*Journal of Applied Dental and Medical Sciences*
*NLM ID: 101671413 ISSN:2454-2288*
*Volume 2 Issue3 July- September 2016*

**Review article**

# A Rationale Approach To Wear Evaluation Of Dental Materials

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ARTICLE INFO

Keywords:
wear, wear simulator, abrasive wear, two body wear, three body wear

ABSTRACT

Tooth wear is a multi-faceted common dental condition, which constitutes a variable amount of tooth substance loss not related to cariogenic conditions. Tooth wear has been linked to several alarming or clinically disturbing conditions for the patient, namely loss of vertical dimension, disorders related to the temporomandibular joint, aesthetic considerations, or hypersensitivity. The dynamic interface of natural tooth enamel and prosthetic dental materials is an area subjected to certain stress conditions when natural dentition is compromised, especially following increasing years of functional capacity of the masticatory system. The majority of researches undertaken with dental materials and duplication of masticatory forces and movements has been concerned with wear of the materials. The present article reviews different aspects and considerations which play an evident role while evaluating wear of dental materials.

## Introduction

Tooth wear is a multi-faceted common dental condition, which constitutes a variable amount of tooth substance loss not related to cariogenic conditions.[1] The wear of dental hard tissue is a natural and unavoidable process. Wear is a progressive phenomenon characterized in the oral cavity by the loss of the original anatomical form. This process may result from physiological or pathological conditions.[2] Wear may appear as a result of the effect of acid-containing solutions, mechanical loading and related forces generated by masticatory function within a tooth-to-tooth or tooth-to-restorative material contact interface, or else through abrasive effects of intermediate factors (i.e., abrasive particles).[3,4] Tooth wear has been linked to several alarming or clinically disturbing conditions for the patient, namely loss of vertical dimension, disorders related to the temporomandibular joint, aesthetic considerations, or hypersensitivity. The amount of wear is therefore evidently a significant determinant of the severity of clinical manifestations.[4] Excessive wear results in unacceptable damage to the occluding surfaces and alteration of the functional path of masticatory movement. It may also destroy anterior tooth structure that is essential to acceptable anterior guidance function or esthetics, resulting in increased horizontal stresses on the masticatory system and associated temporomandibular joint remodeling. Excessive wear of a single tooth, restoration or an entire dentition has

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been associated with overeruption of opposing teeth, mesial drift of teeth distal to an eroding contact, traumatic occlusion and temporomandibular disorders.[5,6]

The dynamic interface of natural tooth enamel and prosthetic dental materials is an area subjected to certain stress conditions when natural dentition is compromised, especially following increasing years of functional capacity of the masticatory system. Although most restorative materials resemble enamel, they do not necessarily have similar characteristics in terms of surface roughness, fracture toughness, and microstructural features.[7] The wear of enamel and of restorative material is often a critical concern when selecting a restorative material for any given clinical restorative treatment. Dentists who select materials for clinical use still look at the wear resistance of prospective materials. Furthermore, dental associations such as the American Dental Association (ADA) has formulated wear threshold values for the acceptance of restorative materials. These standards require that the wear of a dental material does not exceed 150 m within 3 years thus calculating an annual wear rate of 50 m.[8] The majority of researches undertaken with dental materials and duplication of masticatory forces and movements has been concerned with wear of the materials. The present article reviews different aspects and considerations which play an evident role while evaluating wear of dental materials.

## TYPES OF WEAR-

### Abrasive wear

Abrasive wear can be defined as the wearing away or removal of material by the act of rubbing, cutting, or scraping and occurs when a rough surface or loose hard particles plough out softer material. Abrasion depends on many factors including, hardness, size and shape of the abrasive, speed of movement of the abrasive and the substrate against each other, pressure applied on the substrate and the amount and type of lubrication between them.[9,10]

Harrison (1978) has described the wear process that takes place in the mouth as either two or three-bodied wear or combination of both. With only saliva in the system wear is restricted to a two-body process (i.e., between two rubbing surfaces). The introduction of an abrasive such as toothpaste or food produces a three-body situation.[11,12]

### Adhesive wear

Adhesive wear results from friction between the moving surfaces which causes local cold welding between asperities. Further movement of the surfaces fracture these welds and transfer material from one surface to another. Although this type of wear is normally associated with metals it has been shown to occur between two surfaces of polymethylmethacrylate.[12,13]

### Fatigue wear

Fatigue wear is wear due to the generation of intermittent stresses where the degree of scratching may be minimal [18]. Some of the movement of the surface molecules is transferred to the subsurface causing rupture of intermolecular bonds and a zone of ‘subsurface damage’. Eventually ‘microcracks’ form within the subsurface and, if these coalesce to the surface, then there can be loss of a fragment of material inducing fatigue wear.[14]

