Differential Wear of Teeth and Restorative Materials: Clinical Implications

Kevin H.-K. Yip, BDS, MEd, MMedSc, PhD[a]/Roger J. Smales, MDS, DDSc[b]/
John A. Kaidonis, BDS, BScDent, PhD[c]

Purpose: This study reviewed the wear of commonly used dental restorative materials and their effects on the opposing dentition. ***Materials and Methods:*** Key words were used with PubMed to retrieve pertinent references to publications on tooth and restoration wear. ***Results:*** The wear resistance of newer esthetic restorative materials has generally improved, and the damage caused by several materials to the opposing dentition has been reduced. However, the different structures and physical properties of tooth substance and restorative materials will eventually lead to varying degrees of differential wear. The extent and rate of wear are influenced by many intraoral factors. ***Conclusion:*** 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 microfilled and microfine hybrid resin composites. *Int J Prosthodont 2004;17:350–356.*

The excessive differential wear of teeth and restorative materials has significant deleterious effects on the biologic, functional, and esthetic condition of the masticatory system. However, controlled investigations of numerous factors that might influence tooth and restoration wear have been mainly laboratory studies, the findings of which might not correlate with either the physical properties of the substrates or clinical experience.[1,2]

Laboratory studies have examined the effects on restorative material wear of, for example, thermocycling,[3] cyclic loading,[4,5] applied load,[6] degree of polymerization,[7] aging,[8] water absorption,[9] lubricant pH,[6,10] surface coatings,[11–13] and toothbrushing/dentifrices.[14] These studies have used two- and three-body wear simulation methods and various methods of measurement over widely differing time periods. Many laboratory studies have also examined the antagonistic wear of restorative materials and teeth.[15–24] There have been far fewer laboratory studies of factors other than restorative materials that might influence tooth wear; these have mainly involved the examination of, for example, lubricant pH[6,16] and the interplay between applied load and lubricants.[25,26]

Clinical studies of restoration wear have been mainly concerned with the development of more wear resistant and less abrasive posterior resin composites[27] and, to a lesser extent, more wear resistant glass-ionomer cements (GIC)[28] and less abrasive porcelains.[2] Few studies have examined the in vivo antagonistic wear of restorative materials and teeth.[29–32] Clinical studies of tooth wear have focused mainly on the effects of abrasive diets and parafunction,[33,34] toothbrushing/dentifrices,[35] and acid erosion.[36] The purpose of this article is to discuss the clinical implications of differential wear between teeth and restorative materials.

[a]*Associate Professor, Faculty of Dentistry, The University of Hong Kong.*
[b]*Visiting Research Fellow, Dental School, The University of Adelaide, South Australia.*
[c]*Senior Lecturer, Dental School, The University of Adelaide, South Australia.*

Correspondence to: *Dr K. H.-K. Yip, Faculty of Dentistry, Prince Philip Dental Hospital, 34 Hospital Road, Hong Kong SAR, People's Republic of China. Fax: + (852) 2547 0164. e-mail: hkyip@hkusua.hku.hk*

Types of Wear

The loss by physical wear of tooth substance or restorative material caused by direct tooth contact between the occluding or approximal surfaces is known as attrition. A

Fig 1 Severe generalized acid erosion of the maxillary dentition in a young adult who has had gastric reflux since her early teens. (From Yip et al.[83] Reprinted with permission from World Dental Press.)

Fig 2 Severe localized wear of maxillary first molars has exposed much of the dentin. Acid erosion has also affected the incisal edges and palatal surfaces of anterior teeth and buccal cusps of premolars. (Reprinted with copyright permission from the Academy of General Dentistry. For additional information, contact the Academy of General Dentistry, 211 E. Chicago Avenue, Suite 900, Chicago, IL 60611, 312-44004300, or visit their website at http://webmaila.hku.hk/redirect?http://www.agd.org.)

