In vitro occlusal wear of restorative materials on primary teeth

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Since primary tooth enamel wears more rapidly than permanent tooth enamel, it is important to study the mechanical wear patterns of restorative materials used in the primary dentition. It is important that an in vitro *evaluation of wear resistance of different restorative materials is done in order to establish a valid in vitro test protocol for use in pediatric dentistry.*

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INTRODUCTION

In the past twenty years, efforts to replace amalgam as a restorative material for primary molars have increased. Hence, modern dentistry is in search of restorative materials, that not only offers adequate wear resistance, but also good marginal adaptation, biocompatibility and esthetics.

Requirements for a restorative material in the primary dentition are rather different from those on the permanent dentition. The deciduous teeth have a maximum life of about 8 to 9 years. Consequently, a restoration will only have to last a limited time in function. Many theories state that the enamel of primary teeth wears more rapidly than that of permanent dentition. Thus, being aware of the mechanical wear of a restorative material is very important before selecting posterior restorations on primary teeth.

Since there are few standardized studies that compare the wear rate of restorative materials on primary teeth, the aim of this *in vitro* study is to compare and quantify the wear rate of the following four restorative materials on primary teeth: resin composite, polyacid-modified composite resin, resin modified glass ionomer cement, and amalgam.

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MATERIALS AND METHODS

The materials evaluated in this study are presented in Table 1.

Primary teeth that showed sound buccal or lingual surfaces were chosen from the Human Teeth Bank of the Pediatric Dental Department of the University of São Paulo. The buccal or lingual surface was carefully ground flat by wet grinding with a 600-grit silicon carbide paper until a flat surface with a diameter of at least 4mm was obtained. Care was taken not to expose dentin and all flat surfaces were observed under a stereoscopic microscope to verify that these surfaces consisted only of enamel. Specimens that showed dentin were excluded from the study. The root tips on each molar were removed and then mounted in a polyvinyl specimen holder using a self-cured acrylic resin.

Cylindrical Class I preparations (2.0mm in diameter and 3mm in depth) were prepared on the center of the flat surface (n=32), and were randomly divided into 4 groups, representing the four restorative materials to be tested (8 samples per group). Preceding cavity filling, enamel surfaces were cleaned using pumice and water on a rubber cup with a slow-speed hand-piece.

Table 1. Materials Evaluated

Material	Manufacturer	Particle size
Filtek Z250	3M ESPE	0.01 to 3.50µm
Dyract AP	Caulk-Dentsply	0.8µm
Vitremer	3M ESPE	-
Dispersalloy	Caulk-Dentsply	Spherical particles

Cavities were restored according to the instructions of the manufacturer. After storage in deionized water at 37ºC for 24 hours, restorations were finished and polished by wet grinding with a 600-grit silicon carbide paper, followed by fine and superfine Sof Lex (3M) polishing disks. The specimens were placed in deionized water at 37ºC for an additional 24 hours.

Wear simulation was performed using an eight-station Leinfelder-Type wear device.[1] The assembly was mounted in a water bath fixture of the wear simulator. A tight fitting cylinder was used to create a reservoir for a slurry of unplasticized polymethylmethacrylate (PMMA) beads averaging 44ºm in diameter. PMMA powder was mixed with tap water at a 1:1 weight ratio and used as an artificial food bolus. Each assembly was placed under a flat-planed 4.0mm diameterpolyacetal stylus mounted in a spring-loaded piston and centered so that the stylus traversed the dental material specimen and 2.0mm of the adjacent enamel surface. Each stylus was vertically loaded with 75 N at a rate of 12,000 cycles/hour. During the loading process the stylus rotated clockwise 30º as the maximum load was achieved, and then counter-rotated as the piston moved to the original position. At this point, the surfaces of the restored teeth were covered with a slurry of water and PMMA beads. Each specimen was subjected to 800,000 cycles. Two impressions of each specimen were taken at baseline and every 400,000 cycles with polyvinylsiloxane impression material and an epoxy cast (positive) was made from the impression. The first impression served to débride the surface and was discarded. The second was used to determine the actual loss of material.

Wear analysis was conducted by the indirect method of visual inspection. Three examiners, previously calibrated, analyzed twice each replica and compared them with the Moffa and Lugassi (M-L) scale.[2] The examiners were blind to the type of restorative material in each replica. If they were in between two values on the M-L scale, the average of the values was calculated. Inter-and intra-examiner reliance was tested and confirmed by the Friedman test. The analysis of variance ANOVA ($p<0.5$) was used for statistical analysis the results.

