Chemical Durability of Dental Ceramic Material in Acid Medium

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Abstract

Dental materials need to be thoroughly examined in order to assess their long-term therapeutical value. Chemical degradation of dental ceramic material enhances its roughness, leading to the wear of the opposing natural tooth or restorative material, greater plaque attachment to ceramics, weakening of the ceramic structure causing the critical ion exchange at the surface and enhancing the sensitivity to future chemical agents. The aim of this study was to test loss of mass in samples of four different dental ceramic materials in an acid medium. The least mass loss was recorded in apatite glass ceramic (IPS-Empress 2 for layering) (4.9±0.3 μg/cm2), and most mass loss was recorded in alumina ceramic (Vitadur alpha) (15±0.2 μg/cm2). Lithium disilicate glass ceramic (IPS-Empress 2 for coloring) and alumina (IPS-Classic) showed very similar results (9.4±3.4 μg/cm2 and 10.1±0.3 μg/cm2). The values of mass loss in samples in this work, as well as in the most of the literature, are minimal and presumably do not have any clinical or toxicological effects. However, it does not imply that these values can be generalized and transferred to dental ceramic materials that were not yet analyzed.

Key Words: Ceramics, Dental Restoration Wear

Article Outline

Introduction

Dental materials need to be thoroughly examined in order to assess their therapeutic value. One of the most important properties of a restorative material is that it is biologically inert. This property depends on the structure, composition, laboratory handling and the environment having its effect on the material. It can also be described by means of chemical degradation.

Chemical degradation of dental ceramic materials enhances its roughness leading to the wear of the opposing natural tooth or restorative material, greater plaque attachment to ceramics, weakening of the ceramic structure causing the critical ion exchange at the surface and enhancing the sensitivity to future chemical agents. In some ceramic materials, the chemical and mechanical influence on the surface enhances it by lowering the rate of ion exchange (1).

Despite of all the knowledge, the properties of dental ceramic materials in oral cavity are still not completely understood. There are many different examination methods of chemical durability of restorative materials; two most frequently used being the methods according to ISO (2) and ADA (3) standards. These two methods use 4% acetic acid as a medium that speeds up the degradation process, and later analyze the mass loss of the samples after immersion. There are different methods that tried to analyze the chemical durability in more detail, simpler or longer (4-11). All these methods differ in medium that is used in degradation analysis, time of analysis and the results that are expressed either as a mass loss or loss of specific ions in the samples.

The aim of this study was to assess the chemical stability of four different dental ceramic materials in an acid medium.

BACK TO THE TOP

Materials and methods

Samples of four types of dental ceramic material (table 1) were constructed in a Plexiglas cast (10×10×2 mm). The tested dental ceramic materials were prepared according to the manufacturer's instructions. When preparing samples of alumina ceramics we used a cast made of Plexiglas in which the ceramic mix was condensed. After condensation the samples were transferred to foil and to standard ceramic ovens. When preparing samples of IPS Empress 2 glass ceramics the cast was used for wax samples that were cuvetted and from which we obtained the ceramic samples under pressurized procedure. Since the guideline in this study was ISO standard 6782 (2) for assessing the durability of dental ceramic materials, we manufactured ten samples of each ceramic material. All samples were completely glazed in order to represent the prosthetic work more accurately.

Samples were washed in distilled water in an ultrasonic bath (UltraSonic Bath Model 1510 DTH, Electron Microscopy Sciences, Hatfield, USA) and dried in a sterilizing unit (Sterilizator, Instrumentarija, Zagreb, Croatia) at 150±5 °C during four hours. After determining the mass of the sample with the accuracy of ±10-5 g (analytic scale, Ohous, Analytical plus), each sample was immersed in 25 ml of 4% CH3COOH solution in a polypropilene bottle. The bottles were placed in a thermostatic shaker (Innova 4080 Incubator-shaker, Herisau, Switzerland) at 80°C with 200 rpm for 16 hours. After the time has elapsed, the samples were washed with distilled water in an ultrasonic bath (ISO 3696) and dried in a sterilizing unit at 150±5 °C during four hours, and weighed.

The results are described by descriptive statistics and Mann-Whitney test.

