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Wear Properties of Different Additive Restorative Materials Used for Onlay/Overlay Posterior Restorations

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Clinical Relevance

Recently introduced indirect resin composites and dental ceramics show a wear behavior similar to traditional gold alloys. The present laboratory findings support a successful use of such new materials on load-bearing occlusal surfaces of posterior teeth, even for extensive occlusal rehabilitations.

SUMMARY

The purpose of this laboratory study was to compare the two-body wear resistance of different restorative materials commonly used for the indirect restoration of posterior teeth. The tested materials, based on ceramic (Imagine Press X, IPS e.max CAD, Milled Celtra Duo, Glaze-Fired Celtra Duo, Vita Mark II) and composite (Enamel Plus HRi, Enamel Plus HRi Bio-Function, Filtek Supreme XTE, Lava Ultimate), were compared with the wear properties of a type III gold alloy (Aurocast 8). Flat samples were prepared with a 6-mm thickness (n=10). Composite samples were tested after a heat polymerization cycle. All samples were exposed to a two-body wear test in a dual axis chewing simulator performing over 120,000 loading cycles. The opposing abrader cusps were fabricated from yttria-stabilized tetragonal zirconia polycrystal. The vertical substance loss (mm) and the volume loss (mm^3) were recorded, as was the wear of the antagonist cusp (mm). Mean values were analyzed by one-way analysis of variance. Significant differences among materials were detected. The heat-cured resin-based composite material Enamel Plus Bio-Function and the type III gold

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alloy demonstrated similar mean values for wear depth and volumetric loss.

INTRODUCTION

The evolution of esthetics and adhesion has strongly modified the approach to restorative dentistry, raising the necessity to find the most suitable biomaterials. In recent years, ceramics and resin composites have become the most commonly used restorative materials. Adhesive dental ceramics and resin-based composites have proven to guarantee optimal esthetic results alongside satisfactory mechanical properties. Due to these qualities, today they are considered the first-choice restorative materials both for minimal restorations and for the reconstruction of severely compromised teeth. Gold alloy reconstructions preferred in the past, especially for their optimal wear properties, have been progressively substituted by these new technologies.

Loss of hard tooth substance is a natural process taking place during mastication. The rate of wear depends on many individually resulting factors that interact all at the same time.[1] The wear can be caused by abrasiveness of the food (so-called three-body wear) in case of normal masticatory function or by attrition in the case of parafunctional oral habits[2] (such as bruxism or grinding) that lead to direct contact of the occlusal surfaces. Other possible participating factors are muscular strength of the temporomandibular apparatus, the quality of enamel,[3,4] and salivary composition and acidity. The effect of these circumstances naturally changes the surface anatomy of the tooth, the cusps of the posterior teeth become flatter, and the incisal edges of anterior teeth reduce their length and volume of the mamelon area.[5]

Increased wear is a common reason of failure for restorations exposed to masticatory forces. Excessive wear may be responsible for numerous problems, such as hypersensitivity, loss of occlusal contact, defects of the periodontium, reduction of masticatory efficiency, tooth migration and wrong tooth relations, weakness of masticatory muscles, and changes in the vertical and horizontal jaw relations, which may cause functional and esthetic impairments.[6-10]

An optimal restorative material should provide similar characteristics to natural dental tissues. The physiological wear of enamel and dentin should represent the reference for a reasonable wear pattern of restorative materials, which typically wear out through different mechanisms, such as microplowing, microcutting, microcracking, and microfatigue.[11,12]

Previous studies[13,14] have documented that the wear behavior of type III gold alloy (Aurocast 8) is very similar to that of human enamel. Over previous decades, gold restorations were considered an appropriate solution, especially for the occlusal surface of teeth, participating in the functional contact with the opposing enamel or other prosthetic materials.[15,16] Because of the wear similarity to natural enamel, gold restorations lead to minimal wear of the antagonist tooth surface.[17] In addition, gold restorations show no correlation with the onset of pathologies related to the musculoskeletal system and occlusal disharmony.[18] The accuracy of the marginal fit is another favorable feature of gold-based restorations.[19,20] In contrast, the metallic aspect is considered its main shortcoming, as it leads to reduced esthetics and translucency. This feature has contributed to a more limited use in practice today.