similar loss caused by physical factors other than direct tooth contact, namely exogenous material being forced over the tooth and restoration surfaces, is known as abrasion. The loss of tooth substance or restorative material caused by nonbacterial chemical action is usually known as erosion or, more correctly, corrosion[37] (Fig 1). Erosion is not directly associated with physical wear or dental caries, although all of these processes may coexist to varying extents (Fig 2). Acids weaken the tooth or restoration surfaces, allowing other wear processes to occur more easily. The hydroxyapatite crystals of tooth substance and the matrices of conventional GICs are particularly susceptible to acid degradation. Tensile forces induced by occlusal loads might also result in the microfracture of cervical enamel on the facial and lingual tooth surfaces, a process described as abfraction.[38]

The presence of an intervening medium or slurry between the moving opposing surfaces is known as three-body wear. This occurs typically during the "open phase" of mastication, and the degree of wear present is determined partly by the hardness, shape, and size of the particles in the slurry.[37] The direct contact of teeth and restorative materials moving without an intervening medium is known as two-body wear. This is observed with tooth grinding, or bruxism especially, where the opposing occlusal surfaces show closely fitting matching facets on mandibular excursion. The production of microfine fragments of tooth and restorative materials quickly converts this process to three-body wear.

Physiologic tooth wear results in a slow, progressive loss of tooth substance. Initially, this process manifests as a flattening of the occlusal cusp tips and incisal edge mammelons. The approximal surfaces also flatten and increase in area. Continued wear leads to the exposure of softer dentin and potentially an acceleration of the wear rate. However, as the facet area increases, there is a substantial reduction in pressure and a slowing of the wear process.[39] The anisotropic nature of tooth substance adds further variability to this wear process.

The clinical significance of the extent and rate of tooth wear varies with age, but the wear can be regarded as pathologic when the biologic, functional, and esthetic condition of the masticatory system is effectively compromised. Similarly, problems may also arise from the excessive wear of restorative materials. Evidence from comparative and paleontologic studies demonstrates that tooth wear is an essential part of the normal, continually changing relationship between the form and function of the dentition. It is important to understand this relationship in order to replicate nature's "intentions" in clinical dental procedures.[33]

Measurements of Wear

Numerous direct and indirect clinical assessment methods have been used to measure tooth and restoration wear. Direct clinical methods, such as the widely used US Public Health Service (USPHS)–Ryge criteria, are largely subjective and qualitative, even after training and repeated calibration of examiners.[40] The rating scale intervals used by the USPHS–Ryge method to detect wear at the margins of restorations are coarse and unable to detect early changes.[41] Such direct methods have been shown to be unreliable for measuring restoration wear.[42] Indirect clinical methods include the use of somewhat less subjective, semiquantitative methods for measuring margin wear from serial replicas made of the restorations.[43] Such methods are reasonably accurate for ranking relatively fast-wearing

Table 1 Approximate In Vitro Wear and Selected Characteristics of Dental Restorative Materials

Material	3-body ACTA machine wear (μm/2 × 10^5 cycles)*	Dimensionally stable	Chemically stable	Non-allergenic	Ease of adjusting	Ease of repairing
Type I gold	50	+++	+++	+++	+	–
Cobalt chromium	0.4	+++	+++	+	–	–
Porcelain	0.2	+++	+++	+++	+	–
Amalgam	10–20	++	++	+++	+++	++
Resin composite	15–65	++	+	++	+++	++
Resin-modified glass-ionomer cement	80–350	+	+	++	+++	++
Viscous glass-ionomer cement	20–60	+++	+	+++	+++	++
Enamel	2–55					
Dentin	165					

*Adapted from previous studies[8,59–61] and de Gee, personal communication, Aug 2003.
+++ = very good; ++ = satisfactory; + = fair; – = poor.

restorative materials, although the actual amount of wear present will be underestimated.[44,45] For other materials and where greater absolute accuracy is required, more objective, quantitative, and expensive indirect clinical methods should be used to measure the entire surface of the restoration.[44–49]

However, these research methods are not of much practical relevance to the dental practitioner who might need to monitor the wear rates of teeth and restorations. Instead, the authors recommend that changes in wear are best observed by the careful comparison of serial casts poured in a high-density die stone from addition-cured silicone impressions.

