An *In Vitro* Investigation of Mechanical Behaviour in Composite Resin Materials

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Summary

Both the development of the aesthetic dentistry and a favorable approach towards amalgam resulted in an increasing interest in using the composites in restoration of posterior teeth. The most important factor that limits composites the usage of posterior area is that they do not have enough resistance to wear and mastication strength. Physical properties such as wear; surface hardness and compressive strength are important factors choosing posterior composites. In this study, wear resistance, microhardness profile and compressive strength of three different composite materials offered for using in posterior area were investigated. The results have shown that the

most resistance filling material was the Alert. The highest surface hardness values were found for the Valux–Plus. After applying compressive tests to the composite resins, The Valux–Plus material exhibited the highest compressive strength.

CLINICAL SIGNIFICANCE

Although intensive studies have been carried out so for to produce the most appropriate restorative materials, there are still considerable differences between the mechanical properties and wear hardness of the tooth tissue and composite resins. In addition to that volume fraction of the filler, composition, resin type and polymerisation degree significantly affect the hardness of the restorative materials. For this purpose, in this study was to investigate the mechanical properties and find out a relationship between wear resistance, hardness and compressive strength values of the three types of restorative materials.

BACKROUND

Composite restoratives are rapidly becoming strongest candidates as a dental material for some applications such as aesthetic dentistry. Composite resins materials are considered to be more suitable than conventional materials like amalgam as they have favourable mechanical, physical and frictional properties. Four types (Porcelain, acrylic resin, composite resin and metal) of restorative materials have been used commonly for the restoration of posterior teeth. Among these materials the most widely used materials for this purpose were porcelain and resin. When compared to the wear behaviour of these materials, porcelain possessed high abrasive wear strength than resin; however, it was also more prone to fracturing. Resins, on the other hand, possess excellent strength and adhesiveness to the base of the tooth. Microfilled composite resin tooth materials have been introduced as an alternative to conventional acrylic resin teeth.

As for the mechanical properties of the composite resins, Hirano *et al.*[1] who studied the abrasive wear of four different types of resins against abrasive enamel found that the most important mechanical property of restorative materials is abrasive wear strength. As a matter of fact that many researchers have shown that the excessive wear of dental restoration materials is one of the main problems encountered in their use in stress bearing applications.

Yap *et al.*[2] were investigated the effects of the chemical environment on the wear of composite restorative materials. They found that the amount of wear loss strongly depended on the chemical degradation in the mouth. The explanation for this behaviour is that conventional composites have significantly lower wear resistance when they were immersed in chemicals that softened the resin matrix copolymer[3]. Moreover, Abe *et al.*[4] demonstrated that the wear resistance of high strength resin tooth, with a chemical structure similar to the resin composite tooth, is influenced considerably by opposing materials.

Determine of the composite surface hardness has been studied extensively. However, hardness measurement of the composite resin surface is an effective way to evaluate the degree of the polymerisation. Because after polymerisation of the surface layer, removes the hardest layer and exposes a slightly softer layer of material than was previously present on the surface[5-8].

In addition to wear resistance and hardness values, the compressive strength of the composite resin has become a subject of great interest both from scientific and clinical viewpoints. Although, extensive investigations have been done on the mechanical properties of the composite resins, different results have been reported[9]. Consequently, there are no well-established guidelines for optimising the mechanical properties of the composite resins.

The aim of this study was to investigate the mechanical properties and find out a relationship between wear resistance, hardness and compressive strength values of the three types of restorative materials.

MATERIALS AND METHODS

Three different composite resins were studied for this study as seen in Table 1. Ten samples were prepared from each composite resins by using flexi glass mould for all tests. Schematic illustration and dimensions of the mould was shown in Fig.1. All composite resins were cured for 40 s using a light-curing unit (Degulux, Degussa, Germany) and stored in distilled water at 37 ^{o}C in seven days prior being the tested.

