group mean value as indicated by two-way ANOVA test (p=0.03934<0.05)*

Irrespective of material, totally it was found that:High load (150 N) group recorded statistically significant higher weight loss mean value than *low load (50 N) group mean value as indicated by two-way ANOVA test (p=0.0011<0.05).*

DISCUSSION

The popularity of ceramic restorations stems from its properties such as translucency, esthetic, and biocompatibility. They offer better light transmission than other restorative materials which improve the reproduction of color and translucency of natural teeth .

The clinicians' care after restorative treatment is mostly directed towards how to avoid the pathological damage of natural teeth during the friction process between restorations and natural teeth. It is therefore of particular interest to carry out in vitro friction tests between dental materials and natural teeth[13, 14].

Several ceramic materials including veneering porcelain, glass ceramics and zirconia ceramic, etc. have been widely used in dental practice because of their esthetics, chemical stability and biocompatibility. Zirconia which is a polycrystalline ceramic with mechanical properties very close to metals. Therefore, it has been called "ceramic steel". Due to its white opaque color, zirconia cores or frameworks are veneered with feldspathic porcelain for a more acceptable esthetic outcome. In clinical service, the most frequent failure of this combination is chipping of the veneer.

Nowadays, by increasing the translucency of zirconia ceramics, the translucent monolithic full contour zirconia (FCZ) restorations become very attractive dental solution as it can totally avoid the porcelain chipping problem commonly encountered in ceramic restoration of bilayer structure[14]. They are indicated for use in patients with limited inter-occlusal space. This will put the translucent monolithic (FCZ) restorations in direct contact with opposing natural dentition and saliva at oral temperature[15].

There is great worry about behavior of zirconia stress concentration and wear on opposing natural teeth. This study evaluates the effect of monolithic zirconia vs. gold alloy on the wear of human enamel.

In the present study, 40 plates were constructed, 20 were zirconia and 20 were type IV gold with dimensions (6X6X2mm). The specimen dimension was not expected to affect standardization of tested specimens as only 2 mm of bar specimen was needed to contact antagonist human enamel during testing procedures.

Gold was selected because with normal occlusal force Wear studies evaluating type IV gold reported no significant difference between type IV gold opposing enamel and enamel opposing enamel.

In this study the bruxism effect was evaluated in occlusion between teeth and gold.

The Zirconia specimens used in this study were cut as flat bar-shaped specimens which facilitate comparison with previous studies(13).

Maxillary premolars that extracted recently after eruption for orthodontic reasons were used as antagonist to simulate clinical situation . The enamel cusps of natural were used without standardization as recommended by *Krejci et al*(22) who considered it is suitable as antagonistand according to what was reported by others that enamel preparation or polishing can change the wear characteristics (21).

All specimens were finished and polished to eliminate rough surfaces that would act as a variable between the two groups and an unconsidered factor that would affect the final results of the current study (23).

Specimens and antagonists were mounted in Robota chewing simulator with load of 50 N which considered an average value for physiological masticatory forces in the teeth of nonbruxism patients. The specimens were designed to move in the anterior-posterior direction simulating the sliding movement during occlusal contacts in the chewing cycle. A distance of 1 mm vertical and 3 mm horizontal was defined as the envelope motion provided a slide of 3 mm with the opposing surfaces in contact (16) .

With bruxism the chewing force are three times the magnitude of the normal chewing force as indicated by some literatures. And since 50 N load is considered to be the average value for physiological masticatory forces in the teeth of non-bruxism patients, so 150 N load is considered to represent the normal pathologic paranormal chewing force.

ROBOTA chewing simulator which has four chambers simulating the vertical and horizontal movements simultaneously so, it could almost mimics the Mandibular movements and gives reliability for the testing procedure(15). Although the number of cycles is debatable but the number of cycles used for this study was 50.000 cycles at frequency of 1.6 Hz (19). This sequence has been previously reported to simulate approximately 3 months of clinical wear(18). The specimens were tested in distilled water at room temperature which was not variable(20) in this study to act as lubricant.

The wear of human enamel in this study was evaluated by weighting the teeth samples before and after wear testing procedures and calculating amount of weight loss. This was in accordance with other study(17).

The hypothesis that type IV gold showed less wear effect on teeth surfaces than bruzxir was accepted in accordance with the results of this study significantly with high load and nonsignificantly with low load so the hypothesis was accepted.

The results of the current study showed that tooth wear took place at low load (50 N) but with statistically non significant difference. This may be because of the short cycle of chewing used in the study (50,000 cycles) which were equal to 3 months. This was not enough to cause noticeable amount of wear. Also the low magnitude of force used might have been not enough to cause significant amount in the weight of the enamel of the antagonist teeth.

The Results also showed that non-significant weight loss took place in both materials used in the study (Bruxzir and type IV gold) at low load (50 N). This may be a result of the high hardness number of zirconia and the relative high hardness of gold type IV compared to that of the tooth structure. The low magnitude of force, the short cycle of chewing and the ductility of gold alloy may also has acted in favor of the type IV gold. This was in agreement with Lee et al (2014).

The results of the current study showed the that significant weight loss took place tooth structure antagonist (enamel) opposing both materials (Bruxzir and type IV gold) at high load (150 N). This may be because of the low hardness of teeth compared to that of zirconia and gold alloy with the high load used that represents the heavy bruxismal force. This was in agreement with Arcangelo et al (2014)

The Results also showed that significant weight loss took place in type IV gold alloy, while Bruxzir was non significantly reduced in weight. This may be because of the low hardness compared to that of zirconia that make it relative to teeth, while the hardness of zirconia makes it absolute to the tooth surface used as antagonist to it.

Limitations for this study: The lack of correlation between clinical and laboratories studies is fact but the use of wear machines is to investigate the underlying mechanism rather than to rank potential clinical performance. All wear machines lack the evidence of their clinical relevance because prospective studies correlating in vitro studies with longterm in vivo results with identical materials are not available[15].

Although In vitro studies offer several advantages, starting from standardization of several variables (force, frequency of cycles, displacement, number of cycles, lubricant, etc.) which facilitates making of comparative statements. Larger number of specimens can be examined over relatively short time as controlled exposure time can be adjusted.

Wear behavior of tested groups were evaluated without thermocycling. Fracture resistance was investigated under static loading instead of dynamic loading.

Finally, there is no single in vitro test can predict clinical performance of in ceramic prosthesis.

FUTURE STUDIES

- The wear behavior of ceramic restorations under thermocycling conditions.
- The wear behavior of anatomic ceramic restoration on human enamel need to be evaluated.
- The amount of wear produced by ceramic restorations on human enamel need to be correlated with normal annual enamel wear rate.

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