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An in vitro investigation of human enamel wear by restorative dental materials

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A radiometric method was applied to assess enamel wear by another enamel and by restorative materials. The radioactive enamel was submitted to wear in a machine which allows sliding motion of an antagonistic surface in contact with the radioactive enamel. The enamel wear was evaluated by measuring the beta-activity of ^{32}P transferred to water from this irradiated tooth. Results obtained indicated that dental porcelains cause pronounced enamel wear when compared with that provoked by another natural enamel or by resin materials. Resin materials caused less enamel wear than another natural enamel. Vickers microhardness data obtained for antagonistic materials showed a correlation with the wear caused to the enamel.

Introduction

Dental enamel is the hardest material in the human body which supports the high level forces of mastication, however, even the normal function of the masticatory system causes its wear. The rate of wear may vary depending on factors such as diet abrasivity and parafunctional habits like bruxism. Also this wearing process may be disturbed by the introduction of restorations with different wear properties compared to natural dental structure.[1,2]

Consequently, the purpose of restorative dentistry should be the insertion of occlusal surfaces with resistance to wear and poor capacity to induce excessive wearing on the surfaces of their antagonists.

One of the most used prosthetic restorative materials is the dental porcelain. Despite its aesthetic properties, the dental porcelain has been described as an abrasive to the antagonists. New resin materials have been recently developed to be used as an alternative to dental porcelains.

Most articles about dental porcelains focus their characteristics of low fracture resistance, difficulties on getting ideal translucency, aesthetics. There is also an increasing demand and interest to study the dental porcelain wear as well as about the abrasion effect on antagonistic teeth. Regarding the new resin prosthetic materials, there are few studies concerning their general properties including the wear resistance and the abrasion effect.

Several methods, including clinical testing, the use of wearing machines and measurement of related properties such as hardness, have been used to investigate enamel and dental material wear. The dental wear evaluation, in general, is carried out using in vitro tests, that is simulating the masticatory cycle using an eletromechanical machine that allows movements of the tested specimens under controlled conditions.[3,4] The wear provoked to the tooth is assessed by the surface profile measurements on the specimens, before and after the test, using a wearing machine.[5–7] Also the gravimetric method is used and it consists of measuring the weight of the enamel specimens before and after the test.[8]

The purpose of this work was to compare the human enamel wear caused by different restorative materials using a radiometric method. The radiometric method used in this work was based on the paper of HEFFEREN[9] who proposed this method to the American Dental Association (ADA) of the USA to evaluate dentifrice abrasivity. The method consists on measuring beta activity of ^{32}P transferred to water when a neutron activated enamel is submitted to wear in a mechanical machine which allows sliding contacts of the enamel specimen with antagonistic material.

Vickers microhardness data were also obtained for the antagonistic materials in order to study whether there is a correlation between the enamel wear and the hardness of antagonistic materials as well as to examine the reduction of hardness caused to enamel by neutron irradiation.

Experimental

Materials

The following dental materials were used in this study: human dental enamel, three dental porcelains: Finesse (Ceramco Inc.), Ceramco II (Dentsply) and Noritake (Noritake Kizai Co.) and two prosthetic resin materials: Artglass (Heraeus Kulzer) and Targis (Ivoclar A.G.).

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Preparation of the materials used as antagonists

All the samples used as antagonists were prepared in cylindrical shapes with polished flat surfaces having a diameter of 3.8 mm to be eroded.

For the restorative dental materials, these were prepared according to manufacturers' instructions. Firstly, dental material was obtained in a cylindrical shape with a 4 mm diameter and a 6 mm height. These cylinders were mounted in the center of tubes (20 mm diameter × 20 mm height) and cemented with acrylic resin. The dental materials inside the tubes were ground to have an eroded surface of 3.8 mm diameter and 1.5 mm height using a lathe.

As to the enamels, these were cut to obtain a square surface (4×4 mm^2) and inserted in the centre of the tube. Then the enamel specimens were also ground using a lathe to have a surface of 3.8 mm of diameter.

Preparation of the enamel to be submitted to testing

Human enamels (4.0×7.0 mm^2) were prepared from freshly extracted adults lower incisors. The bucal surfaces of these teeth were ground flat and polished, and they were stored in distilled water in order to avoid their dehydration.

These enamels were irradiated together with a standard of phosphorus (30.0 mg of $NH_4H_2PO_4$) at the IEA-R1m nuclear reactor under a thermal neutron flux of 10^{12} $n\cdot cm^{-2}\cdot s^{-1}$ for 30 minutes. For this irradiation, the enamels were placed in a polyethylene capsule and the P standard was weighed in an aluminium foil envelope. These enamel samples and the P standard were placed together into an aluminium cylindrical container ("rabbit") for irradiation.