The specimens in the form of 4 x 6 mm rectangular pieces were prepared for sliding wear tests (pin on plate). Wear tests were performed on a reciprocating dry sliding tester as shown in Fig. 2. The counter material was prepared from tooth. The tests were carried out at a sliding velocity of 0,05 ms^{-1} at ambient in vitro conditions. A load of 10 N was used for test material. After the end of sliding distances, the testing device was stopped, the surface of sample was cleaned with brush and surface particles (or debris) were removed and weight loss was determined. Wear rates were computed from weight loss measurements taken after 120 m sliding distances. Microhardness measurements were performed at room temperature and minimum of ten hardness readings were taken for each sample. Vickers diamond pyramid indentor was used under a 100 gr load for microhardness.

Compressive tests were performed on a computerized AG-50 kNG Shimadzu universal testing machine at ambient, using cylindrical specimens with a diameter of 4 mm and a length of 6 mm. The applied crosshead speed was 0.5 mm/min and the standard procedures were used to evaluate the results. All test results were analysed by the Duncan test ($p<0.05$).

RESULTS

The mean values for the composite resins were not statistically different ($p<0.05$). The wear results of the Valux–Plus, Clearfil AP–X and Alert type composite resins are given in Table 1 which shows the mean wear lost and standard deviation. The wear lost after 120 m sliding distance of the samples are shown in Fig. 3. As seen both from Table 2 and Fig. 3, the wear lost is minimum in Alert and maximum in Clearfil AP–X type composite.

The average hardness values of the materials are listed in Table 2. A comparison of the hardness values for the samples is shown in Fig. 3. It is clear from the figure that the hardest composite resin type is Valux–Plus and softest is Clearfil AP–X.

Compressive test results are given in Table 2 and comparatively illustrated in Fig. 3. Although, the results show that there is no significant difference in compressive strength values between the samples, the compressive strength of Valux–Plus type sample is slightly higher than the others.

DISCUSSION

It is well known that the type, size, amount and distribution of the inorganic particles reinforced in the composites strongly affect the wear behaviour. In addition, increase the volume fraction of the filler decreases the wear loss[10-12]. In this study, the filler volume fraction of the Valux–Plus, Clearfil AP–X and Alert are, 85, 86 and 84%, respectively. Although, there are not a significant difference among the filler volume fractions of the composite resins the wear loss of the samples are quite different. As a matter of fact that, the least wear loss was observed for Alert sample which filler volume fraction is lowest. Similar results have also obtained by Jaarda *et al.*[13], they explained that there is not a correlation between the filler volume fraction and wear behaviour. From this result it is possible to draw a conclusion that, the filler content is not the only factor that affect the wear behaviour of the composite resins. On the other hand, the size, type, distribution of the filler and the bonding strength between the matrix and filler affect the wear behaviour[14-17]. Wear results strongly depend on the interfacial bonding characteristics between the matrix and filler. In general, wear behaviour of the composite resins show that, composites contain coarser, harder and high volume fractions of filler exhibit higher wear resistance. Due to the fact that Alert type composite resin contain coarser and irregular shaped filler compared to Valux–Plus and Clearfil AP–X hybrid composites, Alert type composite offer superior wear properties. It should be also noted that, tooth wear is a complex process that depends on extrinsic factors, such as: the masticatory function, the tooth form, and the position of the teeth relative to the arch as a whole[18].

As known, hardness implies a resistance to indentation, permanent or plastic deformation of the material. The filler volume fraction, composition, resin type, and polymerisation degree significantly affect the hardness values of the restorative materials. After polymerisation, monomers that not participate in reactions lead to a decrease in hardness and the hardness of the inorganic fillers affect directly the overall hardness of the materials. Manhart *et al.*[19] who studied on condensable, which also contain Alert type, hybrid and ion-relased composites, demonstrated that there is correlation between filler fraction (wt.%) and surface hardness. They have also found that Alert which contain the highest filler fraction posses the maximum surface hardness values. In this work, although Alert type composite contains the lowest filler fraction, the hardness value of this sample is higher than hybrid Clearfil AP–X composite. The results of the hardness measurements of the samples show that there is no correlation between hardness values and wear loss. As seen from Table 2 and Fig. 3, while the lowest hardness value observed for Clearfil AP–X type composite resin, the wear loss is highest for this sample.