Dental ceramics generally provide optimal optical qualities, color stability, and biocompatibility,[21-23] as well as clinically acceptable flexural strength and hardness.[24-29] On the other hand, their main disadvantage is that they can be used just for indirect restorations (which typically leads to higher prices and a higher number of patient sessions), there is no chance for intraoral microrepairs, and they seem to lead to enhanced wear of the opposing occlusal material.[30-33]

Resin composite indirect restorations[25,34] (onlays and overlays) represent a valid alternative for an adhesive and conservative approach.[35-37] Moreover, resin composites can also be used following a direct technique,[38] making them suitable as a minimally invasive treatment.[39-41] These key characteristics make them ideal materials to be used in the treatment of extended occlusal rehabilitations and full mouth rehabilitations and in patients with parafunctions and occlusal disorders. Other advantages include easy handling properties and a relatively low cost. Furthermore, they allow easy intraoral adjustments for proper occlusion and effective surface polishing, according to actual clinical needs, which may reduce patient chair time.

The fact that the manufacturers tend to improve the mechanical behavior of their products leads to the progressive offer of new composites and ceramics for daily practice. Assessment of their wear behavior and comparison through detailed tests become necessary at this point.

The purpose of this study was to investigate and compare the wear behavior of different additive materials frequently used for indirect restorative

Table 1: *List of Materials Tested and Their Composition as Provided by the Respective Manufacturers*

Commercial Name	Manufacturer	Material Description
Imagine Press X	Wieland Dental Ceramics (Pforzheim, Germany)	Heat-pressed silicon oxide (SiO)–based glass ceramic
IPS e.max CAD	Ivoclar Vivadent AG (Schaan, Liechtenstein)	Milled lithium disilicate glass ceramic block Filler content: approx. 70% wt Lithium disilicate crystals ($Li_2Si_2O_5$), glassy matrix Composition (W/W): SiO_2 = 57%-80%, Li_2O = 11%-19%, K_2O = 0%-13%, P_2O_5 = 0%-11%, ZrO_2 = 0%-8%, ZnO = 0%-8%, other oxides and ceramic pigments = 0%-10%
Celtra Duo	Dentsply DeTrey GmbH (Konstanz, Germany)	Zirconia-reinforced lithium silicate ceramic block Fine-grained lithium silicate, with high glass content, 10% zirconium oxide Glass with completely dissolved zirconia Lithium silicate crystallites: 500-700 nm
Vita Mark II	Vita Zahnfabrik (Bad Säckingen, Germany)	Milled feldspathic porcelain block Fine feldspathic crystalline particles embedded in a glassy matrix: vol % ≈ 30 Density (g/cm^3): 2.44 ± 0.01, small Particle size: average 4 μm
Lava Ultimate	3M ESPE (Neuss, Germany)	Milled resin composite block Filler content: almost 80% Silica nanomers: 20 nm; zirconia nanomers: 4-11 nm; silica-zirconia nanoclusters: 0.6-10 μm Highly cross-linked polymeric matrix: Bis-GMA, Bis-EMA, UDMA, TEGDMA
Enamel Plus HRi Bio-Function	Micerium (Avegno, Italy)	Resin composite Filler content: 74% wt (60% in volume) Dimension of particles of silicon dioxide: 0.005-0.05 μm Dimension of glassy particles: 0.2-3.0 μm
Enamel Plus HRi	Micerium (Avegno, Italy)	Resin composite Filler content: 80% wt (63% volume) Composition: 12% zirconium-oxide fillers, 68% innovative proprietary glass-based filler Mean particle size: 1 μm
Filtek Supreme XTE	3M ESPE (Seefeld, Germany)	Resin composite Filler content: 78% wt fillers (combination of nonagglomerated/nonaggregated 20-nm silica filler, nonagglomerated/nonaggregated 4- to 11-nm zirconia filler, and aggregated zirconia/silica cluster filler)
Aurocast 8	Nobil-Metal (Villafranca d'Asti, Italy)	Type III high-gold dental alloy Composition (W/W): Au = 85.4%, Ag = 9.0%, Cu = 5.0%, Pd < 1.0%, Ir < 1.0%

purposes in posterior sectors following a simulated laboratory two-body wear test. All materials included in this protocol were exposed to 120,000 chewing simulation cycles, and the measured results of wear depth, volume loss, and antagonist wear were compared to the wear properties of a traditional gold-based dental alloy.

