IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 15, Issue 6 Ver. XI (June 2016), PP 63-68
www.iosrjournals.org

Methods of Wear Measuring in Dentistry

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Abstract: *Wear in dentistry affects both the natural tooth structure as well as reconstructive materials that replace them. For perfect understanding of the properties and the correct indication of dental materials it is necessary to understand their wear mechanism. Wear of hard dental tissues and dental reconstructions can be measured in vivo or in vitro. In developing of new materials their investigation using different devices is especially important. It's the first system to distinguish inappropriate material that could in extreme cases threaten the patients. It is also an orientation aid for the dentist with respect to be able to compare materials without distorting by the patient individuality. In doing so, it should be kept in mind that it is impossible strictly use only laboratory or clinical tests, but it is always necessary to combine them. In the paper the authors descript the measuring methods of hard dental tissues and dental reconstructions wear.*

Keywords: *filling materials wear, nanoindentation, scratch test, microscopy, wear indices*

I. Introduction

One of the physiological properties of hard dental tissues is their natural wear throughout the life. Besides physiological wear, there is also aware a pathological wear that also affects the surface of filling materials substituting the enamel and dentin. The mechanism of tooth wear lies in the interplay of various factors such as the mechanical load due to compression, flexion and tension, friction and chemical influences. Rarely these factors operate separately, so the term multifactorial nature of hard dental tissues wear is mostly used. A similar effect these factors have on restorative materials. For the correct choice of dental restorative material it is important to understand perfectly their chemical and mechanical properties, as well as take into account their wear during exposure to the effects described above. For example, an incorrect choice of too hard materials can result in wear of antagonists due to attrition. The use as a substitution for hard dental tissue of the material that is not quite resistant against the acidic environment of the oral cavity, occurring in patients with frequent vomiting, reflux, or after consumption of large amount of acidic foodstuffs and drinks, could eventually lead to the failure of reconstructive therapy and the need for making of new restorations. Wear of the tooth surface and reconstructive materials can be measured in in vivo and in vitro conditions.

II. Measuring in Vivo

2.1. Measuring of Tooth Wear- Wear Indices

For the determination of hard dental tissues wear degree different indices are used. The most commonly used index is a tooth wear one according to Smith and Knight (1) (Table 1) distinguishing the wear of incision edge, occlusal surfaces as well as the cervical area of the teeth.

Table 1 Tooth Wear Index (TWI) according to Smith and Knight (1)

Score	Tooth surface	Criteria
0	Labial/oral/occlusal/incisal Cervical	Without signs of enamel loss Without signs of crown contours loss
1	Labial/oral/occlusal/incisal Cervical	Loss of enamel surface relief Minimal loss of crown contours
2	Labial/oral/occlusal Incisal Cervical	Loss of enamel; dentin baring less than 1/3 of surface Loss of enamel with minimal baring of dentin The depth of defect is less than 1 mm
3	Labial/oral/occlusal Incisal Cervical	Loss of enamel; dentin baring more than 1/3 of surface Significant loss of enamel and dentin The depth of defect is 1–2 mm
4	Labial/oral/occlusal/incisal Cervical	Extensive loss of enamel and dentin with baring of dental pulp The depth of defect is more than 2 mm; baring of dental pulp

In 2008 D. W. Bartlett, C. Ganss and A. Lussi introduced a new diagnostic system enabling fast and simple diagnosis of dental erosion. This system is named Basic Erosive Wear Examination system (BEWE). This screening test can be for its simplicity easily used both for research purposes and in routine clinical practice (1). For the erosion diagnosis according to the system the teeth are divided into six sextants. Consequently the vestibular, oral and occlusal surface of each tooth will be examined. For each tooth the highest value according to the following gradation is recorded:

- **0-** intact surface
- **1-** initial loss of surface enamel layer (**moderate erosion)**
- **2-** obvious defect of hard dental tissues affecting upto 50 % of tooth surface (**advanced erosion)**
- **3-** extensive defect of hard dental tissues affecting more than 50 % of tooth surface (**serious erosion**)

In each sextant the highest value found in the examined groups of teeth will be recorded. The sum of the values of all sextants provides a total value of BEWE. Based on the clinical findings the patient can have:

- Moderate stage of erosive lesions (BEWE 3–8)
- Advanced stage of erosive lesions (BEWE 9–13)
- Serious stage of erosive lesions (BEWE ≥ 14)

2.2. Measuring of Tooth Restorations Wear

For detection of tooth restorations wear and quality some special criteria are used (modified USPHS criteria). They include: evaluation of reconstruction anatomic shape, colour, marginal quality, presence of marginal discoloration or secondary caries (Table 2; Fig. 1, Fig. 2).

