

Qualitative and quantitative wear rate analysis of direct restorative materials

Avaliação qualitativa e quantitativa do desgaste de materiais restauradores diretos

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ABSTRACT

The aim of this in vitro study was to analyze the wear rate of three direct restorative materials (Dispersalloy, Z250 and Surefil) using two methods of evaluation: visual M-L scale and profilometry. The occlusal surfaces of twelve human molars were ground flat using diamond disc. Standardized cavities were prepared using n° 721PM diamond bur and restored according to the manufacturers' instructions. They were then stored in distilled water at 37°C for 24 hours, polished, replicated and mechanical cycled. Wear assessment was performed using the M-L scale and profilometry. Different values were observed for the tested materials depending on the method of evaluation. For the M-L scale no difference was found among Dispersalloy, Surefil and Z250, whereas the profilometer showed that Dispersalloy had lower wear than Surefil and Z250 ($p < 0.01$). The M-L scale demonstrated poor accuracy when compared to the profilometer method ($p < 0.05$) to evaluate the wear rate of restorative materials.

UNITERMS

Dental restoration wear, composite resin, amalgam.

INTRODUCTION

The amalgam was the most commonly employed material for restoration of posterior teeth for several years⁷. Among its advantages, we may emphasize its easy manipulation¹¹, high wear resistance²⁴, clinical longevity⁵ and self-sealing ability of the tooth/restoration interface⁴.

However, the great demand for aesthetic restorations contributed to the improvement of light-cured resin-based composite materials¹². Initially, the use of these materials for restoration of posterior teeth presented some problems, such as low wear resistance¹⁷, complex restorative technique¹¹, besides difficult achievement of proximal contact²³.

In an attempt to enhance the wear resistance of composite resin materials, modifications were introduced in their inorganic portion³, such as reduc-

tion in the filler particle size^{25,27} and increase in the filler/matrix proportion⁹. Although an improvement was observed regarding wear, a less sensitive material to the restorative technique¹³, which also did not adhere to the manual instruments²⁰ and had a consistency that facilitated placement into the cavity and achievement of proximal contacts⁷, continued to be the goal of dental manufacturers.

To fill these requirements, the so-called condensable composite resins were recently introduced in the market¹⁴, with similar or even superior mechanical properties to the conventional composite resins^{8,12,18}, and presenting satisfactory clinical performance for restoration of posterior teeth²¹. However, contrary to amalgam, whose wear resistance was scientifically proved²⁴, few studies can be found in literature regarding the wear rate of these new condensable composite resins, thus

making it necessary to evaluate this property by means of *in vitro* studies.

To evaluate the wear rate of restorative materials, Leinfelder¹²(1989) presented a device that simulated mastication, in an attempt to establish a correlation between *in vitro* and *in vivo* studies. For McCabe & Smith¹⁹(1981), to adequately simulate wear, the test should be able to stress and abrade the restorative material. These requirements are achieved by means of mechanical cycling¹⁵, in which a water slurry of acrylic resin beads is also interposed between the specimen and the loading tip, thus reasonably simulating the presence of food bolus, as it occurs in the mouth during normal mastication¹².

In 1985, Lugassy & Moffa¹⁶ presented a more precise method to evaluate wear than the USPH criterion of direct visual analysis. The Lugassy & Moffa method consists on the indirect visual analysis of replicas obtained from the worn restoration surfaces by three previously calibrated examiners and comparison with standardized models with increasing wear values (M-L scale). Although this is a classic methodology, authors^{2,6} have searched for alternative methods to obtain more precise and less subjective wear measurements.

Hence the purpose of this *in vitro* was to verify the wear rate of three restorative materials for direct restoration of posterior teeth using two methods of evaluation: visual (M-L scale) and profilometer.

MATERIAL AND METHODS

This research protocol was submitted and approved by the Ethics Committee in Research of the School of Dentistry, University of São Paulo (Protocol 81/02).