The null hypothesis was that there are no significant differences between the gold alloy and the evaluated materials concerning laboratory wear properties.

METHODS AND MATERIALS

The different dental materials included in this protocol are summarized in Table 1.

Specimen Preparation

Proceeding with the conventional lost-wax technique, 10 specimens were made out of Imagine Press X pressable ceramic. Plexiglass discs (Plexiglas, Evonik Rohm GmbH, Darmstadt, Germany) were prepared (with dimensions of 7 mm in diameter and 6 mm in thickness) and then invested and burned out by heat. The pressable ceramic was brought in to replace the empty space and pressed at a temperature of 930°C for 20 minutes.

In order to produce specimens for computer-aided design/computer-aided manufacturing (CAD/CAM), the blocks of each material (IPS e.max CAD, Milled Celtra Duo, Glaze-Fired Celtra Duo, Vita Mark II, Lava Ultimate) were milled into the desired shape of 6-mm-thick slices.

Afterward, the lithium disilicate specimens (n=10) were crystallized in a ceramic oven (Programat EP 5000, Ivoclar Vivadent, Schaan, Liechtenstein) at 840°C to 850°C. The glaze-firing protocol for zirconia lithium silicate specimens of the Glaze-Fired Celtra Duo material was conducted in accordance with the manufacturer's instructions. The Milled Celtra Duo samples, together with the feldspathic ceramic Vita Mark II, were not exposed to any firing after milling.

In order to create composite specimens (Enamel Plus HRi Bio-Function, Enamel Plus HRi, Filtek Supreme XTE), silicon molds were used, with an inner diameter of 7 mm and a height of 6 mm. Each mold was put on a glass surface. The composite resin material was stratified in three layers of about 2 mm and light cured for 40 seconds each (L.E. Demetron I with a 1200 mW/cm^2 output, Sybron/ Kerr, Orange, CA, USA), placing the curing unit tip as close as possible to the mold. After light curing, all specimens underwent a heat curing procedure in a composite oven (LaborLux, Micerium, Avegno, Italy) for 10 minutes at 80°C. The top surface of each composite sample was treated with 600-grit silicon carbide (SiC) paper under running water for 30 seconds, finished using diamond pastes (Shiny A, 3 μm, and Shiny B, 1 μm, Micerium), and finally polished with aluminum oxide paste (Shiny C, Micerium) delivered with a specific brush (Goat Brush Shiny S-HP and Felt Shiny F-HP, Micerium).

To fabricate 10 type III gold alloy samples (Aurocast 8), the traditional lost-wax technique was used following the manufacturer's guidelines.

Antagonist cusps were fabricated from yttria-stabilized tetragonal zirconia polycrystalline blocks (Katana Zirconia ML, Kuraray Noritake Dental Inc, Tokyo, Japan) with the use of a computer-aided milling machine (Dental CAD/CAM GN-1, GC, Tokyo, Japan), shaped like a blunt conus with a round 3-mm-wide tip, and then sintered at 1500°C for two hours. The polishing procedures were carried out with 6-μm diamond pastes.

All specimens were stored in distilled water for 24 hours at 37°C before wear simulation.

Wear Testing and Scanning Electron Microscope Analysis

All specimens were fixed in a dual axis chewing simulator (CS-4.2, SD Mechatronik GmbH, Feldkirchen-Westerham, Germany) specimen holder and subsequently exposed to the two-body wear test against zirconia cusps.

In this study, following the Ivoclar method for laboratory wear testing,[42-44] the masticatory cycle involved three stages: contact with a vertical force of 5 kg, horizontal sliding of 0.7 mm, and separation of the specimen and its antagonistic cusp. A total number of 120,000 masticatory cycles were performed at a frequency of 1.6 Hz in wet condition under distilled water.[42-44] The parameter set for the masticatory simulation is shown in Table 2.

