A Method for Testing Abrasive Wear of Aesthetic Prosthetic Materials

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Summary

Friction and wear occur due to the contact of surfaces which are more or less rough. During abrasive wear the extrusion of material occurs, caused by hard particles which apply pressure toward the surface or slide along it (three-body abrasive wear) or by hard protrusions (two-body abrasive wear). Because of demands to provide a satisfactory aesthetic mastication surface the clinician is faced with the problem of the choice of material for veneering.

The article describes a method for testing abrasive wear of pairs of tooth-prosthetic material for veneering. In order to test the method two different prosthetic veneering materials were tested (polymer material SR Chromasit, Ivoclar and Clay ceramic, Sign-Ivoclar) on a modified Taber abraser, in dry conditions. Significant differences were determined in the wear scars on specimens of the tested materials. The method enables the testing of specimens of different materials mutually or in a pair with a natural tooth, under different loading and with or without a third body (food or artificial saliva), which in clinical practice represents valuable data during the choice of the type of construction and veneering material.

Key words: *abrasive wear, polymers, dental ceramics.*

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Introduction

Friction and wear of material have accompanied man since his very beginning, in some ways advantageously and in others disadvantageously. Friction leads to loss of energy and wear to loss of material, undesired movement and loss of precision, frequent vibrations and increased mechanical loading. An efficient tribo-system achieves satisfactory friction and wear, during which conflicting requirements occur: resistance to wear and suitability for shaping (1).

The demands of patients for restorations that will most convincingly simulate natural teeth and mask each metal construction encourage the increasing use of ceramic as the material of choice in dental prosthetics. However, a clinical problem occurs because of the possibility of abrasive effects on the opposing teeth, and on the other hand polymer materials wear markedly during function (2-4). The correct choice of prosthetic material is important for the maintenance of normal functioning of the stomatognathic system (5-7). Investigations of wear through clinical studies are long-term and monitoring of changes in the material on a large number of patients is necessary, which represents a problem both from the economic and the ethical point of view. Consequently numerous laboratory methods of testing have been developed in which the characteristics of wear of certain materials can be determined (8-13). On the basis of such results the behaviour of the material in the oral cavity can be assumed. However, so far no standard method has been developed by which the results and characteristics of wear obtained would be identical to those which materials display during function in the mouths of patients.

Simulation of the conditions of the oral cavity require the presence of three components: artificial saliva which reacts with the surface of the material, specific temperature of the medium (37ºC), aeration and control of moisture, and movements of the jaws and forces which develop during mastication cycles. The development of methods for laboratory testing varies from those very simple, non-physiological (Wig-L-Lug methods) to those perfected (post-disc systems) (14-17) which imitate forces and movements during the masticatory cycle and temperature conditions within the oral cavity.

Aim of the study

The aim of this study was to construct and develop a new apparatus and method by which it would be possible to test wear, i.e. the mutual behaviour of materials in pairs: a natural tooth-prosthetic material for veneering or two different prosthetic materials for veneering, in order to contribute to better understanding of the three-body systems of the aforementioned materials. The results should be reliable and repeatable.

Materials and methods

The research was carried out in the Department of Materials, Faculty of Engineering and Shipbuilding in Zagreb, and the specimens on which the apparatus was tested were constructed in the Dental-Technical Laboratory of the School of Dental Medicine in Zagreb. One specimen each was made of the prosthetic material for veneering: polymer (SR Cromasit-Ivoclar) and one specimen of dental ceramic (Sign, Ivoclar), in the form of a disc, 20 x 25mm. The surface of the specimen of polymer material was polished and of the ceramic glazed.

A Taber abraser was used which works on the pin on disc method, which is used for three-body testing in engineering. For testing biomaterial the method was modified so that instead of a pin a natural tooth was used and instead of a disc the examined material. The working mechanism of the apparatus is presented in Figure 1. The specimens were immovable, fixed onto the rotating part by acrylic adhesive (Figure 2). By rotating the fixed specimens contact occurred between the tooth and the specimen, and by sliding over the surface of the specimen, the tooth left a wear scar (Figure 1). All the photographs were recorded during the laboratory testing.

Human, intact third molars were used to test the method, extracted because of orthodontic reasons, and stored in physiological solution after extraction (Figure 3). The teeth were fixed on the moveable part of the apparatus, which slides over the rotating part on which the specimens of prosthetic materials for veneering were fixed. It was possible to change the amount of loading applied to the specimens. The mesiobuccal cusp of the tooth slides over the surface of the tested material, marking a circle of 10mm, with frequency of 60 cycles per minute.

The test was performed without a third medium lubricant, with loading of 20N, during 60 cycles (Figure 4).

The procedure was performed with a specimen of polymer material and in the same way with a specimen of dental ceramic. The tests were performed by the same individual in order to reduce the possibility of error and manipulation.

Results

The choice of tribo-pairs: natural tooth-polymer veneering material and natural tooth-ceramic, with loading of 20 N showed results which were already visible after 60 cycles (Figure 5).

