Tribological Comparative Study on Two Composite Materials for Restorative Dental Applications in Smoking Affected Teeth

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Due to the multitude of restorative materials on the today market, the studies presented in this paper come to make some contributions regarding the evaluation of biomaterials in terms of resistance to the wear process, the factors influencing the tribological behaviour of hard structures and restorative dental biomaterials in the oral environment.

Keywords: composite materials, tribology, wear, dental medicine

There are nowadays modern means of investigation and assessment of biomechanical properties of biomaterials and restorative dental structures, characteristic of the last decade being the moving of research from the macroscopic to the microscopic level, from destructive means for resistance determination to the non-destructive methods.

In this way, the literature gives a major interest on the problems specific for tooth wear, how to approach and solve the many existing forms of wear [1]. There are still a number of uncertainties related to tribological events in the oral cavity and thus hard dental structures. Different mechanisms of production, corellation between shape and events, and new biomaterials such as composites appeared on market justified to focus the study on these aspects.

But the main parameter used to assess the phenomenon of wear is the volume of spent material.

Experimental part

To determine the wear coefficient and the volume of spent material were tested two types of composite materials used in restorative dentistry practice: *D.SIGN* (IVOCLAR) and *VM13* (VITA-VIDENT$_{TN}$) from which there were made samples in the form of discs with a radius of 25 mm and a thick of 2 mm (0.5 mm metallic support and 1.5 mm phiz composite component).

The experiment was realized using a CALOWER-CS tribometer [2]. The applied methodology and all imposed conditions for experimental researches were presented in [3].

Tabel 1
VOLUME OF SPENT MATERIAL AND THE COEFFICIENT OF ABRASIVE WEAR FOR
D. SING COMPOSITES

Shaft rotation [min^{-1}]	Crater diameter [mm]							Length of friction [mm]	Spent volume [mm^3]	Deviation	Wear coefficient *k* [mm^3/Nm]
	D1	D2	D3	D4	D5	Media	Abaterea				
75	1,4	1,2	1,3	1,2	1,2	1,275	0,095743	3255	0,010214	3,2478E-07	0,008964643
150	1,5	1,5	1,6	1,4	1,5	1,5	0,08165	6511	0,019567	1,71784E-07	0,00858672
225	1,6	1,65	1,8	1,7	1,7	1,6875	0,085391	9766	0,031343	2,05504E-07	0,00916951
300	1,8	1,8	2	1,8	1.9	1,85	0,1	13022	0,045274	3,86515E-07	0,009933886
375	2	2	2,1	1,95	2	2,0125	0,062915	16277	0,063403	6,05607E-08	***0,011129248***

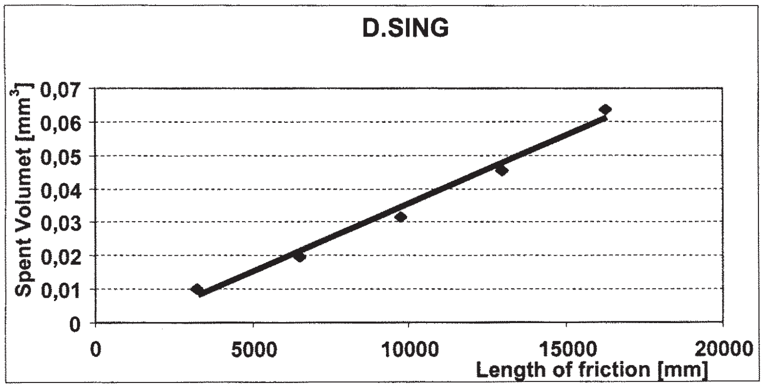

Fig. 1. Average volume of spent material depending on the length of friction for *D.SING* composites

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Tabel 2
VOLUME OF SPENT MATERIAL AND THE COEFFICIENT OF ABRASIVE WEAR FOR *VM13* COMPOSITES

Shaft rotation [min^{-1}]	Crater diameter [mm]							Length of friction [mm]	Spent volume [mm^3]	Deviation	Wear coefficient *k* [mm^3/Nm]
	D1	D2	D3	D4	D5	Media	Abaterea				
75	1,1	1	1,2	1,2	1,2	1,14	0,089443	3255	0,006528	2,4737E-07	0,005729433
150	1,3	1,2	1,4	1,4	1,6	1,38	0,148324	6511	0,014018	1,87073E-06	0,006151466
225	1,6	1,6	1,6	1,7	1,9	1,68	0,130384	9766	0,03079	1,11703E-06	0,00900758
300	1,9	1,7	1,8	1,8	2,1	1,86	0,151658	13022	0,046261	2,04466E-06	0,010150421
375	2	1,9	2	1,9	2,15	1,99	0,10247	16277	0,060615	4,26133E-07	***0,010639827***