After about one week of decay time the irradiated enamel was fixed in a support to secure the enamel for testing, made by dental methacrylate resin by using a metal matrix.

Abrasion experiment

A mechanical machine was used to cause the wear of the material. This machine has a long stick, in which bottom is adapted the antagonistic material, and also it has an acrylic reservoir where the acrylic block with the irradiated enamel is placed. The machine allows the sliding motion of antagonistic material on the surface of the irradiated enamel producing wear. A mass of 285 g was applied to the antagonist to produce a constant force. The electric engine device allows movements with a frequency of 120 cycles per minute. Each cycle refers to a complete forward-and-backward movement.

The irradiated enamel is placed inside an acrylic reservoir with 10 ml of distilled water and mounted in the wear machine. The antagonistic material is also placed in the moving stick part of the machine and the wear operation is carried out until 2500 cycles are completed. Each natural enamel was wear tested with each one of six antagonistic materials (enamel, two prosthetic resin materials and three dental porcelains).

After the wear operation the water from the acrylic reservoir was transferred to a planchet and dried for beta radiation measurements. A preliminary experiment was carried out to assure that there was no interference of other activated radionuclides of the samples in counting. The identification of ^{32}P was carried out by measuring the sample for different decay times and then determining the half-life. The half life of 14.27 days of ^{32}P was obtained in this determination indicating there is not interference of other radionuclides. The beta particles from ^{32}P of the enamel, resulting from wear, were measured for 10 minutes using a Geiger-Müller detector and the counting rates varied from 1.2±0.6 to 657±10 cpm. Each sample was measured three times. The mean value of these three measurements after correcting for background radiation was used for P analysis.

The phosphorus standard was prepared for counting in the same geometry of the sample. After irradiation, the ammonium phosphate was dissolved and diluted with distilled water obtaining a solution containing 323.9 μg P/ml. An aliquot of 50 μl of this standard solution was pipetted and dried to be counted.

Using the counting rates from the sample and standard, the amount of P transferred to the water was calculated by comparative method of neutron activation analysis. The amount of worn enamel was obtained considering that P concentration in enamel is 18±2%, according to SÖREMARK and SAMSAHL[10] which have used the method of neutron activation analysis for this determination.

Vickers microhardness measurements

The restorative materials and human enamel were prepared in so as to produce a polished flat surface for testing. The measurements were carried out using M-Testor device from Otto Wolpert-Werke, Germany.

Statistical analysis

Statistical parameters of means and standard deviations were calculated and also analysis of variance (ANOVA) was used to verify whether there are statistically significant differences between the wear data obtained for the six antagonists tested. A difference between the groups of materials was verified, then the comparisons of mean values were performed using TUKEY's method[11] at the level of significance of 5%.

Table 1. Vickers microhardness of dental enamel before and after neutron irradiation for 1 hour

Specimen	Vickers microhardness Before	After
Enamel 1	377 ± 34[a]	296 ± 16
Enamel 2	392 ± 33	293 ± 16
Enamel 3	413 ± 41	282 ± 21
Enamel 4	379 ± 20	275 ± 16
Enamel 5	380 ± 31	245 ± 18

[a] Standard deviation obtained from mean of ten measurements in each specimen.

Table 2. Vickers microhardness of dental enamel before and after neutron irradiation for 30 minutes

Specimen	Vickers microhardness Before	After
Enamel 6	300 ± 18[a]	281 ± 38
Enamel 7	311 ± 20	313 ± 26
Enamel 8	343 ± 14	329 ± 27

[a] Standard deviation obtained from mean of ten measurements in each specimen.

Table 3. Enamel wear caused by antagonistic materials

Antagonist	Mean*	Standard deviation*
Dental enamel	0.94	0.78
Ceramco	3.32	2.82
Finesse	2.54	1.64
Noritake	4.20	3.13
Artglass	0.34	0.47
Targis	0.37	0.27

*Mean and standard deviation obtained in eight determinations of wear. Results are given in μg of enamel/mm^2 of surface area eroded.

Results and discussion

Preliminary studies carried out to establish adequate conditions showed that a 1-hour irradiation at a thermal neutron flux of 10^{12} n·cm^{-2}·s^{-1} may cause damage of the enamel by the reduction of its hardness. Tables 1 and 2 present the Vickers microhardness of dental enamel before and after irradiation, using irradiation times of 1-hour and 30-minute, respectively. Statistical *t*-test applied in these results, at the significance level of 5%, showed no significant reduction of surface hardness when 30-minute irradiation was used. Therefore, this irradiation condition was adopted in this work. The reproducibility of the wear results were also previously verified by measuring counting rates of ^{32}P released from an irradiated tooth.