In order to find out the performance of restorative materials against mastification forces, it is required to determine the compressive strength values of the restorative materials. The factors that affect the compressive strength of the materials may be the filler volume fraction, size, type, morphology, polymerisation process parameters, and filler loading process. The results of the present study show that there are no significant differences between hybrid composites (Valux–Plus, Clearfil AP–X) and condensable composite (Alert) thus the type of the composite resin do not influence the compressive strength and the obtained results are almost equal (Table 2). Whereas, Cobb *et al.*[20], reported that the compressive strength of the condensable type composite is higher than hybrid type composites. It can be concluded that, the highest compressive strength has been observed for Valux–Plus type composite, which is the hardest composite. The volume fractions of the fillers used in this study were almost equal to each other so its effect on the compressive behaviour is negligible. In contrast, according to the study of Li *et al.*[11], the increase in filler volume fraction increases both the hardness and compressive strength of the composites. Although, the hardness and compressive strength values of condensable Alert type composite is lower than Valux–Plus hybrid composite, in the point of wear resistance, Alert type composite is more attractive.

In conclusion, this study has found that condensable Alert type composite resin exhibits the highest wear resistance compared to hybrid type composites (Valux–Plus, Clearfil AP–X). However, no correlation was observed between hardness and wear for all tested materials. According to the mechanical results, among the restorative resins, Alert type composite resin show better properties and can be considered as the most suitable material to use in posterior area. It is recommended that before the selection of the most appropriate material under these circumstances, the results obtained both from in-vivo and in-vitro should be evaluated together.

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TABLE LEGENDS

Table 1 Composites studied in this work

Table 2 Mechanical properties of the composite resins

FIGURE LEGENDS

Fig. 1 Schematic illustration of flexi glass mould

Fig. 2 The sliding wear test set-up

Fig. 3 Mechanical properties of the composite resins

Table 1

Composites studied in this work

Materials	Manufacturer	Composite type	Resin type	Filler type	Filler particle size (μm)	Filler Content	
						(wt.%)	(vol.%)
Valux–Plus	3M Dental St. Paul, MN, USA	Hybrid	BIS-GMA TEGDMA	Zirconia Silica	0,6-1	85	66
Clearfil AP–X	Kuraray Co; Ltd. Osaka, JAPAN	Hybrid	BIS-GMA TEGDMA	Ba glass Silica	-	86	70
Alert	Jeneric/ Pentron Wallingford, CT, USA	Condensable (Packable)	PCDMA	Glass Fiber	0,8 fibers (6 x 80)	84	70

Table 2

Mechanical properties of the composite resins

Composite resins	Sample number	Mean wear loss (g)	Standard deviation	Mean hardness (HV)	Standard deviation	Compressive strength (MPa)	Standard deviation
Valux–Plus	10	0,00238	0,000932	101,42	4,262	345,6	31,98
Clearfil AP–X	10	0,00242	0,000750	79,72	2,365	324,4	25,18
Alert	10	0,00158	0,000394	90,64	5,672	339,4	33,17