**Corrosive wear**

Corrosive wear results from the interaction of chemical degradation and movement of the surfaces. The surfaces is weakened by chemical degradation and then removed by rubbing against an opposing surface.[15]

**Tribochemical wear (dental erosion)** To some extent this is not a wear process in its own right. It is caused when chemicals weaken the inter-molecular bonds of the surface and therefore potentiate the other wear processes. There is an interplay of erosion, attrition and three body abrasion in tooth wear. In the mouth this effect is normally caused by acids, which may be 'extrinsic' such as dietary acids or 'intrinsic' resulting from gastric reflux. The most important thing to understand is that acids weaken only the surface molecules. These are then rubbed away by the movement of the surfaces and immediately the underlying (previously unaffected) surface is attacked by the acid. Mechanical tooth wear and chemical dissolution act simultaneously.[10]

## CLINICAL IMPORTANCE OF WEAR OF TEETH AND RESTORATIVE MATERIALS

Wear of teeth is physiological and increases with age with males showing significantly more wear than females19). Wear of natural or restored teeth can have mainly three consequences: (1) esthetic effects that compromise the appearance of the natural and restored teeth, (2) in case of severe wear, irritation of the pulp with clinical signs of hypersensitivity or pulpitis or even opening of the pulp, and (3) functional effects that alter the relationship between the tooth and antagonist and/ or tooth and adjacent tooth by promoting phenomena like elongation of antagonists, movement of teeth or reduction of vertical height with possible consequences to the temporomandibular joint (TMJ).Wear particles derived from restorative materials may have a biological and/or toxicological effect if swallowed or inhaled.[5,6,16,17]

Further wear of restorations may involve systemic consequences via the ingestion or inhalation of worn material and, on the other hand, it may have biological consequences on the stomatognathic system via alterations of tissues and cells due to mechanical loading and change of vertical height between the lower and upper jaw.[18]

## IN-VIVO AND IN-VITRO EVALUATION OF WEAR-

Wear testing is one of the most challenging subjects in dental materials science. Wear assessment can be performed in the laboratory or through clinical trials. In-vivo wear studies are the ultimate tests of a dental materials because they test the materials in their clinical situation. A number of attempts have been made to develop a standard method that could simulate in vivo wear, or atleast give useful comparative data. Although, in vivo wear studies would seem ideal to evaluate the wear behaviour of dental materials. The complex nature of wear mechanisms of dental materials makes in vivo wear studies time-consuming, expensive and the results scatter widely due to patient and dentist related factors. Most of all, the fundamental problem with the in vivo wear model is that it is impossible to isolate and vary key factors that may influence the wear process.[18]

Moreover, in vivo wear investigation of dental materials composed of subjective performance assessment of the material using models and then numerical measurement of the various results.[18]

A well controlled clinical trial cannot be entirely substituted by laboratory experiments even though the latter can attempt to simulate the oral environment. However, clinical studies are expensive, difficult to conduct and slow in producing results. Large sample sizes are required for statistical significance, and to allow for the drop-out of participants. Subjective recording of the results may compromise their accuracy. The mechanism of wear and the contribution of individual parameters controlling wear are often difficult to interpret[(19)].

In-vitro experiments have attempted to overcome this problem by accelerating the wear rate in a simulated oral environment. In-vitro studies have the advantage of being quick, easy and less expensive compared to clinical studies.[20] In vitro research, comprising of laboratory simulation studies of the masticatory or chewing function, constitute an initial tool for the comprehension of the clinical behavior of restorative materials in practice. Despite the weak correlation between in vitro and in vivo findings, when new material concepts (systems or technologies) are developed, the wear resistance should be evaluated in the laboratory by reliable wear testing methods before these materials are released for clinical trials.

**IN VITRO WEAR SIMULATING MECHANISM**

In 2001, the International Organization for Standardization (ISO) published a technical specification on "guidance on testing of wear", describing 8 different test methods of two- and/or three-body contact.[21] The advantage of these standards is that defined test methods are described which can be performed and reproduced with relatively easily accessible means in laboratories. The ISO standard tests and recommendations are not necessarily scientifically robust and often lack evidence for correlation between test results and clinical phenomena.