Twelve sound, recently extracted human molars were cleaned of debris and stored in 0.9% phy-

siologic saline solution at 37°C. Root apices were removed using diamond disc (Blade XL 12235/Extex Labcut 1010) and occlusal surfaces were ground flat, so that dentin was not exposed^{8,19}. No beveling was performed. Specimens were embedded in acrylic tubes with 10mm of height and 10mm in diameter using chemically-activated acrylic resin (Jet – Clássico). During this procedure, occlusal surfaces were positioned towards a glass plate and residual acrylic resin was subsequently removed using 600-grit sandpaper. Care was taken to obtain at least 5 mm of enamel in the central portion of each crown. This was visually verified by etching the flattened surfaces using 35% phosphoric acid for 15 seconds.

A cylindrical-shaped cavity preparation was performed in the center of each occlusal surface using 721PM diamond bur (KG Sorensen) in a low-speed handpiece under water cooling attached to a sample aligning device. Cavity dimensions were 3mm in depth and 3mm in diameter.

Teeth were divided in three groups (n=4), according to Picture 1. Restorations were performed following the manufacturers' instructions for each restorative material.

Specimens were then stored in distilled water for 24 hours at 37°C²². They were finished using 600-grit sandpaper under water refrigeration and polished according to the type of restorative material (Vicking polishing rubber tips; finishing and polishing kit for metallic surfaces / KG Sorensen).

After that, two replicas were obtained from the occlusal surface of each specimen using Splash (Discus Dental) polyvinyl silicone impression material. The negative replica was made using type IV stone (Durone / Dentsply) and was stored for posterior comparative visual assessment with models obtained following mechanical cycling procedures. The second replica was used for quantitative wear measurement in a profilometer (Werth/Germany), with precision of 1_μm.

Picture 1 - Experimental groups

GROUP	MATERIAL	MANUFACTURER
01	Dispersalloy	Dentsply Ind. Com. Ltda
02	Z250 + Single Bond	3M ESPE
03	Surefil + Prime & Bond NT	Dentsply Ind. Com. Ltda

Specimens were surrounded by a tight-fitting polyacetal cylinder filled with a water slurry of unplasticized polymethyl methacrylate beads (PMMA), and mounted in a four-station three body wear testing apparatus. Then a flat planned polyacetal stylus was positioned over the central portion of each restoration surface. The stylus loaded onto the restored surface at a rate of 16.000 cycles per hour under a load of 80N^{8,19}. When the maximum load was achieved, the stylus began to rotate 30 degrees and after counter rotating, it moved in an upward direction to its original position. The entire cycling procedure was carried out 1,000,000. New replicas were taken from the worn surfaces as described above and submitted to visual and profilometer analysis.

For the visual analysis, replicas obtained in type IV stone were randomly assessed by three previously calibrated examiners and the wear rate was compared to the M-L scale¹⁶, under the same light conditions. This scale consists of models with increasing wear values varying from 25 μ m to 1000 μ m. Examiner calibration was achieved when they were able to ordinate the stone models three times consecutively.

The second method consisted of a quantitative wear evaluation. The polyvinyl silicone molds were sliced through the center of each restoration and assessed using a profilometer. Each slice was 2mm thick and was obtained using a special device that consisted on a blade that besides standardizing thickness, achieved adequate parallelism for each slice, thus avoiding shadows during observation in the profilometer, which might interfere in the eva-

luation. Wear was assessed by measuring the distance from enamel margins to the worn restorative material surface, with a precision of 1 μ m.

RESULTS

Figure 1 presents the mean wear rate values obtained for the three restorative materials (in μ m) according to the two methods of evaluation.

An interexaminer agreement of at least 85% was considered necessary for determining whether any differences were statistically significant using the Spearman's correlation test^{8,19}. Data obtained in this study for the M-L scale were submitted to Kappa Cohen's agreement test and Spearman's correlation test, and demonstrated a high interexaminer agreement of 99%.