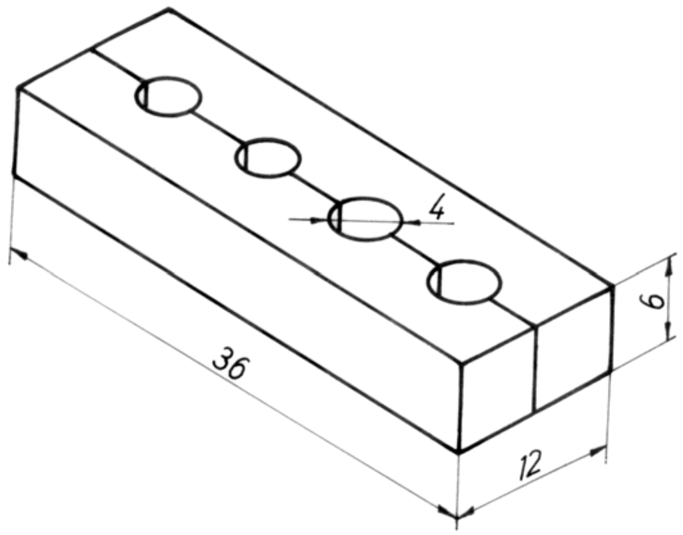

Fig. 1 Schematic illustration of flexi glass mould

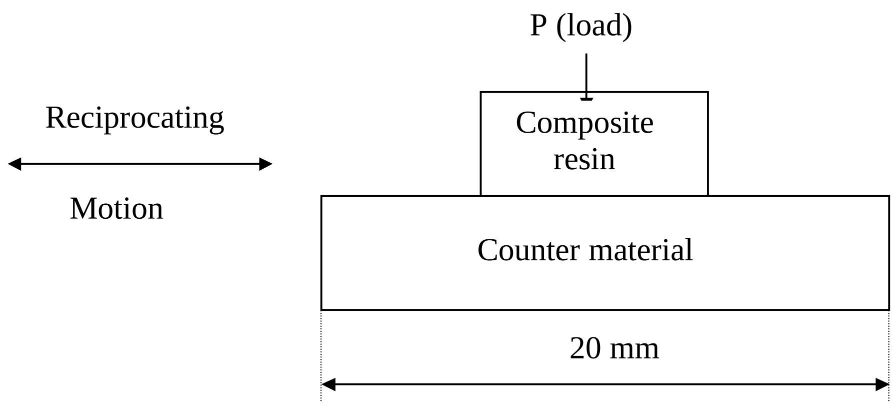

Fig. 2 The sliding wear test set-up

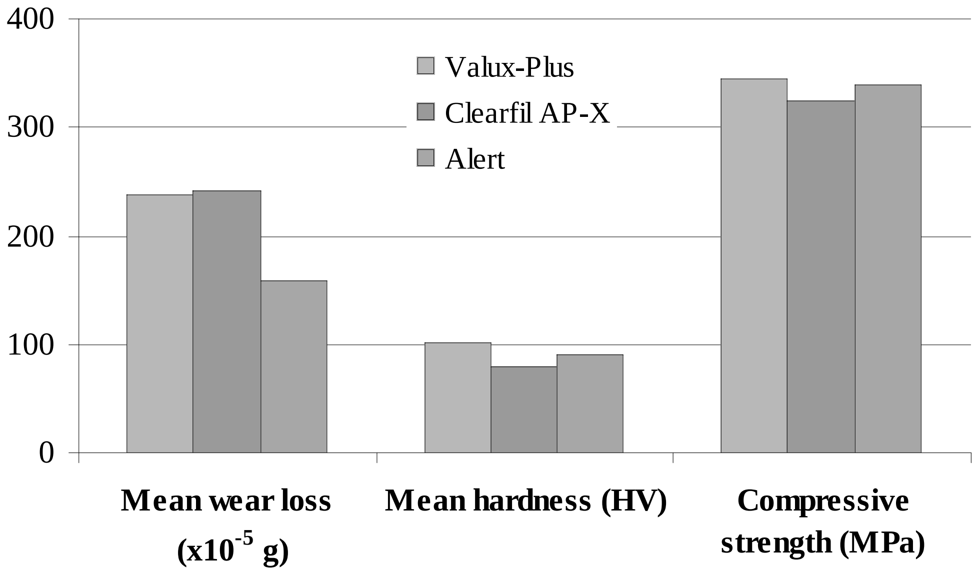

Fig. 3 Mechanical properties of the composite resins