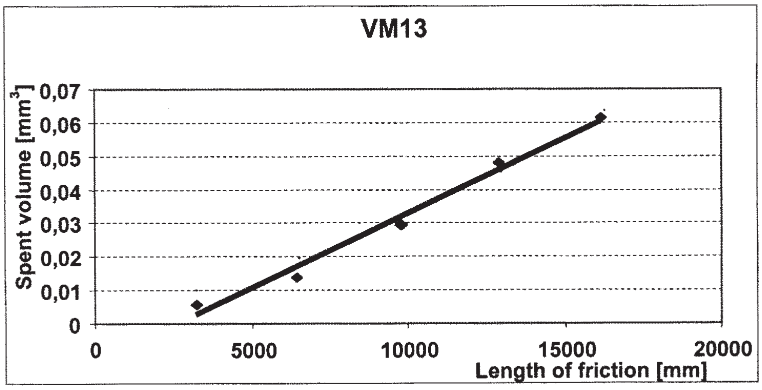


Fig. 2. Average volume of spent material depending on the length of friction for *VM13* composites

Applying the specific calculus for contact theory able to determine the wear of composite material beeing in contact with the metal sphere [3], there were obtained the values for the material parameters, geometry and loading. It was determined the abrasive wear coefficient for the two composite materials taken in the study mentioned above.

The variation of abrasive wear coefficent for *D.SING* composites is presented in table 1 and figure 1.

The variation of abrasive wear coefficent for *VM13* composites is presented in table 2 and figure 2.

Based on all tests performed, there are observed differences between the coefficients of abrasive wear for the two types of composites produced by IVOCLAR – *D.SIGN*: 0.011129248 mm^3/Nm and VITA-VIDENT – *VM13*: 0.010639827 mm^3/Nm).

For both tested composites it is observed a linear relationship between the volume of spent material and the length of friction. In the same time it should be noted a progressive increase of the diameter of wear spots with a corresponding increase in the volume of spent material.

Based on the research results it can be said that the composites *VM13* has a high resistance to abrasion wear (0.060615 mm^3 volume of material used for the wear coefficient of 0.010639827 mm^3/Nm). Material transfer rate decreases proportionately with increasing concentration of silicon, the material becomes more resistant to wear, reflected in the table values (table 2).

Increasing load by using metal spheres with ranging diameters associated with consequent increases in the length of friction material is reflected in the rate of deformed and displaced material by the wear process.

Seen under the optical microscope, the area of wear for *D.SIGN* composites has aspects presented in figure 3.

The infiltration process occupies the space between the alumina grains for *D.SIGN* composites. Dark regions are associated with the process of infiltration. Fine radial cracks are visible marking the areas where abrasion is obvious.