The mean values calculated of the enamel wear obtained using restorative materials and an other enamel are summarised in Table 3. The high standard deviation of results probably reflects the biological nature of teeth, with their peculiar development and maturation processes as well as their structural variability. Despite the variability of results presented by each enamel sample there is a tendency line of wear for each antagonistic material used. An analysis of variance and multiple comparisons using TUKEY's test, at the significance level of 5% demonstrated significant differences between the enamel wear caused by feldspathic porcelains and prosthetic resin materials. Also a significant difference of the enamel wear was obtained for the results for enamel and Noritake. The summary of data obtained from ANOVA and TUKEY's test are presented in Tables 4 and 5, respectively. The difference of means presented in Table 5 were compared to the minimal difference significant value of 2.87 obtained by TUKEY's test at the significance level of 5%.

Therefore, results obtained in this work (Tables 3, 4 and 5) indicate that the dental porcelains Ceramco II and Noritake present a more abrasive performance to dental enamel than an another enamel or the resin restorative materials (Artglass and Targis). Resin materials caused small amount of enamel wear, having a different performance when compared to the feldspathic porcelains Ceramco II and Noritake. Also the Noritake porcelain was more abrasive than enamel. There were no statistically significant differences between the wear obtained for distinct types of porcelains, although the Finesse low fusing porcelain demonstrated less wear than the Ceramco II or Noritake felspathic porcelains.

These findings are in agreement to the results obtained by AL-HIYASAT et al.[12] and HACKER et al.[13] These investigators have measured the profile of wear using a reflex microscope and a profilometer, and concluded that low fusing dental porcelains are less abrasive to dental enamel than conventional feldspathic porcelains.

The method of surface profile measurement and the gravimetric method, for enamel wear assessment, present some technical problems related to control the humidity of the materials and of the need of using long period of artificial abrasion. However, the radiometric method, employed as a routine to measure dentifrice abrasivity, does not present these difficulties. The radiometric method also allows the evaluation of wear caused by several different antagonists using the same enamel sample, since it requires a very low rate of artificial wear to the measurements.

Table 4. Parameters obtained in the analysis of variance

Source	Sum of squares	DF*	Mean squares	*F*-ratio	*F*-probability
Between groups	107.1316	5	21.42632	6.010945	2.437694
Within groups	149.7112	42	3.564552		
Total	256.8428	47			

*Degrees of freedom.

Table 5. Data for TUKEY's test. Comparison between groups

Materials used as antagonists	Difference of means
Enamel vs. Targis	0.57
Enamel vs. Artglass	0.60
Enamel vs. Finesse	1.59
Enamel vs. Ceramco II	2.37
Enamel vs. Noritake	3.26*
Ceramco II vs. Finesse	0.78
Ceramco II vs. Noritake	0.88
Ceramco II vs. Targis	2.95*
Ceramco II vs. Artglass	2.98*
Finesse vs. Noritake	1.66
Finesse vs. Targis	2.17
Finesse vs. Artglass	2.20
Noritake vs. Targis	3.83*
Noritake vs. Artglass	3.86*
Artglass vs. Targis	0.03

* Minimal difference significant = 2.87 at the 5% of significance level.

Table 6. Vickers microhardness values of antagonists

Materials	Vickers
Enamel	388 ± 34**
Noritake	663 ± 50*
Ceramco	759 ± 49*
Finesse	717 ± 63*
Artglass	69 ± 2*
Targis	75 ± 1*

** Mean and standard deviation of 50 measurements.
* Mean and standard deviation of 10 measurements.

The results of the Vickers microhardness measurements presented in Table 6 were compared with literature data. Vickers microhardness values for human enamel obtained in this work are very close to that presented by MCCABE[14] (Vickers hardness = 350) and MAUPOMÉ[15] (Vickers hardness = 344). As to dental porcelains, literature Vickers microhardness values are ranging 430 to 1200, depending on the porcelain type.[14,16]

Results of microhardness values of enamel and dental materials used as antagonists indicated a correlation with the enamel wear results obtained in this work.

Conclusions

Based on the results obtained in this study, it is possible to conclude that feldspathic porcelains are more abrasive than resin restorative materials. On the other hand, resin restorative materials are less abrasive than enamel.

These data could be useful for clinicians to select adequate dental materials for clinical application. Although there was no statistically significant difference between the several types of porcelains, the low fusing Finesse porcelain seems to be more compatible with enamel than feldspathic porcelain. In vivo research is needed to determine whether these in vitro findings are compatible with actual clinical performance of the materials.

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