BACK TO THE TOP

Table 1. Tested dental ceramic materials

Sample group	Product name	Manufacturer	Type of ceramic material
1	Vitadur alpha	Vita Zahnfabrik, Bad Säckingen, Germany	Alumina ceramic
2	IPS-Classic	Ivoclar Vivadent, Schaan, Liechtenstein	Alumina ceramic
3	IPS Empress 2	Ivoclar Vivadent, Schaan, Liechtenstein – for layering technique	Apatite glass ceramic
4	IPS Empress 2	Ivoclar Vivadent, Schaan, Liechtenstein – for colouring technique	Lithium-disilicate glass ceramic

BACK TO THE TOP

Results

Two independent groups of samples were compared by means of Mann-Whitney test. We compared the calculated losses of mass of all groups of samples. Table 2 clearly depicts that the mass losses of the samples are statistically significantly different ($p<0.05$). Table 3 depicts the results of descriptive statistics for all sample groups. The results of the testing are depicted in figure 1. The smallest mass loss was measured for apatite glass ceramics (4.9±0.3 μg/cm2), and the greatest for alumina ceramics (15±0.2 μg/cm2). It is interesting that lithium-disilicate ceramics and alumina ceramics (IPS Classic) show very similar results (9.4±3.4 μg/cm2 and 10.1±0.3 μg/cm2).

BACK TO THE TOP

Table 2. Mann-Whitney test for comparison of independent groups (sample groups were described in Table 1).

Comparison of sample groups	Mann-Whitney U	Z	p
1 - 2	0	-3,368	0,001
1 - 3	0	-3,371	0,001
1 - 4	0	-3,368	0,001
2 - 3	8	-2,526	0,012
2 - 4	11,5	-2,162	0,031
3 - 4	0	-3,368	0,001

BACK TO THE TOP

Table 3. Descriptive statistics (μg/cm2). Sample groups were described in Table 1.

Sample group	Arithmetic mean	Standard deviation	Minimum	Maximum
	Median	Interquartile range	25th percentile	75th percentile
1	15,0	0,2	14,7	15,3
	14,9	0,4	14,8	15,2
2	9,4	3,4	1,0	10,8
	10,6	0,5	10,3	10,8
3	4,9	0,3	4,6	5,3
	4,9	0,4	4,7	5,1
4	10,1	0,3	9,7	10,5
	10,1	0,5	9,8	10,3

BACK TO THE TOP

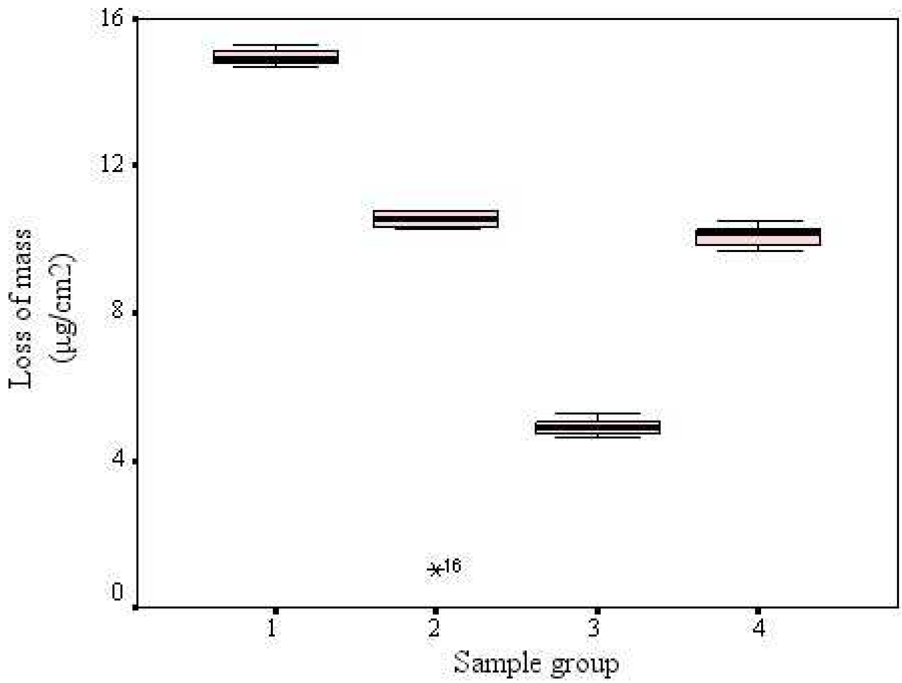

Figure 1. Graphic depiction of loss of mass of samples (µg/cm2), depending on sample group (as described in Table 1)

BACK TO THE TOP

Discussion

Degradation in the oral cavity due to mechanical or chemical influences, or their combination, challenges the initial properties of dental ceramics. In practice, these influences are inseparable, so they exhibit synergistic effect on every prosthetic restoration, including ceramic ones. Since the literature mentions studies on only mechanical, or only chemical, influence, a question whether their synergistic influence causes more or less material degradation can be raised. White et al. gave an answer to that question (12), proving that combined influences do not have different outcome when compared to their addition, lending credence to the fact that separate monitoring of chemical and mechanical on the materials is possible.