Table 2: *Settings of Parameters for the Wear Resistance Protocol*

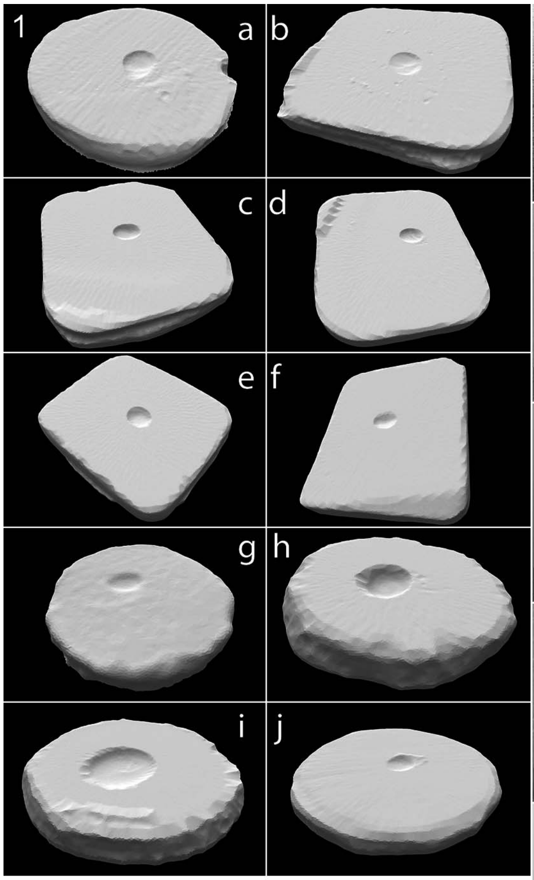
Parameter	Value
Number of cycles	120,000
Force	49 N
Height	3 mm
Lateral movement	−0.7 mm
Descendent speed	60 mm/s
Lifting speed	60 mm/s
Feed speed	40 mm/s
Return speed	40 mm/s
Frequency	1.6 Hz

Afterward, a quantitative surface analysis was performed on all samples. Using a CAD/CAM three-dimensional contact scanner (Renishaw Dental Scanner, Renishaw, Wotton-under-Edge, UK), a three-dimensional mesh was acquired from every sample (Figure 1). Subsequently, the wear depth (mm) and the volume loss (mm^3) were measured employing CAD software (AutoCAD 2009, Autodesk Inc, San Rafael, CA, USA). The height of each zirconia cusp was registered before and after the test procedure using a digital caliper with an accuracy of 1 μm. The difference was calculated and considered as antagonist wear (mm).

The wear facets of some representative samples from each experimental group were also subjected to a qualitative surface evaluation using a scanning electron microscope (SEM) (EVO 50 XVP LaB6, Carl Zeiss SMT Ltd, Cambridge, UK) at 60× magnification (Figure 2). The microstructure of the resin composite materials underwent a more detailed SEM analysis, up to 5000× magnification, using both secondary and back-scattered electrons (Figure 3).

Statistical Analysis

Achieved data of wear depth, volume loss, and antagonist wear were analyzed through SigmaStat for Windows 3.0.1 (Systat Software Inc, San Jose, CA, USA) statistical software. Mean values and standard deviations were calculated in each group. After having confirmed the homogeneity of the variances (Levene test) and the normal distribution of the data set (Kolmogorov-Smirnov test with the Lilliefors correction), three different one-way analysis of variance tests, followed by Tukey multiple comparison tests, were performed to assess the significance of mean differences (α=0.05).