Table 2. Modified USPHS Criteria of Filling Evaluation (2, 3)

Colour match	
Grade	*Description*
Oscar (0)	Anterior restoration, invisible without a mirror
Alfa (A)	Posterior restoration, matching the adjacent tooth in colour, shade and translucency
Bravo (B)	Posterior restoration, the mismatch in colour, shade and translucency between the restoration and the adjacent tooth within normal range
Charlie (C)	Posterior restoration, the mismatch in colour, shade and translucency between the restoration and the adjacent tooth outside normal range
Cavo-surface marginal discoloration	
Grade	*Description*
Alfa (A)	No discoloration anywhere on the margin between the restoration and the tooth
Bravo (B)	Discoloration is present but does not penetrate along the margin toward the pulp
Charlie (C)	Discoloration is present and penetrates along the margin toward the pulp
Anatomic shape	
Grade	*Description*
Alfa (A)	Restoration is continuous with existing anatomic form
Bravo (B)	Restoration is under-contoured i.e. discontinuous with existing anatomic form but dentin/base is not exposed
Charlie (C)	Restoration is under-contoured i.e. discontinuous with existing anatomic form and dentin/base is exposed
Marginal adaptation	
Grade	*Description*
Alfa (A)	No visible evidence of a crevice along the margin into which an explorer penetrates
Bravo (B)	Visible evidence of a crevice along the margin into which an explorer penetrates, but dentin/base is not exposed
Charlie (C)	Visible crevice along the margin with exposed dentin/base but the restoration is not mobile, fractured or missing in part of the tooth
Delta (D)	Restoration is mobile, fractured or missing in part of the tooth
Secondary caries	
Grade	*Description*
Alfa (A)	Caries absent along the restoration margin
Bravo (B)	Caries present along the restoration margin

These criteria can be used in oral cavity during patient's examination as well as on study models, macrophotographs or 3D intraoral scans made using scanner.

Figure 1 Fractured and percolated due to secondary caries amalgam filling of Black class 1 on the tooth 46

Figure 2 Percolated composite fillings on the teeth 25 and 26

III. Measuring in Vitro

For the testing of the hard dental tissues and reconstruction materials wear in laboratory conditions many devices were created. The aim of their use was to imitate the conditions which exist in the mouth as much as possible and to keep definability of testing conditions. The main problem of wear testing is the fact that every patient is different. Tests are therefore varied in complexity, used testing strength, trajectory, surface treatment of samples and the number of cycles used.

Most of the devices are used for two-body wear test. However this only simulates the contact of teeth without the presence of food. During the chewing food components formed depending on their hardness important component of wear mechanism. Therefore, some testers have been already adapted to add a third component wear - food sample. However, it complicates the possibility of tests standardizing.

In an effort to unify the testing parameters two ISO standards were introduced (4):

ISO/TR 14569-1:2007 Dental materials -- Guidance on testing of wear -- Part 1: Wear by toothbrushing

ISO/TS 14569-2:2001 Dental materials -- Guidance on testing of wear -- Part 2: Wear by two -and/or three body contact

They describe only some of the many testing methods that will be discussed later.

During the development of dental materials the following tests have been implemented:

1. Pin on disc tribometer
2. Toothbrush simulator
3. Jaws simulator
4. Nanoindentation
5. Scratch test

Pin on Disc Tribometer

Pin on disc is the most common and simplest method of wear testing used in other industries. The base of the method is the use of two-component wear. During the analyzing using this method on the disc-shaped sample surface a 'PIN' body in the form of a roller or a non-rotating ball is applied. At a chosen distance from the sample center the "PIN" is stressed by a predetermined force. The disc starts to rotate with selected engine speed and executes the predetermined number of rounds. Thus, "PIN" body forms a track (path) on the sample surface, which is analyzed (shape, depth, surroundings etc.) (5).

This test is very simple, standardized and inexpensive. In the past, however, various researches configured the various parameters - such as the pressing force, rotational speed or number of cycles. It makes impossible to compare the studies. Another problem is that the test device significantly differs from the conditions in the oral cavity.

Like endeavour to make a more realistic test conditions for chewing investigation the third component of wear- abrasive food particles- is added (milled rice in phosphate buffer, corn pulp and wholemeal flour in distilled water) or artificial saliva. Still a rotational movement remains very distant to mastication movement of the jaws.

Toothbrush Simulator

Hard dental tissues wear as well as dental materials wear does not occur during chewing of food only, but also during the toothbrushing. The size of such wear in patients depends on many factors, like toothbrushing technique and frequency, hardness of toothbrush bristles, dexterity of the patient and finally also toothpaste used. It is also important, whether before toothbrushing acidic food were ingested, that can lead to erosion of tooth surface (erosive-abrasive additive effect) (6).