RESULTS

The results of the *in vitro* wear test for the materials are presented in Table 2. The materials are presented in the order of least wear to most wear occurring after 800,000 cycles. The first material presented is the resin based composite: Filtek Z250 followed by the amalgam: Dispersalloy and the polyacid-modified resin composite: Dyract AP. These three materials showed similar mean wear values; while the resin-modified glass ionomer cement: Vitremer showed higher mean wear values ($p<0.05$)

Table 2. Mean wear (μm) and critical value

Material				Turkey (5%)
Filtek Z250	Dispersalloy	Dyract AP	Vitremer	
-2.1μm	2.8μm	9.6μm	41.4μm	11.8

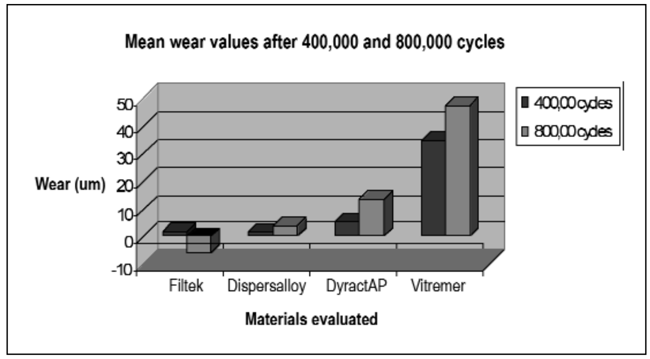

Figure 1. Mean values after 400,000 and 800,000 load cycles.

No statistically significant difference was observed between the mean wear values found at 400,000 and at 800,000 load cycles. Likewise, data did not show significant interaction between material and the number of load cycles used, showing that all restorative materials performed the same at measured load cycles. However, we noted a certain tendency of the resin modified glass ionomer cement (Vitremer) to show a slightly greater wear rate after the first 400,000 cycles than after 800,000 cycles (Figure 1). The composite resin (Filtek Z250) showed less occlusal wear after 800,000 cycles than dental enamel of the primary teeth.

DISCUSSION

The occlusal wear mechanism can be defined as the progressive loss of superficial substance from a specimen due to mechanical action. In the oral cavity, restoration failure can occur from abrasive mechanisms, but also from impact, corrosion and failure in adhesion.[3] These processes are all influenced by the masticatory movements, load applied on the restorations and the chemical, thermal and biological challenge that exists in the oral cavity. Therefore, mechanical wear resistance is very important in posterior restorations on primary and permanent teeth.

Our study investigated the occlusal wear of the four restorative materials used most in pediatric dentistry. Three calibrated examiners evaluated the occlusal wear of these restorations using the indirect method of visual inspection using the Moffa and Lugassi (M-L).[2] This particular scale was chosen because it allows an easier comparison between the replicas.[4] We evaluated occlusal wear of the restorations at every 400,000 load cycles since Leinfelder and Suzuki[5] demonstrated that there was a close relationship between the mechanical wear produced by the simulator and the one detected after 3 years of clinical trial on permanent teeth.

After 400,000 and 800,000 load cycles, Vitremer showed higher mean wear values ($p<0.05$). These results agreed with those reported by Peuttzfeld and others[6] and Faria and others,[7] though different methodologies were employed in this study. These authors verified that resin-modified glass ionomer cements showed lower wear resistance than resin composite and polyacid-modified resin composites. Based on these findings, Smales and Koutsikas[8] have suggested some alterations when using resin-modified glass ionomer cement that could yield similar clinical performance to resin composites. These are: a more dense mixture of powder and liquid in order to diminish the wear of the material; the use of dental sealant after the restoration is completed and the use of un-cured composite resin posts, while inserting the material. We used a finishing glaze as indicated by the manufacturer, but this did not improve the occlusal wear when compared to the other materials tested.

The mean wear values of the polyacid-modified composite resin (Dyract AP) obtained in this study were similar to those observed clinically by Hse and Wei[9] where Dyract restorations showed higher wear values than a resin-based composite (TPH) after six months, and one year of follow-up. Leung and others[10] have also reported similar results after a two-year of clinical trial.

The high wear resistance observed in amalgam restorations after 400,000 and 800,000 cycles are similar to the results reported in many other clinical studies[11-19] where amalgam was tested as a restorative material in primary teeth. Even though the mean wear values of Dispersalloy restorations were slightly lower than those of Dyract AP restorations, we believe that the polyacid-modified composite resins have more clinical advantages than amalgam when considering restorative materials for primary teeth.

