In vitro wear of denture teeth acrylic resin milled glass fiber composite

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Summary

Statement of the problem. **The wear of denture teeth is very important when considering long term function.**
Purpose. **The purpose of this study was to evaluate the effect of milled glass fiber reinforcement in vitro wear of denture teeth acrylic resin. The effect of storage in open atmosphere on wear was also studied.**
Material and methods. **Denture teeth acrylic resin was reinforced with unsilanized and silanized milled glass fiber at four percentages (5, 10, 15, 20%) by weight as the test groups. Unreinforced acrylic resin was used as control group. The specimens were abraded on the two-body abrasion-testing device, which conforms to DIN 53516 standard.**
Results. **With the addition of glass fiber, the wear values of all test specimens decreased in comparison to the control group ($p < 0.01$) except for unsilanized milled glass fiber at 5% by weight ($p = 0.15$). Silanization significantly reduced wear relative to comparable unsilanized controls ($p < 0.01$). Both silanized ($p = 0.019$) and unsilanized ($p = 0.004$) test specimens showed statistically significant descending wear scores due to increasing glass fiber concentrations (5% to 10%). The storage of control and test groups did not affect wear ($p > 0.05$).**
Conclusions. **To improve the wear resistance of denture teeth polymethylmethacrylate resin, the optimum formulation is by incorporation of 10% by weight silanized milled glass fiber.**

Key words: wear, milled glass fiber, denture teeth, PMMA resin.

Introduction

The wear resistance of denture teeth acrylic resin can be significantly increased by the addition of silanized milled glass fiber at various concentrations, but after a certain concentration this result has no importance.

Acrylic resin denture teeth are widely used in removable dentures and have some advantages over porcelain teeth. Acrylic resin teeth have excellent fracture toughness, easy occlusal adjustment and high bond strength to denture base material, but their wear resistance has been questioned [1-3]. A major disadvantage of resin tooth is the rapid wear of posterior tooth surface [4]. The wear of denture teeth is crucial when considering long-term function and esthetics. Wear is a concern to both patient and the dentist because it will cause loss of vertical dimension, loss of masticatory efficiency, faulty teeth relationship and increased horizontal stress and their associated sequelae [5]. Denture teeth have been developed that claim improved wear resistance because of new material combinations, of which there are two types. The first type is of composite composition with inorganic filler particles whereas the second group consists of acrylic resin based teeth having polymer fillers to enhance the physical properties of the denture teeth. Improved wear resistance has been reported for both composite and acrylic resin tooth composition [6-9].

Glass fibers were shown to be the most

suitable for dental applications because of good cosmetic qualities and good bonding to the polymer matrix via silane coupling agents [10]. Glass fibers have been shown to improve the mechanical properties of acrylic resin denture base material especially the fatigue resistance and transverse strength [10-12]. It has been reported that the wear of polycarbonate with 10% glass fibers was less than the high resistant teeth, metallic alloys and porcelain and this was probably due to the glass fibers in its content [13].

Incorporation of small and heterogeneous shape of milled glass fiber could increase the wear resistance of acrylic resin teeth. The wear resistance of denture teeth polymethylmethacrylate (PMMA) resin reinforced with milled glass fibers has not been fully studied yet. The purpose of this study was to investigate the in vitro two-body wear of denture teeth acrylic resin reinforced with unsilanized and silanized milled glass fibers in four different concentrations by weight (wt). For a polymeric composite material, performance tests after aging are designed mainly in two different groups: the final performance of the sample after subjecting the material to specific conditions in which they are stored (shelf life) and to specific conditions which simulate the environment in which it actively works. The effect of 90 days storage at open atmosphere on wear was also studied in this study.

Material and Methods

Denture teeth acrylic resin (Rutinium Dental Manufacturing, Italy) was used in this study. The milled E glass fiber (1.2 µm in diameter, 0.8 mm in length and 2.7 g/cm3 in density) was supplied by Cam Elyaf A. S, Çayirova, Turkey. The silane coupling agent, A-174, 3-methacryloxypropyl trimethoxy silane (3-MPS) was supplied from Union Carbide, UK.

The nine groups (G) of specimens (totally 90 specimens) were divided as follows: 10 specimens of unfilled acrylic resin used as control group (G1) and the others test groups (G2-G9). Acrylic resin modified with 5, 10, 15, 20% by wt untreated milled glass fiber added to polymer were assigned to their respective groups (G2, G3, G4, G5) (n = 10). Acrylic resin modified with 5, 10, 15, 20% by wt silane-treated milled glass fiber added to polymer, were assigned to their respective groups (G6, G7, G8, G9) (n = 10).