This method uses a toothbrush which cyclically linearly moves on the surface of tested material with the adjustable pressure force (e.g. 200 g, which corresponds to the strength 2 N) (7).

This test is basically similar to the method pin on disc, but instead of a disc it uses a toothbrush. The test is inexpensive, simple and has its foundation in materials or localization of materials which are not loaded by articulation (e.g. fillings in foramen caecum of molars or fillings of class 3 according to Black). The test does not take into account the abfraction. Standardization of this test is important not only with regard to the device, but also to the selected toothbrush. For a truer simulation it is possible to add a third component of wear – toothpaste or only abrasive particles of toothpaste. Various toothpastes use the abrasive grains of different sizes. Another difference of toothpastes is their ability to change the pH of the oral cavity. So, again we meet with different testing conditions inside one method.

Jaws Simulator

Devices development continued in an effort to best mimic the oral cavity conditions and jaw chewing movements. Scientists have tried to devise a test that will correspond to in vivo conditions. In 1980 DeLong and Douglas constructed so called 'artificial oral environment'. It was a connection of the device simulating the movement of the jaws towards one another and an artificial oral environment.

Jaws simulator consisted from a model of the upper and lower teeth (or just one particular tooth with filling), that were moved towards each other by two or more servo-hydraulic motors. The first engine ensures the movement in the vertical axis, the second one in horizontal axis. Both engines were driven by the computer for the most accurate reproduction of the physiological movements during chewing. It was possible to individually adjust the strength of bite and number of cycles. Another part of the device was the artificial oral environment. It included the possibility of temperature setting like in the human body. Artificial saliva was also created. Other authors have added the food samples for more realistic simulation. They were for example milled rice in phosphate buffer, corn pulp and wholemeal flour in distilled water (8).

More realistic simulator of a human mouth cannot be done. Nevertheless, when the results of experiments in vivo and in vitro using this simulation were compared, there were considerable differences. Sajewicz and Kulesza argue this by the fact that these devices mimic defined chewing movements and strength, but in reality such standard conditions in patients mouth do not exist. Likewise the wear of dental reconstructive materials is influenced by their load, the contact surface and contact geometry (8).

Nanoindentation

Due to the fact that to mimic artificially the conditions in the oral cavity and jaw movements like in real patient is not realistic, studies began to focus on research of the materials physical properties, which are related to the rate of wear. These characteristics include in particular the hardness and elastic modulus. They are given by material properties and in the case of respecting of the material preparation technological process these values are for this material constant. This allows to compare different materials between themselves without the results distortion by test conditions (1).

The test is realized by pressuring of diamond tip with a defined shape into the sample materials prepared under conditions specified by the manufacturer. Previously using known force F, measured diagonal line and the constant characterizing the tester the sample hardness was calculated. At present the test is controlled by computer and in real-time the graph is drawn. By the load curve the computer evaluates the hardness. Using reliever curve the computer evaluates the elastic modulus.

The test is based on the classic test of indexing used in industry, it is only adapted for testing of small samples. This means that the index point was reduced scaled as well as the load forces were adjusted.

Due to this there are two scales: micro and nanoindentation. The advantage is the testing of small samples without their destruction. However the test is sensitive to the sample homogeneity and surface roughness. Therefore, within one sample several scratches are made and they are consequently separately evaluated (1, 9).

There are several scales and hardness tests. Test according to Brinell, Knoop, Rockwell, Vickers. In the industry nowadays scales and test according to Knoop are most commonly used. In contrast, for dental materials testing is more common Vickers hardness.

Vickers hardness test uses the tip in a shape of tetrahedral pyramid with an apex angle 136 °. The result of measuring is the Vickers hardness number. The method of execution is described a unified by standard EN ISO 6507-1:2005.

This method of hardness and elastic modulus measuring is currently the most promising in comparison of reconstructive materials and prediction of their wear during the function.

Scratch test and Confocal Laser Scanning Microscope (CLSM)

Scratch test has been used for hardness testing since 1824, when Mohs scale of hardness was assembled. Originally it was used for determining of minerals hardness. The test used the principle that harder material makes a scratch in less hard one. It was therefore selected 10 minerals from the least to the hardest one and they were used for testing of other materials. They were assigned to these 10 categories according to the table (10).

