Review of Restorative materials wear's Process

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Abstract: Teeth and restorations are continuously subjected to physical and chemical degradation in the hostile oral environment. Although wear is usually slowly progressive, the extent and rate can be exacerbated by many patient, clinician related and material wise factors. No current material is able to satisfy all requirements of an ideal restorative material, and esthetic demands with economic considerations of patients often conflict with other important biologic and functional requirements. Tooth wear is an increasing problem, and many persons now wish to retain their natural dentitions for a lifetime. However, oral rehabilitation is often necessary because of the extensive "wear and tear" that has occurred over many years. The selection of appropriate materials to minimize further tooth and restoration wear is an important consideration during treatment planning. A mismatch of wear rates between teeth and restorations can result in more rapid exposure of dentin, with occlusal destabilization. Selection of restorative materials must be based on knowledge of their wear behavior and the individual needs of each patient. The lowest wear rates for restorations and the opposing dentition occur with metal alloys, machined ceramics, and hybrid resin composites. In this review, the behavior and process of restorative materials wear will be thoroughly explained.

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Introduction

Tooth and restorative materials wear is a common problem in dentistry. Wear occurs whenever two surfaces undergo slipping movements when a load is applied. The institute of mechanical engineering in the United Kingdom has defined wear as "The progressive loss of structure from the surface of a body brought by mechanical action" (Yap *et al.,* 1997). Enamel to enamel wears approximately 20 to 40 microns per year. This value may be much higher for single tooth or in patients with parafunctional habits (Oh WS *et al.,* 2002).

Wear can be caused by direct surface to surface wear, intervening slurry, or a corrosive environment. Wear occur during mastication, but also at other times, often at night. The same processes that cause tooth wear will also cause wear to restorative materials, so to diagnose and prevent wear; its process must be understood (Mair 1999). Tooth and restorative material wear rarely occurs as a result of one factor alone, however, the hardness of a material, surface finish and microstructure are material related factors. Other major patient related factors include biting force, frequency of chewing, abrasiveness of diet, type of brush and tooth paste, composition of oral liquids (pH), decrease in salivary flow, temperature changes, enamel composition, age and gender (De Baat *et al.,* 1997). In addition to these patient related variables, the way the clinician manipulates the material during and after preparing the restoration will also affect clinical wear rate. Air incorporation, efficiency of curing, grinding and polishing procedures, and occlusal design of restoration are some of the operator-related variables that will affect clinical wear (Oh WS *et al.,* 2002). Intra-oral wear of dental materials is a highly complex process due to challenging nature of oral environment and brittleness of enamel. Therefore, restorative materials must fulfill esthetics, fit, strength and biocompatibility in order to minimize wear process as possible.

During the early use of dental materials, it was noticed that these restorations lose their original shapes and surface properties during time. The mechanism for the degradation initially was related to a purely mechanical wear process, but researches revealed that chemical process could be also involved. After the different degradation products have left the surface of the restorative material, they may continue degradation as they are transported through the body, where they participate in various biologic reactions. These reactions can cause health problems, which may show up in regions located far away from the original restoration site. It can be extremely difficult to link these problems to the composition of the different restorative materials (Eliades *et al.,* 2003).

Wear of direct dental restorative materials:

Composite resin restorative materials:

Resins are used to replace missing tooth structure and modify tooth color and contour, thus enhancing facial esthetics. Of the direct restorative materials, silicates were developed first, followed by acrylic resins then resin composites.

Acrylic restorative resins were unfilled, low molecular weight and lacked the reinforcement provided by the ceramic filler particles used in composites. Early clinical failure of acrylics was related directly to dimensional instability along with low wear resistance (Graig and Powers, 2002).

The development of composites about 1960 has resulted in higher mechanical properties, lower coefficient of expansion, lower dimensional changes on setting, and higher resistance to wear, thereby improving clinical performance. Incorporation of filler particles into a resin matrix greatly improves material properties, provided that the filler particles are well bonded to the matrix. Because of the importance of well-bonded filler particles, the use of an effective coupling agent is extremely important for the success of a composite material. The primary purposes of filler particle are to strengthen a composite and to reduce the amount of matrix material, thereby increasing wear resistance (Suzuki and Leinfelder, 1997).

Clinical studies have shown that composites are superior material for anterior restorations in which esthetics is essential and occlusal forces are low. One problem with composites is the loss of surface contour in the mouth, which results from a combination of abrasive wear from chewing and tooth brushing and erosive wear from degradation of the composite in the oral environment (Eliades *et al.,* 2003).

Wear of posterior composite restorations is observed at the contact area where stress is the highest. Wear resistance of composites on occlusal surface of posterior restorations has received considerable attention in clinical studies. At least five types of composite wear events are based on location on the restoration surface (Roberson *et al.,* 2002):

1. Wear by food (contact free area, or FCA wear).
2. Impact by tooth contact in centric (occlusal contact area, or OCA wear)
3. Sliding by tooth contact in function (functional contact area, or FCA wear).
4. Rubbing by tooth contact inter proximally (proximal contact area or PCA wear).
5. Wear from oral prophylaxis methods (tooth brush or dentifrice abrasion).