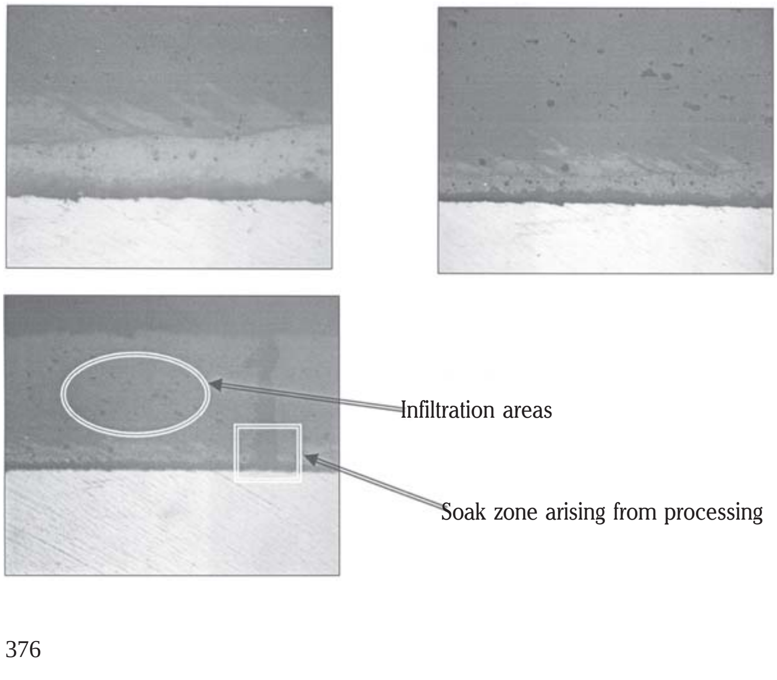


Fig. 3. Microscopic aspects of *D.SIGN* composites

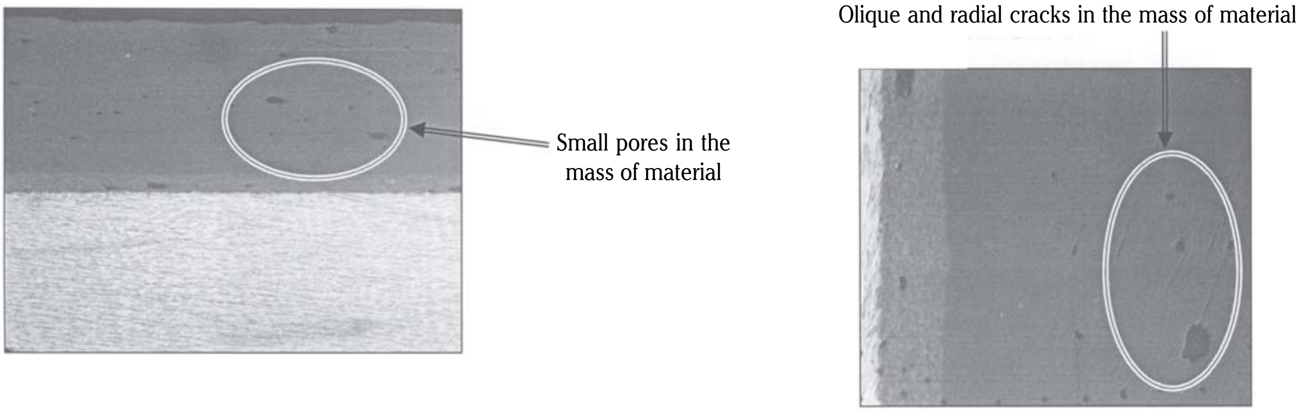


Fig. 4. Microscopic aspects of *VM13* composites

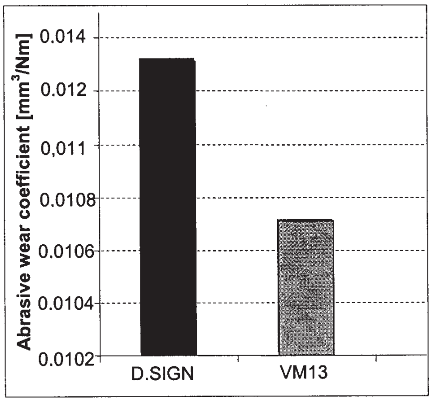
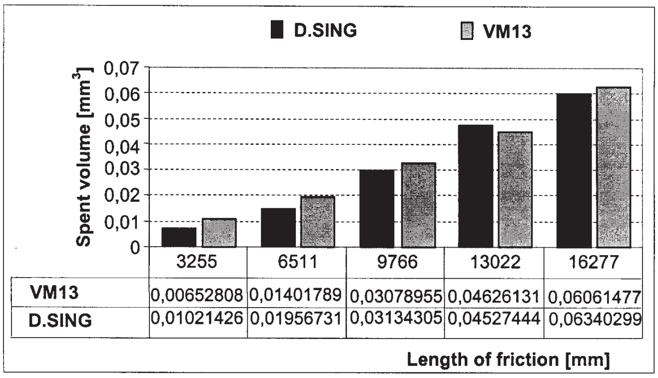


Fig. 5. Variation of composites abrasive wear coefficients



	3255	6511	9766	13022	16277
VM13	0,00652808	0,01401789	0,03078955	0,04626131	0,06061477
D.SING	0,01021426	0,01956731	0,03134305	0,04527444	0,06340299

Fig. 6. Volume variation of spent material volume of composites depending on the length of friction

These microscopic aspects characterize each wear surface.