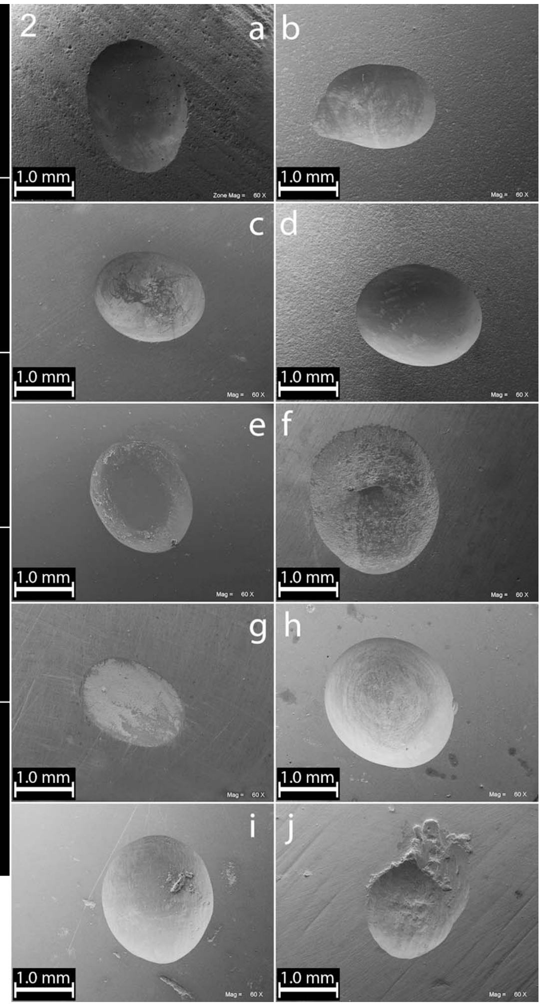


Figure 1. *Three-dimensional meshes of representative wear facets from the experimental groups. (a): Wieland Imagine Press X. (b): IPS e.max CAD. (c): Milled Celtra Duo. (d): Glaze-Fired Celtra Duo. (e): Vita Mark II. (f): Lava Ultimate. (g): HRi Bio-Function heat cured. (h): Enamel Plus HRi heat cured. (i): Filtek heat cured. (j): Aurocast 8 gold alloy.*

Figure 2. *Scanning electron microphotographs (original magnification 60×) of representative wear facets from the experimental groups. (a): Wieland Imagine Press X. (b): IPS e.max CAD. (c): Milled Celtra Duo. (d): Glaze-Fired Celtra Duo. (e): Vita Mark II. (f): Lava Ultimate. (g): HRi Bio-Function heat cured. (h): Enamel Plus HRi heat cured. (i): Filtek heat cured. (j): Aurocast 8 gold alloy.*

RESULTS

Table 3 summarizes the mean values of the wear depth and volume loss recorded for every material after 120,000 chewing simulation cycles against the antagonist cusp, whose wear is also shown.

The one-way analysis of variance confirmed statistically significant differences among the mean values for wear depth (F=23.310; $p<0.001$) and volume loss (F=69.026; $p<0.001$).

Glaze-Fired Celta Duo exhibited mean values for wear depth and volume loss statistically similar to those of gold alloy ($p>0.05$), while, when used soon after grinding, Milled Celtra Duo was significantly less wear resistant ($p<0.05$). The results of other tested dental ceramics were not statistically different from values of the gold alloy ($p>0.05$).

Wear depth and volume loss mean values recorded for the heat-cured Enamel Plus HRi Bio-Function resin composite, compared to the other investigated composites and ceramics, were the closest to the mean values achieved on gold alloy samples. The highest wear values were recorded in the Enamel Plus HRi and Filtek Supreme XTE groups, with no statistically significant differences between one another but with significant differences compared to other studied materials ($p<0.05$).