If only chemical influence is monitored, one can realize that oral cavity represents a rather aggressive environment for every dental material. The acidity of saliva is constantly changing, depending on food intake, amount of plaque, saliva composition and acidity of the gastric juice. It has been proven that the fracture resistance of ceramic material in aqueous environment decreases. With degradation of mechanical properties, corrosion processes increase the roughness of the surface of some ceramic materials, thus enhancing plaque adhesion (5,13); corrosion increases the wear of antagonistic teeth and material and change of color, thus diminishing the esthetic outcome of the ceramic restoration (1). Even minute changes in surface roughness can cause changes in interaction between the ceramic surface and the environment. Furthermore, possible decrease of chemical stability of the ceramic material can contribute to advanced dissemination of anorganic ions and other components that can potentially be toxic (for example, lithium from lithium-glass ceramics).

Corrosion of dental materials must be known and understood in order to foresee the durability of the material and its long-term biocompatibility. Although dental ceramic materials are considered to be inert, possible effects of corrosion products on the biological system cannot be overlooked. Safety of the tested ceramic material cannot be transferred to other types that were not tested, and it cannot be transferred to other conditions (1,5).

Different acids are often used for testing chemical durability, such as hydrochloric acid (4), or acetic acid (2). The advantages of acids when compared to artificial saliva or distilled water is the speed of the corrosion, i.e. faster degradation of materials, and the wish for better prediction of the durability of the ceramic material in the mouth. Tests with artificial saliva or distilled water would last for years, whereas acid tests are much shorter. Some authors (4) like to include the processes in the oral cavity occurring at much greater acidity when testing the durability of the material; it is well known that the acidity of the mouth varies and in some cases, like, for example, in patients with gastric symptoms, the acidity can be very high. For these reasons ISO standard 6872 (2), which is related to chemical durability of dental ceramic materials, uses 4% acidic acid for testing. This study used acetic acid, which, apart from ISO standardization, is the most widely used acid. The acidity level (pH = 2.4) is the same as in some refreshing drinks and fruit juices, as well as the level that has been established in plaque. Although acetic acid is a weak organic acid, it is still corrosive enough for glass by establishing soluble complexes (5).

The results of this study show that apatite glass ceramic material (4.9±0.3 µg/cm2) loses three times less mass than alumina ceramics (Vitadur alpha, 15±0.2 µg/cm2). Lithium-disilicate glass ceramic material and alumina (IPS-Classic) ceramic material show similar results (9.4±3.4 µg/cm2 and 10.1±0.3 µg/cm2). It is interesting to note that apatite ceramics has almost twice as good results than lithium-disilicate, although they share the same production name. There are also significant differences in mass loss between samples of IPS-Classic and Vitadur alpha ceramic materials, although both of these materials fall into the group of alumina materials. It must be stressed that all values of mass loss fall well below 2000 µg/cm2 that is the set limit according to ISO standards No. 6872 that is valid for all ceramic materials (2).

Grossman and Walters (8) reported on loss of mass of Dicor ceramic material that in 4% acetic acid at 80°C amounts to 4.2×10-3 mg/cm2 daily. Chemical durability of Vitadur ceramic material was 16.5×10-3 mg/cm2 daily, of Vitadur aluminum-oxide material for hard shells 20×10-3 mg/cm2, and of Ceramco alumina ceramic material 9.5×10-3 mg/cm2.

Anusavice (1) has computed that the maximum ion release from 32 ceramic teeth in acetic acid at 80°C amounts to 0.1 mg daily. The established depth of the penetration defect in ceramic material after one year was only 0.3 µm for glass ceramics and 1.4 µg for Vitadur N opaquer.

The study by Esquivel-Upshaw et al. (7) showed that out of three tested ceramic materials IPS Empress was the least stable with regards to the color and flexural strength, while the chemical durability of In-Ceram was not acceptable even for ADA Standard No. 69 (3). Procera, as the third tested material for copings, showed the best values of chemical durability and mechanical toughness.

Although there were minute values of mass loss of the samples, it does not imply that the values are the same for all dental ceramic materials on the market. The testing should be done over a longer time period, as suggested by De Rijk et al (6).

BACK TO THE TOP

Conclusions

1. Different ceramic materials have different values of loss of mass, without regards to the similarity of chemical composition of product name.

2. Losses of mass values were minimal.

3. The established values most probably do not have any clinical or toxicological consequences.

4. The values cannot be generalized and cannot be transferred to dental ceramic materials that were not tested.

BACK TO THE TOP

Acknowledgments

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BACK TO THE TOP

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BACK TO THE TOP