Over the years, this test has been modernized. Instead of 10 minerals only the hardest one- the diamond- has begun to use. Measurements are provided by computer that using increasing force acts by exactly geometrically defined diamond tip (cone of 120 ° with a radius of the apex rounding 0.02 mm) on the surface of the tested material, and also performs a linear movement over its surface. Measure of the hardness is the force F that is necessary for the formation of scratch with wideness 0.01 mm. Test was firstly described by German metallurgist A. Martens and since 2003 is the standard test of the materials according to ISO 14577 (10, 11).

Thus, in the previous test the sample hardness was detected. Scratch test later offered another option for investigation. With the development of microscopy it was possible to view the scratch in the sample in great detail and identify the violations of its borders, its depth and influence of the material homogeneity on the test. For this purpose a confocal laser scanning microscope (CLSM) is used, which allows to get the image of three-dimensional objects. Unlike a conventional microscope, which can focus on just one place and sharpness of another place depends on the magnification and depth of focus, confocal microscope focuses on the individual points of a three-dimensional object, and after the synthesis of images the result is a sharp in all parts of the object, in our case, of the scratch (12). The Figure 3 and 4 presents the scratches in amalgam and composite material.

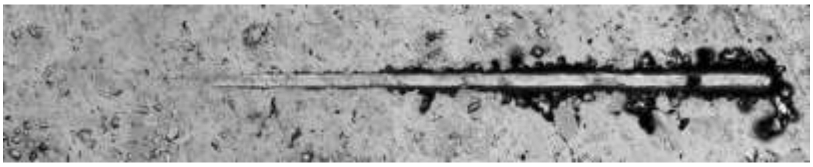

Figure 3 Scratches in dental amalgam (CLSM image)

Figure 4 Scratches in composite material (CLSM image)

IV. Conclusion

One of the patient requirements is the long lifespan of dental reconstruction. At each removal of dental reconstruction there is the remaining dental tissues loss. The reconstructions lifespan depends on biocompatibility, marginal seal or bond to tooth structure. The surface wear is also very important. The situation for each patient is different, and it is advisable to choose the correct type and brand of reconstructive material. It must be resistant enough, but also gentle to antagonist teeth. In this case our wear rate knowledge along with other factors will help to predict the reconstruction lifespan.

Wear rate can be predicted and compared by number of laboratory and clinical tests. They include the initial evaluation of the reconstructions during the dental examination upto currently available today nanoindentation and three-dimensional models making, which will determine the exact place of material loss as well as the most worn filling area. This data can be used not only by dentists to ensure the best possible care and awareness of patients, but also by dental reconstructive materials manufacturers.

References

[1]. A. Lussi, C. Ganss, *Erosive tooth wear from diagnosis to therapy* (Basel: Karger, 2014).

[2]. G. Ryge. Clinical criteria. *International Denal Journal,* 1980, 30(4), 347–358.

[3]. Cvar J.F., Ryge G. Criteria for the clinical evaluation of dental restorative materials. USPHS Publication. San Francisco: National Institute of Public Health, 1971:190–244.

[4]. ISO, Dental materials - Guidance on testing of wear. [online] 2015 [cit. 7.5.2016]. Available from http://www.iso.org/iso/home/search.htm?qt=dental+wear&sort=rel&type=simple&published=on

[5]. A. Kříž. Tribologická analýza Pin-on-disc. Metal 2004.

[6]. T. Attin, U. Koidl, W. Buchalla, H. G. Schaller, A. M. Kielbassa, E. Hellwig. Correlation of microhardness and wear in differently eroded bovine dental enamel. *Archives of oral Biology,* 1997, 42(3), 243–250.

[7]. M. Eisenburger, R.P. Shellis, M. Addy. Comparative study of wear of enamel induced by alternating and simultaneous combinations of abrasion and erosion in vitro. *Caries Research*, 2003, 37(6), 450–455

[8]. L. H. Lee, He, K. Lyons, M. V. Swain. Tooth wear and wear investigations in dentistry. *Journal of Oral Rehabilitation*, 2012, 39(3), 217–225.
[9]. N.E. Kurland, Z. Drira, V. K. Yadavalli. Measurement of nanomechanical properties of biomolecules using atomic force microscopy. *Micron (England: Oxford, 1993)*, 43 (2-3): 116–28.
[10]. Wikipedie. Mohsova stupnice tvrdosti. [online] 2014 [cit. 7.5.2016]. Available from https://cs.wikipedia.org/wiki/Mohsova_stupnice_tvrdosti
[11]. M. Hrdý, I. Štěpánek, R. Reindl, M. Podlahová. Vrypová zkouška z pohledu hodnocení pomocí obrazové analýzy. Metal 2003
[12]. U. Panne, E. V. Adolf. Martens Fonds. [online] 2012 [cit. 7.5.2016]. Available from http://www.amf.bam.de/de/index.htm