However, the relative contributions of these processes are poorly understood. If a posterior occlusal composite restoration is narrow enough, occlusal contact wear is significantly reduced or eliminated. Finishing of composite is best achieved before curing, but if required it can be done after 24 hours of curing, to ensure complete polymerization. If the finishing procedure can't be delayed, it can be done at least after 15 minutes. To avoid microcracks that will propagate and lead to wear of restoration, we should delay finishing of composite. Accordingly, we have to rebond composite restoration in order to seal the micofractures increasing wear resistance (Eliades *et al.,* 2003).

Mechanisms of wear process of composite material (Roberson et al., 2002):

1. *Micro fracture theory:* acting on the filler particles. Filler particles are compressed into the adjacent teeth matrix during occlusal loading (mastication) creating micro fractures.
2. *Hydrolysis theory:* acting on the coupling agent. The coupling agent between the resin matrix and the filler particles is debonded and become unstable due to absorption of water and saliva.
3. *Chemical degradation theory:* acting on the resin matrix. Chemicals from food and saliva are absorbed into the matrix causing degradation.
4. *Protection theory:*

Micro protection: sheltering of resin matrix by close interproximal spacing of the filler particles.

Macro protection: sheltering of composite by narrow, small sized cavity preparation.

Wear of different types of composites (Eliades *et al.,* 2003 & Suzuki and Leinfelder 1997).

1. *Mega-fill, macro-fill and midi-fill (size above 1 μm):* it contains 60-80% by weight of filler particles so high mechanical properties indicating high wear resistance. In this type of composites, puckling out phenomena do exist. It is due to great differences in the wear pattern between the matrix and the fillers, the macro fillers are fractured and dislodged selectively from the faster wearing resin matrix in stress bearing areas or during polishing or during tooth brushing. It is also called non-polishable composites and it is indicated for posterior restorations.
2. *Mini fill, micro fill and nano fill (size below 1 μm):* it contains sub-micron particles of filler. These very small particle size produce a massive increase in the available surface for a given volume of filler. It produces smooth surface, so no puckling out phenomena would occur. The mechanical properties and dimensional stability are reduced than in the conventional composite. Anterior esthetic restorations use micro fills due to its polishability.
3. *Hybrid composites:* a blend of conventional (macro-fill) and sub micron (micro-fill) particles, attaining high physical properties and wear resistance.
4. *Flowable composites:* these light cured, low viscosity composites are recommended for cervical lesions, pediatric restorations, and other small, low stress bearing restorations. Because of their lower filler content (42-53% by volume), they exhibit higher polymerization shrinkage and lower wear resistance than other types of composites. The low viscosity of

these composites allows them to be dispensed by a syringe for easy handling.

5. *Packable composites:* these composites are recommended for the use in high stress bearing areas, since they have low wear rate (3.5 µm/year), which is similar to that of amalgam. Improvement of mechanical properties is due to their high filler content (66-70% by volume).

6. *Laboratory composites:* it is done indirectly on dies and processed in the lab using various combinations of light, heat, pressure, and vacuum, which increase the degree polymerization and wear resistance.

7. *CAD/CAM Composites:* A number of studies show that CEREC materials levels of tooth enamel wear essentially is equivalent to that of tooth enamel against tooth enamel if the surface is polished or glazed (Giordano, 2006).

Glass ionomer (GI) restorative materials:

Conventional GI and resin-modified GI (RM-GI) materials are unsuitable as long-term restorations in high-stress situations. The RM-GI materials show high wear rates, and the conventional GIC materials show low fracture resistance. The occlusal wear resistance of a RM-GI is improved by concurring it with a resin composite. The newer esthetic viscous conventional GIs can also show variable and high early wear rates of even small occlusal restorations (Yip *et al.,* 2004).

Polyacid modified resin materials (compomeres):

They are probably best described as composites to which glass-ionomer components have been added. So, their wear resistance is superior to traditional glass ionomers and RM-GIs but inferior to those of composites (Yip *et al.,* 2004).

Amalgam:

Dental amalgam restorations have low wear rates, largely because of their ability to adapt through smearing from deformation under load. Amalgam is also kind to opposing teeth and other restorations, and even large amalgam restorations can have satisfactory long-term clinical performance (Yip *et al.,* 2004).

In the study of Heintze *et al.,* in 2004, they found that the wear mechanism of amalgam is different. Amalgam material exhibit good wear resistance in many wear stimulators, which can be explained by the fact that surface tension induced by abrasion is partly compensated by plastic deformation in the amalgam.