A laboratory test device has to be qualified in order to be suitable for a test method. when talking about wear testing devices: We have to differentiate between two processes the wear generating process and the wear quantifying process. The wear quantifying process has already been extensively described and standardized in literature. For the wear generating process, a device should have the following features[18]: -

- **Force and force impulses** should be reproducible and adjustable in the range of 20 N to 150 N. As force generation is the most important and most critical point of the entire wear testing system, special attention should be paid to this issue. There are different force generating principles called actuators. Even if the wear parameters are identical, the use of different force actuators can generate different levels of quantitative wear. Therefore, if the same wear method is repeated using a different device and force actuator, different results may be obtained.
- A lateral movement of the stylus should be integrated in the system to be able to test the material for microfatigue.
- Continuous water change should also be integrated to remove abraded particles from the interface between stylus and material.
- All movements should be computer-controlled and adjustable.
- High precision of results

- Robustness and longevity of components
- Low maintenance time for device
- It should corelate to clinical wear

**Correlation with Clinical Wear**

A wear method should not only be internally valid, which means that the results for the same material tested at two different points in time are similar. In addition, the wear method should also be externally valid, and correlate with in vivo findings. Any laboratory investigation of the wear resistance of dental materials needs to consider oral conditions so that in vitro wear results can be correlated with in vivo findings. For differences among materials to be easily detected, low variation in in vitro wear tests is desirable. As wear simulators try to simulate the mechanisms which occur in the oral cavity during the masticatory process, the wear test set-up has to fulfil various prerequisites. The following factors that influence wear should be controlled and standardized:

- **Surface roughness of specimen**: The surface roughness of the specimens prior to carrying out the wear should be standardized.[22]
- **Number of specimens**: The scattering of the results expressed by the standard deviation determines the number of specimens required to statistically differentiate between materials.[18]
- **Loading force**: Higher forces in general produce more wear. However, the relationship does not seem to be linear.18.23 The wear testing device simulator should generate clinically relevant forces, which are in the range of 20–120 N. The food hardness affects the human masticatory patterns and correlates with the masticatory force.
- **Force profile**: The force profile should be of a clinically relevant dimension. Studies on human beings who chewed on different food items revealed that the force profile resembles more or less half of a sharp sine wave or haversine waveform.[18]
- **Type of stylus material**: Enamel would be the material of choice due to its physiological relevance. The pressable leucite-reinforced ceramic IPS Empress was tested as a suitable material for this purpose and generated a similar wear rate as an enamel stylus of the same shape.[18,24]
- **Size and shape of stylus**: A pointed stylus produces more wear than a ball-shaped stylus as a ball-shaped stylus has a larger contact area between stylus and material thus producing less fatigue stress on the material.[25,26]
- **Sliding of stylus**: Sliding is an essential component of a wear testing method in order to subject the material to microfatigue. The average sliding movement was measured to be 0.3 mm in the first molar towards the anterior and 0.18 mm towards the medial side. A lateral movement should be integrated into the wear simulator to test the fatigue strength of the material.[18,25]
- **Distance**: The highest kinematic values of vertical movements were measured to be between 16 and 20 mm.[18]
- **Descent/lifting speed of stylus**: The speed with which the stylus hits the surface of the specimen creates a force impulse, which is different with varying speeds. If weights are used to exert a force, then the force that is generated on the material is the product of the weight and the descent speed (F=m×a, N).[26]
- Another variable is the time during which the force is exerted i.e. the force impulse is the

product of the force and the time the force is applied (F=F×t, Ns).

- **Clearance**: It should be ensured that worn material is cleared from the test surfaces. This can be achieved by a constant exchange of liquid (e.g. water) or “abrasive medium”, which fills the test chamber. Lubricants, such as artificial saliva, reduce the wear as they lower the friction coefficient. A constant change of water removes the worn particles from the interaction zone between stylus and material, thus reducing the effect of the worn material, which, otherwise, may act as an abrasive medium.[18.27]

- **Number of cycles**: The wear increases with increasing number of cycles. Most in vitro wear test methods demonstrate a running-in phase with a steep increase in wear in the initial phase and a flattening of the curve thereafter because of the increase in the area exposed to the wear forces.[28,29]
- **Abrasive medium**: An intermediate medium may reduce or increase the wear, compared with water. Furthermore, the composition and the type of the abrasive medium affect the wear rate.[30,31]
- Contact time The contact time between stylus and material should be of a clinically relevant length and should be kept constant during the simulation phase.[18,32]

## CONCLUSION

The clinical significance of increased wear can mainly be attributed to impaired aesthetic appearance and/or functional restrictions. Little is known about the systemic effects of swallowed or inhaled worn particles that derive from restorations. As wear measurements in vivo are complicated and time-consuming, wear simulation devices and methods had been developed, systematically looking at the factors that influence important wear parameters. Wear simulation devices shall simulate processes that occur in the oral cavity during mastication, namely force, force profile, contact time, sliding movement, clearance of worn material, etc.

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