Results were then submitted to split-split ANOVA and Tukey's test (Table 1) to verify any statistically significant differences between values. A statistically significant difference was found among restorative materials ($p < 0.01$) when the profilometer method was used, so that Dispersalloy presented lower wear than Surefil and Z250, although no statistically significant difference was found between the two latter materials. Regarding methods of evaluation, the profilometer demonstrated greater accuracy ($p < 0.05$) than the M-L scale. Statistically significant difference was also observed when the interaction materials x methods of evaluation was considered ($p < 0.05$). This indicates that the wear analysis was influenced either by the method of evaluation or type of restorative material.

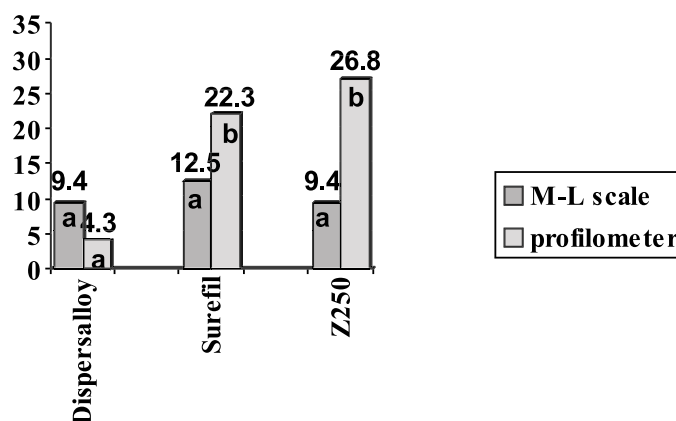


FIGURE 1 - Mean wear rate values (μ m) obtained for the studied materials according to the two methods of evaluation. Similar letters indicate no statistically significant differences ($p < 0.05$).

Table 1 - Mean wear rate values (μm) obtained for the studied materials according to the two methods of evaluation. Similar letters indicate no statistically significant differences ($p < 0.05$)

METHOD OF EVALUATION	MATERIAL			TUKEY (5%)
	Dispersalloy	Surefil	Z250	
M-L scale	9.4 (a)	12.5 (a)	9.4 (a)	
profilometer	4.3(a)	22.3 (b)	26.8 (b)	14.4

DISCUSSION

Data presented in Figure 1 and Table 1 demonstrated a statistically significant difference ($p < 0.01$) between Dispersalloy and the composite resin materials when the profilometer was employed for quantitative evaluation. On the contrary, wear was similar for Surefil and Z250. It is interesting to notice that the same was not observed when the visual analysis was made. The wear rate obtained for Dispersalloy was not statistically different from the two composite resins, a fact that might be considered as strange, if we consider the high wear resistance presented by amalgam materials, as it has been reported in several literature studies^{4,5,7,11,24}. Recent studies²⁸⁻⁹ corroborate with this statement, demonstrating that Dispersalloy presented superior resistance to wear than Surefil and other resin-based composite materials. This high resistance presented by amalgam materials is one of the reasons why they were so extensively employed for restoration of posterior teeth^{4,5,7}.

Surefil presented a numerically inferior wear rate than Z250 when the profilometer was used for evaluation (Table 1), although no statistically significant difference was found between them. Although literature reported higher wear resistance for Surefil condensable resin when compared to other composite resins², in the present study the wear rate observed for this material was statistically similar to Z250, which is a small particle composite resin. Probably this may be explained by the similar filler particle size for these two materials: $0.8 \mu\text{m}$ for Surefil^{13,18} and $0.6 \mu\text{m}$ for Z250¹⁰. A reason that may have contributed to the enhanced wear resistance of current composite resin materials was the reduction in filler particle size^{25,27}, which resulted in increased filler/matrix proportion¹⁰. The inorganic portion of both resins evaluated in this study (66% per volume for Surefil^{13,18} and 60% for Z250¹⁰) emphasizes this statement.