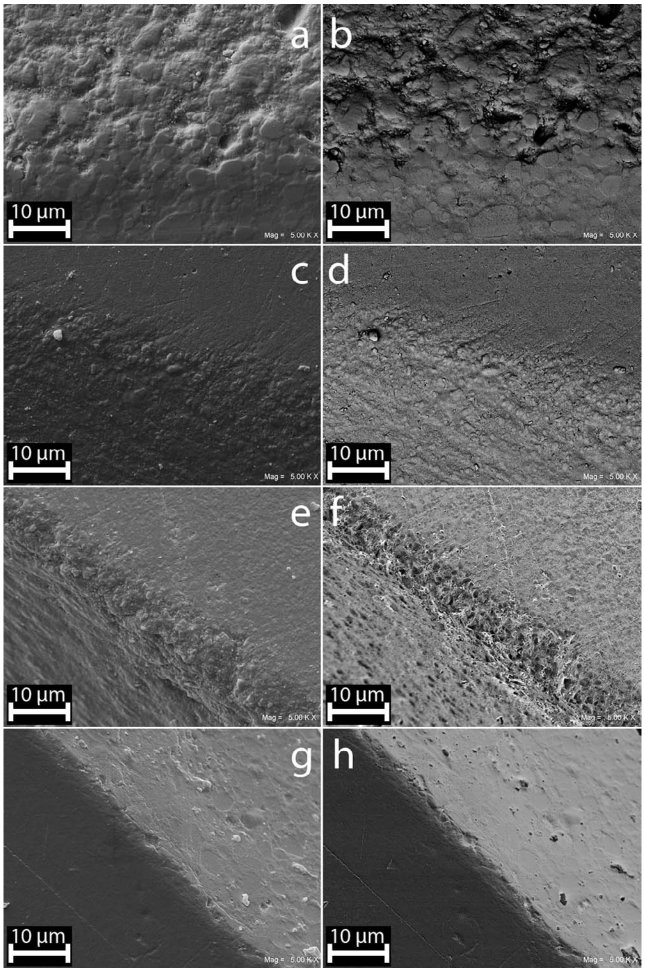


Figure 3. *Secondary (left row) and back-scattered (right row) electron microphotographs of the following resin composite materials, which were examined at higher magnification (5000×) in order to analyze their microstructure. (a, b): Lava Ultimate. (c, d): HRi Bio-Function heat cured. (e, f): Enamel Plus HRi heat cured. (g, h): Filtek heat cured. Back-scattered electrons help one better appreciate the differences in filler particle sizes and morphologies.*

DISCUSSION

The wear behavior of dental materials and dental tissues during mastication is an important factor that should be carefully evaluated when planning dental treatments. An optimal material that replaces missing enamel and opposes to natural enamel should have a wear behavior as similar to the natural dental tissue as possible.[12] It should be sufficiently wear resistant while presenting at the same time a minimal abrasiveness toward the opposing surface. Such material should provide optimal adaptation and response to the masticatory action. Optimal wear behavior is a central aspect to be considered, especially in the treatment of parafunctional patients with occlusal imbalance.

The null hypothesis tested in the present study, which assumed no difference in terms of laboratory wear properties among the several restoratives, must be rejected.

As already documented, the type III gold alloy (Aurocast 8) presents wear behavior very similar to that of human enamel, which shows great hardness, although is still subjected to wear when in contact with other restorative materials.[13,14,17] This characteristic has made gold alloy the preferred material for occlusal restorations over the past years due to its excellent adaption to the physiological occlusal needs of the patient.[15,16] Therefore, considering such a characteristic, it is supposed to minimize risk of occlusal disharmony and functional pathologies.[18]

According to the observed results, both ceramic- and resin-based composite indirect materials may show a satisfactory wear behavior compared to the gold alloy reference.

SiO-based pressable glass ceramics are among the most frequently used materials for metal-free fixed restorations. The present results demonstrated their wear resistance as satisfactory since their wear depth and volume loss mean values were very close to the mean values recorded for type III gold alloy. In the present study, we focused also on testing the wear behavior of a CAD/CAM feldspathic porcelain. This highly esthetic material is composed mainly of a glass phase, with a reduced crystalline phase, which is the reason for its excellent translucency and its optimal esthetics. The limited amount of crystalline phase, however, can affect its mechanical properties.[45] From the obtained results, the CAD/CAM feldspathic porcelain also did not differ from gold alloy and from other ceramic materials in terms of wear properties.

Glass ceramic and feldspathic porcelain hardness results in major abrasive power compared to composite materials in general. Although their behavior in terms of wear resistance is physiologically valuable, abrasiveness is still higher than composite materials.[46-48] Even if some enhanced ceramics may present improved flexural strength, feldspathic porcelains are typically more brittle than resin composites, which can increase the risk of fracture while milling extremely thin CAD/CAM restorations.[46,49,50] It is also true that glass ceramic restorations ensure a very high esthetic outcome, but any eventual intraoral occlusal correction or any new finishing/polishing procedure is certainly more problematic compared to what is allowed by resin composite materials.

Table 3: *Mean Values (and Standard Deviations) for Wear Depth and Volume Loss Achieved in the Experimental Groups.*[a]

Material	Wear Depth (mm)		Volume Loss (mm^3)		Antagonist Wear (mm)	
Imagine Press X	0.301 B	(0.058)	0.536 B	(0.107)	0.005 A	(0.001)
IPS e.max CAD	0.254 BC	(0.054)	0.351 CD	(0.091)	0.005 A	(0.002)
Milled Celtra Duo	0.320 B	(0.063)	0.555 B	(0.093)	0.004 A	(0.001)
Glaze-Fired Celtra Duo	0.280 BC	(0.051)	0.375 CD	(0.090)	0.005 A	(0.002)
Vita Mark II	0.282 BC	(0.057)	0.475 BC	(0.110)	0.005 A	(0.003)
Lava Ultimate	0.281 BC	(0.078)	0.456 BCD	(0.099)	0.005 A	(0.002)
Enamel Plus HRi Bio-Function	0.213 C	(0.052)	0.375 CD	(0.052)	0.005 A	(0.002)
Enamel Plus HRi	0.458 A	(0.057)	1.002 A	(0.121)	0.004 A	(0.002)
Filtek Supreme	0.456 A	(0.029)	1.026 A	(0.115)	0.006 A	(0.001)
Aurocast 8	0.216 C	(0.056)	0.327 D	(0.082)	0.004 A	(0.002)