In the present study, Filtek Z250 showed a greater occlusal wear rate than the deciduous enamel around the restoration after 400,000 cycles, whereas after 800,000 cycles the resin-based composite showed negative wear values (less wear than the surrounded enamel). This finding was not observed in other reported clinical studies[12,14,15,18,20] using different brands of resin-based composites. These studies showed greater wear compared with amalgam restorations. Our results are similar to those reported by Tonn and Ryge after a 4-year follow-up study,[14] where Ful-Fill restorations had similar wear to the enamel of primary teeth explained by an unusual increase in the alpha score, of 77% to 79% from year 3 to year 4 and also a mean wear decrease from 50ºm in the first year to 5.5ºm in the forth year.

Still, many other clinical studies have also observed a greater initial wear of Ful-Fill restorations that diminished as the masticatory cycles increased.[14,21,22] Likewise, an *in vitro* study conducted by Cardoso[23] where the same devise was used reported that Z100 had a mean wear value of 17,7μm after 400,000 load cycles and 23,4μm after 800.000 cycles where 76% of the total wear occurred during the first 400,000 load cycles. This initial increased wear could be explained by possible damage that the finishing process may have had on the restoration promoting cracks on the surface.

The results reported in our study regarding the resin-based composite Filtek Z250 is of special interest as it appears that the silica and zircon particles, sized between 0.01μm and 3.50μm, have greater wear resistance (hardness) than the enamel of primary tooth. Therefore, the use of Filtek Z250 as restorative material for primary teeth is questionable considering that it may promote a greater occlusal wear of the antagonist tooth, and possibly fracture of the restoration.

According to Leinfelder and Suzuki[5] the *in vitro* device used in this study is effective in generating the same wear pattern as that observed clinically. In addition, the 400,000-cycle values correlate well with the *in vivo* values gathered over a three-year period and are equivalent to a three-year period in the oral cavity in permanent teeth. If this were also applicable to the primary dentition, we can assume that Filtek Z250 could be used only if the tooth would remain for a short period of time in the oral cavity. On the other hand, for young children, the use of Filtek Z250 would not be recommended because it could promote all of the harmful consequences mentioned previously. Since there is not any study that determines the relation between *in vitro* mechanical wear testing and *in vivo* wear in primary teeth, it would be recommended to use alternate resin composites that have similar wear patterns to the primary tooth enamel.

It is extremely important to consider the mechanical and physical characteristics of the restorative materials employed on primary dentition. The ideal restorative material should have the same wear pattern that normally occurs in tooth enamel.[24,25] Many studies have reported that enamel of primary teeth wear more rapidly than in permanent teeth.[11,14,20,26] There are several supporting theories. A study comparing the hardness of primary and permanent molar enamel has been reported by Nose.[27] This study found that the hardness of human enamel, expressed by the average Vickers Hardness Number (HV) differed significantly between permanent and primary teeth. The HV of permanent teeth was 126 compared with 106 for primary teeth. Bite force studies have also reported significant occlusal bite force differences between children and adults. A mean bite force of 17.4 kilograms (kg) was recorded for children (mean age 9.3)[3] versus 31.0 Kg for adults (mean age, 26.9) at a 2.5mm opening.[28] The mean values were 15.5kg for children versus 35.6 kg for adults at a 6.0 mm opening.[29] It could be theorized that lower bite forces in children would be expected to be associated with less occlusal wear of posterior composite restorations.

According to our study, it can be stated that the *in vitro* device we used is reliable and effective in generating masticatory movements on primary dentition. It has been able to reproduce the generalized wear pattern observed clinically, even though this device was designed to simulate wear patterns occurring *in vivo* in permanent dentition. However, it must be taken into consideration that the wear mechanism inside the oral cavity is influenced not only by the different masticatory load and movements, but also by the frequency of food ingestion, degree of abrasiveness of foods, toothbrushing frequency, chemical environment (pH of the mouth), changes in temperature, and characteristics of restorative material (type and size, hardness, and distribution of the particles).[3,30] Since *in vitro* studies allow faster results and at less cost than clinical trials, efforts must be taken to develop an *in vitro* test protocol that can predict clinical wear reliably in primary teeth and its correlation to one or four-years clinical studies set forth by the guidelines issued by the American Dental Association Council on Dental Materials, Instruments, and Equipment.[31]

CONCLUSIONS

On the basis of this investigation, we conclude that:

Composite modified glass ionomer cement (Vitremer), showed a mean wear value statistically higher ($p<0.01$) than all other restorative materials tested;

After 800,000-cycles, composite resin Filtek Z250 showed less wear than the adjacent primary enamel.

No statistically significant difference was observed between the mean wear values observed on primary teeth in relation to the number of cycles used.

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