Wear of indirect restorative dental materials:

Ceramic restorations:

Ceramic restorations have a long history of satisfactory clinical performance. However; rough porcelain surfaces can cause substantial wear of opposing teeth and other restorations. This is also the case with resin-bonded all-ceramic restorations, which generally have lower survival rates than metal-ceramic restorations. Porcelain is a wear resistant, but the surfaces of the material must remain smoothly glazed or highly polished to reduce damage to opposing teeth and restorations. Low-fusing feldspathic porcelains appear to be less abrasive to enamel but wear more than older feldspathic types. Cast and pressed glass ceramics are also reported to be less abrasive than older sintered feldspathic porcelains. A machined ceramic showed the least enamel wear and was also the most wear resistant among several types of porcelains evaluated. The process of antagonistic tooth wear appears to be closely related to ceramic microstructure, surface roughness, and oral environment influences (Oh WS *et al.,* 2002).

Ceramics are brittle material. Due to crystalline matrix, they are less sensitive to attrition wear but more sensitive to fatigue wear, which occurs during repeated sliding or loading of two materials. The material develops micro cracks, which can lead to fracture, leaving large irregular surfaces (Heintze *et al.,* 2004).

Many dental ceramics materials are glass-ceramics i.e. a crystalline phase surrounded by a glass matrix. This crystalline phase has traditionally been Leucite; these materials have a greater hardness than natural enamel and consequently are abrasive to the opposing dentition (Gorman and Hill, 2003).

Castable ceramics are based mostly on the feldspathic Leucite system. The surface finish of the material often dominates the enamel wear, therefore materials with a fine crystal structure or high glass content should be more easily polished to produce a smooth surface. Low fusing temperature does not automatically generate low enamel wear unless the surface is also smooth (Giordano, 1999).

In a review done by Rosenblum and Schulman in 1997 on all –ceramic dental materials, they found that according to the literature they reviewed that wear of traditional powder slurry system is higher than that of conventional feldspathic ceramic due to higher Leucite contents, while for the Leucite-free ceramics the abrasiveness was close to natural teeth. The wear for castable and machinable ceramics also was the same as that for teeth. For pressable type they found the ceramics to be more abrasive than conventional feldpathic porcelain, while that of the infiltrated ceramics is as much as that of conventional porcelain.

In 1997 Ramp *et al.,* studied the effect of three ceramic materials, two machined (Dicor MGC light and Vita Mark II) and one heat pressed ceramic (IPS Empress) and a type III gold alloy served as control on opposing enamel. They concluded that wear resistance of the pressable ceramic was similar to that of enamel, which was better than that of the machinable ceramics.

Machinable ceramics were found to be mostly less abrasive and more resistant to wear than conventional ceramics, which may be due to the well distribution of particles and the particle size of the ceramic. Machinable ceramics are factory-made ceramics made mostly of small particle size, while conventional ceramics are made by hand condensation. Particles of these conventional ceramics may be comparatively easily loosened and displaced from the porcelain matrix, which may explain why the conventional materials exhibit greater wear (Al-Hiyasat *et al.,* 1999).

In 1999 Al-Hiyasat *et al.,* conducted a three-body wear experiment associated with three ceramics (Vitadur alpha conventional porcelain, Duceram-LFC a low fusing hydrothermal ceramic and Vita Mark II a machinable ceramic) vs. enamel. The wear machine they used provides impact action of the tooth on the ceramic specimen surface, followed by 10mm sliding motion. They selected 80 cycles per minute and stated that is a reasonable estimation of the chewing cycle rate. The load of 40N and the 25,000 cycles that they used were estimated from previous studies. They concluded that both enamel wear and wear resistance of the machinable ceramic were found to be significantly less than that of conventional porcelain and low fusing hydrothermal ceramic.

Researchers tested CEREC materials against natural human enamel in a standard abrasion system and recorded the volume loss of the materials. A “wear ratio” was obtained, which normalized the data relative to the enamel versus enamel to account for natural variations in tooth structure. The closer the value of the tested material to 1, the more material behavior like natural tooth structure with respect to enamel abrasion. The ratios of both the Vitablocks Mark II and ProcCAD blocks were close to 1, whereas the Paradigm MZ100 was slightly higher, indicating some material loss but that wear kindness still was good (Giordano, 2006).

Gold (precious) alloys:

Gold alloy restorations have a long history of satisfactory clinical performance and are said to be “kind” to opposing tooth substance and restorative materials, wearing at approximately the same rate as enamel, depending on the type of alloy used. As expected, biologic and mechanical failures are more common with increasing restoration complexity (Yip *et al.,* 2004).

Al-Hiyasat et al. concluded in 1998 that the hydrothermal low fusing ceramic and the machinable ceramic were significantly less abrasive to enamel than conventional alpha and omega porcelains and all the ceramic materials tested were significantly more abrasive than gold.

Base metal (non-precious) alloys:

Nickel-chromium alloy restorations are more economic and mechanically stiffer alternatives to type III gold alloys, with a lower wear rate. However, base-metal restorations are also harder and more difficult to adjust and polish, and they are reported to wear the opposing teeth more than gold alloys (Yip *et al.,* 2004).

Summary

Wear from the clinical importance point of view is not an essential issue anymore, especially with today’s optimized dental materials. Therefore, there might be no need to investigate this issue any further (Heintze *et al.,* 2006).

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