Tooth Wear

The average rate of enamel occlusal contact area wear varies widely, but it has been reported as approximately 30 to 40 μm per year in the molar region.[39,50] However, many factors will influence the rate and extent of enamel wear. Clinical studies in humans are limited by difficulties in accurately quantifying wear in different regions of the mouth and by the lack of control over the oral environment.

Under controlled experimental conditions, one laboratory study showed that nonlubricated enamel wear remains low at high loads because of the dry-lubricating capabilities of fine enamel powder.[25] However, although low loads with an acid lubricant also lead to little enamel wear, a low-pH lubricant results in a high wear rate under all loads. In another laboratory study involving dentin wear with a lubricant at pH 7.0, specimen weight losses ranged from 0.50 mg/10^3 cycles, at a load of 6.2 kg, to 0.77 mg/10^3 cycles, at a load of 13.2 kg.[51] At higher loads, dentin wear rates are similar to those for enamel. The relationship of wear to load is different for both tooth substrates, reflecting differences in their composition and structure.

Restoration Wear

The different structure and physical properties of tooth substance and dental restorative materials eventually result in their differential wear, even in the same oral environment. However, laboratory studies have generally been unable to find high correlations between individual physical properties of restorative materials and their surface wear.[52–54] Therefore, "artificial mouths" or "masticatory simulators" have been developed instead to simulate intraoral tooth and restoration wear,[10,16,22,25,47,52,55–58] although it is not possible to mimic exactly the oral environment, which is subject to numerous changing conditions in each individual. However, these accelerated laboratory evaluation methods can produce a reasonably accurate ranking of the clinical wear occurring among various materials under specific test parameters. Improved predictive accuracy appears to be related to the use of three- rather than two-body test methods.[58] The alternative method for evaluating wear, by using indirect clinical observations of serial replicas, is far more tedious and may need to be extended over many years. Some in vitro three-body wear findings and selected characteristics of dental restorative materials are shown in Table 1.

Gold (high-noble metal) alloy restorations have a long history of satisfactory clinical performance[62] 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[22,30,32,61,63] (Fig 3). As expected, biologic and mechanical failures are more common with increasing restoration complexity.[64] Base-metal (non-noble metal) nickel-chromium alloy restorations are more economic and mechanically stiffer alternatives to type III gold alloys,[65] 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

Fig 3 Abrasive wear has roughened the occlusal surfaces of the type III gold fixed partial denture opposing the fixed partial denture shown in Fig 4.

Fig 4 Occlusal wear of retainers of metal-ceramic fixed partial denture has exposed metal framework.

teeth more than gold alloys.[63] By contrast, a cobalt-chromium alloy, although also wear resistant, caused less enamel wear than a soft gold alloy.[61]

Metal-ceramic restorations also have a long history of satisfactory clinical performance.[66] However, rough porcelain surfaces can cause substantial wear of opposing teeth and other restorations (Fig 4). This is also the case with resin-bonded all-ceramic restorations, which generally have lower survival rates than metal-ceramic restorations on molars. Porcelain is wear resistant, but the surfaces of the material must remain smoothly glazed or highly polished to reduce damage to opposing teeth and restorations.[2,17,20,67] Low-fusing feldspathic porcelains appear to be less abrasive to enamel but wear more than older feldspathic types.[18,24,68] Cast and pressed glass ceramics are also reported to be less abrasive than older sintered feldspathic porcelains.[15,16] A machined ceramic showed the least enamel wear and was also the most wear resistant among several types of porcelains evaluated.[21] The process of antagonistic tooth wear appears to be closely related to ceramic microstructure, surface roughness, and oral environment influences.[2]

Amalgam alloy restorations are wear resistant, largely because of their ability to adapt through smearing from deformation under load.[37] Amalgam is also kind to opposing teeth and other restorations, and even large amalgam restorations can have satisfactory long-term clinical performance.[66]