According to Teoh et al.²⁶(1998), large filler particles escape from the organic matrix when submitted to mechanical challenges, thus exposing the matrix and becoming more susceptible to wear. Hence, composite resin materials with large filler particles would have greater wear than those presenting smaller-sized filler particles. For the materials evaluated in a study performed by Yap et al.²⁸(1999), Dispersalloy presented the greatest wear resistance, followed by Surefil and other condensable composite resins, and finally by Z100. According to these authors, the higher wear rate observed for Z100 would be due to the greater hardness of its zircon/silica filler particles. They transfer the stresses of mechanical cycling to the matrix instead of absorbing it, thus resulting in the rupture of the filler/matrix interface and loss of the particle, with consequent continuous wear of the material.

As the filler component presented in the composition of Z250 is also based in zircon/silica¹⁰, it might have been expected that it obtained higher wear rate than Surefil, whose filler content is composed of barium, boron, fluoride silicate and aluminum oxide¹³, but that did not occur. Possibly, the wear resistance of composite resin materials may be influenced by other factors, which were also emphasized by Yap²⁹(2002), such as filler/matrix composition, adhesion between filler particles and matrix, and differences in the elastic modulus between these two components, which might result in a stress in the filler/matrix interface. Regarding the elastic modulus, Abe et al.¹(2001), emphasized the importance of performing more studies on the wear resistance of condensable composite resins with different elastic modulus.

Generally, the profilometer detected higher wear, except for Dispersalloy (Figure 1). This may be explained by the fact that the M-L scale is li-

mitted to the restoration margin, whereas the profilometer evaluates the step present in its whole extension. It was also observed that the wear presented by Surefil and Z250 was much superior with the profilometer analysis than with the M-L scale (Figure 1). This may be explained by the fact that the M-L scale is composed of models with increasing wear values, varying from 25 to 25 μ m, an amplitude that probably makes it difficult to identify subtle differences under human eye visualization, which under estimated wear in this case. On the other hand, the same did not occur with the profilometer, which was capable of detecting wear differences with a precision of 1 μ m. In this study the M-L scale visual analysis presented poor accuracy when compared to the profilometer.

Nowadays, the wear rate of new resin-based composites is much lower due to improvements introduced in these materials. Hence, differences in wear rate values tend to be more subtle, thus justifying the importance of using quantitative methods for *in vitro* wear analysis^{2,6}.

CONCLUSIONS

The materials tested in this study presented different wear rate values depending on the method of evaluation. When the visual analysis (M-L scale) was performed, all materials obtained statistically similar values, whereas with the profilometer analysis, Dispersalloy showed lower wear than Surefil and Z 250 composite resins, so that no statistically significant difference was observed between these two latter materials. The profilometer presented better accuracy than the Moffa & Lugassy method for wear rate analysis.

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RESUMO

O objetivo deste estudo *in vitro* foi avaliar o desgaste de três materiais restauradores diretos (Dispersalloy, Surefil e Z250), através de dois métodos: visual (escala M-L) e quantitativo (perifilógrafo). Superfícies oclusais de doze terceiros molares humanos foram aplainadas com disco diamantado e cavidades cilíndricas padronizadas foram confeccionadas no centro delas, com ponta diamantada nº721PM, e restauradas conforme instruções dos fabricantes. As restaurações foram armazenadas em água destilada a 37°C durante 24 horas, polidas, moldadas e submetidas à ciclagem mecânica. A avaliação do desgaste foi feita utilizando a escala M-L e o perifilógrafo. Foram encontrados resultados diferentes para os materiais testados, dependendo do método de avaliação utilizado. Na escala M-L o desgaste entre Dispersalloy, Surefil e Z250 não foi diferente, enquanto que no perifilógrafo o Dispersalloy apresentou menor desgaste que as resinas Surefil e Z250 ($p < 0,01$). A avaliação do desgaste pela escala M-L foi subestimada em relação ao método do perifilógrafo ($p < 0,05$).

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Desgaste de restauração dentária; resina composta; amálgama

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