Seen under the optical microscope, the area of wear for *VM13* composites has aspects presented in figure 4.

Increasing load by using metal spheres with ranging diameters associated with consequent increases in the length of friction is reflected in the rate of deformed and displaced material by the wear process. Thus, for a 2 mm diameter, for the same length of friction, wear coefficient is approximately 0.01063 mm^3/Nm.

Microscopic images do not show the presence of multiple radial or conical cracks in the mass of composites, but the existence of small pores located on the surface. There are visible only rarely oblique and radial cracks which indicate a simultaneous development of significant tension distributed over a relatively small area.

Comparing abrasive wear coefficients of the two composites studied (table 3), it is noted that, for the same length of friction the material amount spent increases with the wear coefficient; the material with the best abrasion wear resistance is *VM 13* (unlike *D.SIGN* which is more sensitive to abrasion).

Graphical representation highlights the difference between the wear coefficients for the two composites studied (fig.5).

This coefficient variation of wear abrasion can be made in close connection with some structural issues, not discussed in this paper.

Comparing the volume of used values obtained for the same length of friction, there is a linear increase in the quantity of material moved with increasing distance of sliding metal sphere (fig.6). Thus, if the initial phases of testing material *D SING* highlights an increased value for the volume of material used, as it increases the length of friction material change occurs in the mass lost by abrasion, reaching, at a length of about 16 277 mm the smallest volume of material used is available for composites *VM13* (0.060 mm^3).

It is thus confirmed that the wear factors are dependent on loading for all areas studied, justifying their use in an attempt to normalize parameters of measurable wear.

Results and discussions

Both composites *D.SING* and *VM13* have a high hardness as evidenced by narrow and shallow signs of wear, unlike other composite materials [3] whose hardness determines the material loss during testing.

As is seen in the study, the volume of material moved (used) increased proportionally with load increasing, but it is independent, both parameters are justified to be used in the normalization of measurable wear values.

Deformed volume of material and degree of deformation are conditioned by two factors: the amount of energy deposited in the deformation process and nature of the material [4].

Wear coefficient could be considered as a parameter in terms of probability generating wear particles at each contact with an antagonist body; its value indicates the loss of volume with the formation of wear particles to each contact (which is consistent with results in this study). Basically, it measures the strength of two bodies in sliding motion. As already known, a low coefficient is accompanied by an increased resistance to wear, as is reflected in our study, although high values depend on the mechanism of wear and friction energy produced [5,6].

In turn, the volume of material is dependent on the area and depth of contact, so the two parameters could be determined in clinical usage, but the great disadvantage which lies in the fact that this will be an indirect method of measuring wear depending of occlusal factors which are varying in time.

It is clear that the contact depth (closely related with diameter crater produced from the contact) as a function of rotation cycles, actually defines the used area and the volume of deformed material.

Fatigue process appears at repeated loadings and leads to the initiation of cracks in the softer layers, with initiation of quasiplastique amendments accumulated in the layer of composite material.

But in our study showed no signs of extensive damage due to mechanical abrasion, deformation or fracture, phase glass is still partially removed at high load.

Also, as shown by the results of this study, surface conditions will influence the wear behaviour.

In these circumstances, at oral cavity level, increasing the contact surface will change the centric contacts, resulting in default, and vertical loss of material by wear.

An indicator of composite material stress could be represented in the oral cavity by the anterior high abrasion (which is the reason for ceramic restorations to fail at this level); most likely they will divide the area in which there are excessive occlusal contacts associated with an increased abrasion [7].

Conclusions

Experimental research results presented in this paper established a number of conditions which contribute both to the initiation of structural changes, the strength and durability, and for establishing of remedies on new dedicated composite materials for restorative dental applications.

The research has focused on addressing and evaluating the tribological behaviour of restorative materials should provide, ideally, a low friction and high wear resistance.

We can not talk about an ideal bio-tribo-mechanical behaviour for a given structure of composite restorative as can not detect the true mechanisms that occur at the contact between the two structures with different compositions and tribological characteristics (in our case structure and restorative dental material), solely in the conduct of the relevant research which generally concerns to simulate the clinical situation by the finite element method help.

Therefore data from these experimental investigations can be used in developing mathematical models that will address the entire complex of factors specific for tribological phenomena developed at the oral cavity level.

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