Resin composite materials show higher wear rates than amalgam alloys when placed as large posterior restorations. Deep microcracks were also formed in a microfilled resin composite when it was subjected to extended cyclic loading.[5] However, densely filled microfine glass particle hybrid and microfilled resin composites show little wear of opposing tooth substance.[17,19] Where fluoride-releasing resin materials are required in low-stress situations, newer polyacid-modified resin composites (compomers) should be satisfactory.[69]

Conventional GIC and resin-modified GIC (RM-GIC) materials are unsuitable as long-term restorations in high-stress situations.[70] The RM-GIC materials show high wear rates, and the conventional GIC materials show low fracture resistance.[28] The occlusal wear resistance of an RM-GIC is improved by cocuring it with a resin composite.[71] The newer esthetic viscous conventional GICs can also show variable and high early wear of even small occlusal restorations.[72] Laboratory studies have shown the adverse effects of acid lubricant on GIC wear.[6,8]

The surface roughness of restorative materials has been regarded as both the consequence of restoration wear and the cause of antagonistic tooth and restoration wear. Surface damage and continued restoration wear result in the exposure of filler particles and inclusion voids, with further wear following the dislodgment of the particles. The roughness of restorative materials is related to light reflectance and appearance, surface staining and plaque adhesion, and patient comfort. Plaque adhesion has been shown to increase significantly at a mean surface roughness of 0.2 µm,[73] which is readily exceeded by viscous GICs.[74] The surfaces of tooth-colored materials can also be readily damaged by acidic fluoride gels,[19,74] which are often used to control caries and tooth hypersensitivity from exposed dentin.

Clinical Implications

The wear of restorative materials needs to be matched to that of normal tooth wear; otherwise, the occlusion may be destabilized and other problems may occur. Excessive wear of both restorative materials and opposing teeth may occur from incorrect selection of materials for the particular clinical situation. The oral environment, dental health condition, and needs of individual patients vary widely, placing considerable demands on esthetic

Fig 5 Posterior amalgam and resin composite restorations show varying degrees of marginal fracture and staining, surface roughness and tarnishing, and occlusal wear. Despite their unsatisfactory appearance, not all of the restorations require replacement or repair.

restorative materials in particular.[75] The type, extent, and rate of tooth and restoration wear are also not uniform over the entire dentition.

Except for conventional GICs and RM-GICs, excessive restorative wear is of decreased significance as a potential cause of long-term failure for current materials. In general dental practice, most restoration failures occur because of caries, fracture, and debonding, or discoloration and marginal deterioration.[62,76,77] Except for resin-bonded fixed partial dentures,[78] indirect single restorations and more complex fixed prostheses appear to have longer survival times than most direct-placement restorations.[62,79,80] However, the longevity of direct-placement restorations could be extended considerably if "unsatisfactory" restoration deterioration, with the consequent inappropriate "replace for preventive reasons" recommendation,[40] was ignored until actual failure had occurred.[81] Many restorations can continue to provide satisfactory service despite having some unsatisfactory characteristics (Fig 5).

Patient factors that might enhance the extent and rate of tooth and restoration wear include heavy biting forces and parafunctional habits, incorrect toothbrushing/dentifrices, abrasive and acidic diets, regurgitation, reduced salivary flow and altered composition, defective tooth structure, and reduced posterior tooth support. Heavy biting forces require the use of metal or metal-ceramic restorations, whereas tooth grinding and clenching also require the construction of a hard acrylic resin occlusal splint to protect the teeth and restorations. Incorrect toothbrushing/dentifrices[35] and inappropriate parafunctional habits and diets require patient education. Regurgitation and inadequate salivary flow require medical investigation and dental management.[36] Inadequate posterior tooth support for effective function requires prosthodontic solutions, and defective tooth substance might require replacement by appropriate restorative materials as part of an oral rehabilitation.[1,82] Careful monitoring of the extent and rate of tooth and restoration wear should be part of routine dental treatment management.

Conclusion

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 factors. No current material is able to satisfy all of the requirements of an ideal restorative material, and the esthetic demands and 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. The wear can be enhanced by adverse parafunctional, toothbrushing/dentifrice, and dietary habits; regurgitation; reduced salivary flow; defective tooth structure; and lack of posterior tooth support.

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