[a] *Same letters indicate no statistically significant differences ($p>0.05$).*

In the present study, a CAD/CAM lithium disilicate ceramic (IPS e.max CAD) was investigated. Lithium disilicate is a material of unique composition, containing 70% small interlocking and randomly oriented crystals that provide extraordinary flexural strength. In this study, the CAD/CAM lithium disilicate demonstrated very similar wear properties to the gold alloy ($p>0.05$).

The zirconia-reinforced lithium silicate (ZLS) ceramic (Celtra Duo) was treated following two different finalization protocols in this study: milled and glaze fired. According to the manufacturer's instructions, the milled version provides the great advantage of saving time due to the possibility of skipping the firing procedure and directly polishing after grinding. This could be favorable for the chairside manufacture of adhesively luted indirect restorations. However, the glaze firing cycle, even if not required, is recommended, as it improves esthetic and flexural strength properties.[51] The wear properties of the ZLS material were examined both soon after grinding and after the optional glaze firing procedure. The wear depth and volume loss of the ground ZLS demonstrated statistically significant differences compared to gold alloy ($p<0.05$). Conversely, the differences found for the glaze-fired ZLS samples, albeit present, were not statistically significant ($p>0.05$). These results point to the glaze firing cycle as an important advanced procedure that may improve the wear resistance of ZLS-based ceramic.

The investigated CAD/CAM resin composite (LAVA Ultimate) demonstrated satisfying results of wear properties similar to gold alloy. According to the information presented by the manufacturer, this material presents enhanced strength, allowing the fabrication of indirect restorations with a minimal thickness and thus the preparation of the tooth with a maximally conservative approach. For restorations with a minimal thickness, an optimal wear resistance seems required, and, according to the collected data, Lava Ultimate may also guarantee a satisfactory behavior from this point of view.

Generally, the composite materials are considered advantageous because of many favorable aspects, such as the ease of handling, workability, low cost, and the possibility to easily carry out any required intraoral adjustment. Three types of frequently used composite materials were tested in this protocol.

Enamel Plus HRi and Filtek Supreme XTE, which are traditional composite restorative materials, displayed significant differences in the wear behavior compared to gold alloy. Excessively high wear depth and volumetric loss mean values may cause undesirable effects from the clinical point of view, such as loss of the occlusal contact, compromised function and esthetics, impaired occlusion, and possible musculoskeletal disequilibrium.[6-10] These aspects should be carefully considered, especially when treating parafunctional patients.

Different from the other samples, the novel composite material Enamel Plus HRi Bio-Function demonstrated the most statistically similar behavior in terms of wear depth, volume loss, and antagonist wear to the type III gold alloy group when submitted to the tests. Such similarity makes this material very promising, especially in terms of low interference with other materials. As stated by the manufacturer, the novel material is free of cytotoxic monomers (eg, 2-hydroxyethyl methacrylate and bis glycidyl methacrylate), which, if released during incomplete polymerization, may be harmful to dental tissue cells and increase the risk of pulp pathologies.[52,53] The absence of these components promises the material's biocompatibility. Thus, Enamel Plus HRi Bio-Function seems to unify the advantageous handling of composites, satisfying wear properties (such as some ceramics) and high biocompatibility. Due to these features, such a material may be adequate for clinical use, especially for complex treatments of parafunctional patients presenting a compromised occlusal balance.