The specimen dimensions were 16 mm in diameter and 7 mm in thickness. Acrylic resin polymer/monomer ratio was 20 gr/10 ml by wt for all the specimens. The percentages of milled glass fibers used were 5, 10, 15, 20% by wt. The denture teeth acrylic resin was polymerized at 175^{0}C under a pressure of 160 bar for 3 minutes (Elimko 2200 Hidrocontrol Machine, Iskitler, Ankara, Turkey) and then cooled with water under a pressure of 160 bar for 3 minutes. After demolding, the specimens were removed and finished to remove excess material by honing with fine emery paper. The exact final dimensions were ensured with a fine digital micrometer (Mitutoyo Digimatic Caliper 500154/CD 15 C, England).

The specimens were stored in distilled water bath (Elektromag-M96K Water Bath, Turkey) at 37 $\pm$ 1^{0}C for 7 days before wear testing. The testing apparatus was an abrading device (APGI 613. 10 Carl Shroder KG Material prüfmachinen 6940 Weinheim Serial Number 40176) and was in compliance with DIN 53516 standard [14]. The Al2O3 emery paper was used as the abrading material (600 grid, 3 M production resin paper 251 U-P 600) and replaced before abrading control and each test group. All wearing tests were performed in distilled water at room temperature (23 $\pm$ 1^{0}C). The difference in weight measurements (Mettler H 20, Switzerland, nearest 0.001 mg) between, before and after wear testing determined weight loss. Weight loss (mg) was evaluated as amount of wear. The specimens were stored at room temperature for 90 days in open atmosphere. Then, the specimens were again stored in distilled water at 37 ± 1^{0}C for 7 days before repeating wear test.

Results

Table 1 shows the means and standard deviations of the wear values and comparison of the mean wear of the control and test groups initially and after storage. Means were compared between control and test groups by Mann-Whitney U test. All the test groups but G5 ($p = 0.15$) displayed statistically significant lower wear compared with the control group ($p < 0.01$). Statistical comparison of the unsilanized and silanized test groups was performed by Wilcoxon test. The silanization procedure significantly reduced the wear compared to unsilanized test groups (z: 2.803, p: 0.005). The effect of the fiber quantity on the wear of the test specimens was compared by Kruskal Wallis One Way Anova test. Unsilanized (x^2: 13.141, p: 0.004) and silanized (x^2: 9.909, p: 0.019) test specimens showed statistically significant descending wear scores due to increasing glass fiber concentrations (5% to 10%) but no difference was found in the other glass fiber concentrations ($p > 0.05$). The statistical comparison of wear values of same test groups in the initial stage and after storage was performed by Wilcoxon test. After storage the wear values of the groups G2 (z: 2.599, p: 0.009), G8 (z: 2.395, p: 0.017), G9 (z: 1.988, p: 0.047) was significantly decreased. In the other groups no difference was observed ($p > 0.05$). All analyses were executed using Unistat Statistical Package (5.1.03 Version, 1984-2001 Unistat Ltd., 4 Shirland Mews, London W9 3DY, England).

Table 1. The means and standard deviations of the wear values and comparison of the mean wear of the control and test groups at initial stage and after storage

		Wear values	
		Initial **Mean ± SD**	**After storage** **Mean ± SD**
Control	G1	0.139 ± 0.021	0.139 ± 0.017
Unsilanized	G2	0.10 ± 0.043 p: 0.15 NS	0.086 ± 0.033 p: 0.002*
	G3	0.071 ± 0.023 p: 0.001*	0.067 ± 0.027 p: 0.001*
	G4	0.064 ± 0.020 p: 0.001*	0.067 ± 0.024 p: 0.001*
	G5	0.062 ± 0.028 p: 0.001*	0.070 ± 0.024 p: 0.001*
Silanized	G6	0.067 ± 0.025 p: 0.001*	0.065 ± 0.026 p: 0.001*
	G7	0.050 ± 0.016 p: 0.001*	0.049 ± 0.020 p: 0.001*
	G8	0.049 ± 0.016 p: 0.001*	0.046 ± 0.018 p: 0.001*
	G9	0.044 ± 0.014 p: 0.001*	0.041 ± 0.017 p: 0.001*

* Indicates significant difference between control and test groups at $p < 0.001$ level.
NS Indicates no significant difference between control and test groups at $p > 0.05$ level