After testing the resulting wear scars on the specimens were examined under a microscope, type Olympus BH 2, magnification 1200. The surface of the specimen was examined in order to detect the two-dimensional appearance of wear, and the depth and width of the wear scar. Figure 6 shows the two-dimensional appearance of the wear scar on different materials tested under identical conditions.

The graphs presented in Figure 6 show significance differences in the depth and width of the wear scar on different materials, indicating that ceramic had greater resistance to wear compared to the polymer material. These results provide the basis for quantitative comparison of the resistance to wear of two different materials. Apart from scars on the surfaces of the specimens of prosthetic materials damage also occurred on the cusps of the tested teeth which were in sliding contact (Figure 7).

As the aim of this study was to test the method, modification of the apparatus and its application on biomaterials, measurement of the resulting wear scars was unnecessary. However, this will be the subject of a test of the materials themselves in a subsequent investigation.

Discussion

Correct choice of material for a specific clinical case ensures the best protection from wear, both of the restoration itself and of the opposing teeth. In clinical practice one frequently comes across completely worn mastication surfaces of restorations in the case of polymer material, and likewise worn parts of the enamel of the opposing teeth in patients treated with metal-ceramic restorations. The choice of material must take account of the envisaged degree of danger of specific mechanisms of wear in the relevant tribologic system. Resistance to wear is not the only integral property of the material, but rather it consists of resistance to adhesion, resistance to abrasion, resistance to surface fatigue, resistance to cavitation, etc. The choice of material includes the choice of methods for treatment of surfaces in order to reduce wear (18). Thus, the basic material fulfils the requirements with regard to the technology and integrality of the tribologic elements and additional treatment of the surfaces completes the tribologic requirements. The sliding process can be monitored in a medium, e.g. artificial saliva, or it can include a third body (mixed food particles).

Koczorowski et al (15) developed a special device for testing wear, tribologic station ST-3, using artificial saliva as a medium. Palmer et al (16) used apparatus for wear according to the National Bureau of Standards, which produces rotation of a disc, similar to an eccentrically sliding movement. They tested the wear of dental ceramics, caste glass-ceramic, with and without veneer under loading of 3.015 kg, for one hour and 15 minutes. Distilled water at 37º was used to rinse the specimens during the cycle in order to simulate the lubrication role of saliva in the oral cavity.

Ramp et al (17) tested the wear of specimens of three dental ceramics and gold alloy, type III, with enamel during a three-body test of wear, under loading of 75N. The upper part of the device was slanted at 30º, which lead to the occurrence of a sliding movement between the enamel and the specimen, in addition to the vertical movement. By removing the loading the upper part then counter-rotated to its original position during each cycle. The test was performed for 100 000 cycles at a frequency of 1.2Hz.

Compared to enamel most ceramics have higher values of hardness. It was considered that the higher values of ceramic hardness are associated with higher abrasive wear of enamel. Tests have shown that hardness alone of the material, particularly brittle such as ceramic, is not the only factor which conditions the wear of dental enamel (18). The results of different in vitro performed studies which examined the effect of the microhardness of prosthetic restorative materials on enamel wear of opposing teeth have shown that ceramics of less hardness lead to greater abrasive wear of the enamel than ceramic materials of higher values of hardness (19-21). Hardness and wear of brittle materials show poor mutual correlation because the contacts of such materials result in fracture and not plastic deformation. Microstructural differences between different ceramic materials may explain the different amount of enamel abrasion (19). The morphology and distribution of crystals in the glass matrix may be changed by incorrect thermal methods in the dental-technical laboratory. Porosity, particularly the presence of sharp edges on the surface, which cause significant wear of the contacting materials, strength of the masticatory forces and chemical agents, are all factors which will increase the wear of tribo pairs (12). Seghi et al (20) tested tribo pairs; enamel with five different ceramic materials. They compared the amount of abrasive wear of the ceramic materials and the enamel with Knoop's hardness values, and found that Dicor caused the least wear of the tooth enamel, and Optec the most wear, which can be explained by the microstructural differences between the materials.

Al-Hiyasat (22) subjected specimens of four types of dental ceramic and specimens of one type of dental gold alloy to loading of 40N during 25 000 cycles with frequency of 80 cycles in a minute, with distilled water as a medium, which was renewed every 5 000 cycles. With the same apparatus he also tested the wear by a three-body test with food particles. The results showed that the abrasiveness of the dental and hydrothermal ceramics were similar, while the hydrothermal ceramic had the least resistance to wear. The wear of ceramic materials can vary in different media due to the interaction of microstructural components of the material and environment.

A third medium was not used in this pilot study, as the purpose was to test the method and apparatus in order to test the wear of different prosthetic veneering materials. For further study a third body would be incorporated in order to create conditions similar to those in the oral cavity, and thus enable better comparison of the results of the present study with those of similar studies.

Conclusion

The test determined significant difference in the depth and width of the wear scar on different materials, which represents the basis for better comparison of the wear resistance of two different materials. The specimen of dental ceramic had greater resistance to wear compared to the specimen of polymer material.

The effectiveness of the apparatus was demonstrated by the occurrence of wear scars on the specimens, which provides the basis for further measurements and tests. Subsequent tests will include a moist medium with the presence of a third body.