Among the factors influencing the wear properties of composite materials, the percentage of filler content and the filler particle size/quality[54] have been extensively discussed.[55-58] Earlier laboratory studies have reported that the higher loading of filler particles into the resin matrix plays a particularly important role in the wear resistance of conventional composites,[59] as it increases the coefficients of friction between filler particles and the matrix and thus the rate of wear loss.[55,60] In recently introduced nano-filled resin composites, with reduced size of particles, the mechanical and esthetic properties seem to be improved with respect to conventional resin composites.[61] Such materials are highly filled with nano-filler particles that are distributed homogeneously in the resin matrix while creating larger interface area between fillers and resin matrix.[61] It was documented that smaller particles for a fixed-volume fraction of filler and decreased interparticle spacing are factors reducing the wear loss of nano-resin composites.[62-65] Nevertheless, there are also other factors that significantly affect the wear resistance of the material,[55] such as the type of resin matrix and the initiators for polymerization of resin composite[66] and the bonding between fillers and resin matrix.[67] The effect of all these factors, which are also influenced by loading details, makes the whole system of wear resistance complex.[55]

In this study, all resin composites investigated had comparable filler loads, ranging between 74% and 80% (Table 1). The filler particle sizes/qualities claimed by the manufacturer for Lava Ultimate and Filtek Supreme XTE appeared also similar (Table 1). Moreover, both Enamel HRi Bio-Function and Enamel plus HRi do contain both nano-scaled and non–nano-scaled particles (Table 1). Despite those microstructural similarities (Figure 3), a significantly increased wear resistance was detected for Lava Ultimate and Enamel Plus HRi Bio-Function when they were compared, respectively, with Filtek Supreme XTE and Enamel Plus HRi. As a consequence, without neglecting the previously mentioned correlation between filler particle size/quality, filler load, and mechanical properties, it seems clear that additional factors may play a paramount role in the determination of the ultimate wear resistance of resin-based materials, such as the degree of conversion of the resin matrix (that is inherently enhanced for an industrially polymerized CAD/CAM resin block) or an effective bond between the inorganic filler particles and the organic matrix (which has been claimed as enhanced in the recently introduced Enamel Plus HRi Bio-Function).

The clinical methods for the evaluation of dental material wear properties have been reported as hardly standardizable, time consuming, and subjected to many patient-related variable factors.[43,68-70] Therefore, different laboratory methods and simulation devices have been developed in order to provide a standard asset for the wear evaluation, and different studies have been reported with the aim to demonstrate their validity and the clinical correlation between clinical and laboratory tests.[43,71,72]

In the present study, based on the methodology already used in previous research,[1,42-44,73] the Ivoclar two-body wear test method was used, which is based on the simulation of 120,000 chewing cycles. Some studies state that in clinical conditions, approximately 330,000 chewing cycles are registered in one year of mastication.[44] This would mean that the quantity of 120,000 may be correlated to 132.7 days (approximately four months) of clinical chewing strokes.

However, as there are many variable factors influencing clinical wear (such as masticatory force, direction of the mastication, quality of meal, composition of saliva, and so on), the possibility of such a direct and strict correlation between laboratory and clinical data does not seem so strong for almost all different laboratory chewing simulation methods available, as reported by Heintze and others[44] in a recent review.

As far as the abraders used for laboratory testing are concerned, the preparation of antagonist samples made of human enamel is subjected to many conditions that may cause variability of its quality. These conditions include the eventual manipulation errors in order to prepare equal abraders introduced in the steps of the protocol and variability in the degree of mineralization and thickness of the enamel from the individual donors. In order to obtain a standardized shape of antagonist cusps,[74] zirconia ceramic spheres were used in the present protocol. They retained their shape during the entire testing period, avoiding any influence of the abrader surface shape on the process.[75,76] In this way, it was possible to obtain standardized experimental conditions in order to reach results not influenced by these variable factors.

CONCLUSIONS

The present protocol showed that distinct materials have a statistically different behavior in terms of wear resistance when exposed to simulated chewing cycles.

Among the heat cured resin composites tested in this study, only one (Enamel Plus HRi Bio-Function) showed vertical wear and volumetric loss results statistically similar to the traditional type III gold alloys. Because of the additional advantage of biocompatibility, it is considered that this material could be a promising alternative for reconstructions of posterior sectors also in the treatment of parafunctional patients. Both Enamel Plus HRi and Filtek Supreme XTE showed insufficient wear resistance and unfavorable results.

The milled Celtra Duo demonstrated a shallow but considerably augmented wear depth compared to Aurocast 8 gold alloy. Results of wear depth and volumetric loss for Celtra Duo subjected to a fire glazing cycle have been recorded and did not appear to be statistically different when compared to gold alloy.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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