Discussion

Assessment of the wear resistance has been conducted through in vivo and in vitro methods. In vivo studies [3,15] have offered only a ranked order of the materials evaluated and it is difficult to draw quantitative comparisons. Due to complexity of the wear mechanism, correlation of the in vivo and in vitro findings is often difficult [16]. In vitro tests are still necessary to test newly developed materials, as the clinical trials are expensive and time consuming. In vitro methods are classified as two-body test [17,18] or three-body test [19]. The phenomena of occlusal wear under clinical conditions are generally divided into two components: an abrasive material loss found in contact-free areas (CFA-wear three-body wear) and a second type at the path of articulation on the occlusal contact areas (OCA-wear, two-body wear) [20-21]. The object of this study is to evaluate the wear resistance of occlusal contact areas in removable prostheses; thus the two body wear testing has been used and the wear testing used in this study was developed to evaluate wear of modified denture teeth PMMA resin directly abraded against abrasive material.

Stipho [22] reported that when glass fiber in loose small cuts (2 mm in length) concentration of 1% was used a clear considerable transverse strength improvement of 14% was however found in comparison with the strength of the control samples (0% glass fiber group). Chen et al [23] reported that incorporation of glass fibers (2 mm in length) generally resulted in a decrease in hardness compared to the controls and suggested that the decreased surface hardness of the bulk reinforced acrylic resin may be caused by both the effects of the incorporated fibers and the reduced proportion of resin matrix. It has been reported that although the hardness of polycarbonate (10% wt glass fibers) was less than that of high strength teeth, polycarbonate was more wear resistant to high strength teeth and polycarbonate (10% wt glass fibers) had less worn volume than porcelain because it contained 10% wt glass fibers which are more abrasive against high strength teeth [14]. Therefore hardness may not be a reliable indicator against wear. In the present study, glass fibers were used in milled form and in random orientation to reinforce one type of denture teeth PMMA resin. The fibers were milled to produce short fibers of different lengths but with an average length of 0.8 mm. The rationale of mixing microfillers and macrofillers was shown by previous investigators to produce homogenous structures and improve the mechanical properties of composites, because the micro fillers prevented the settling of the macrofillers when mixing with monomer [24-25]. In this study, mixing different lengths of milled glass fibers may produce considerable improvement in the wear resistance of acrylic resin.

The increased content of filler in PMMA was previously shown to increase its transverse strength [12,26]. This study revealed increasing wear resistance with increasing filler ratios but above a filler ratio of 10%, this increase in wear resistance was not significant. It is clear that up to 10% addition of both unsilanized and silanized milled glass fibers to powder-liquid PMMA matrix leads to a significant increase in amount of wear of the resultant composites in all compositions, this increase becomes less pronounced. It is well known that the factors such as absolute hardness of the filler and the strength of the interfacial bond are predominant in the effects of fillers on abrasion or wear resistance [27]. If the filler is harder than the abrasive, both the degree of loading and the existence of filler-matrix adhesion are the determining factors. It may be noted from the table that rigid PMMA has inherently good abrasion resistance, which may be doubled by inclusion of low filler volumes of harder and tougher milled glass fibers. Also, silanization seems to be very effective in wear resistance of the composites by improving interfacial bonding. In our study a considerably less wear has been observed in the specimens with silanized glass fibers compared to the specimens with unsilanized glass fibers. In addition to this, the silanization of the fillers decreases the ratio of the filler to be added by increasing the wear resistance. Moreover, it has been observed that the silanized composites, which were aged for 90 days in dry form, exhibited an increase in final performances. This result may be attributed to the possible formation of extra interactions via free radicals which were possibly created by the PMMA chain scissions during the storage conditions which then resulted in some extra cross links between matrix and active double bond on the silane coupling agent [27]. It is obvious that the surface treatment not only contributes to the wear strength but also maintains the long-term durability.

The wear rates of denture teeth in removable dentures and implant prosthodontics are very important when considering long-term function and esthetics. The modification of acrylic resin with either silanized or unsilanized milled glass fibers or fillers has decreased the wear of artificial teeth to a great extent in this study, and seems to be an effective material for strengthening the denture teeth acrylic resin.

Conclussion

Within the limits of this study it can be concluded that the wear resistance of denture teeth can be considerably increased by the addition of milled glass fibers. The silanization has effectively increased the wear resistance of acrylic resin.

The results offer a quantitative increase with the incorporation of milled glass fiber at various concentrations into PMMA, but after a certain concentration this result has no importance.

After storage, the wear resistance of denture teeth acrylic resin either increased or remained unaltered.

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