Fabrication and mechanical properties of short sisal fiber reinforced composites used for dental application

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Abstract

This study investigated the influence of short sisal fiber on the flexural strength and modulus of auto-polymerized denture base resin. The effects of untreated (UT) and silane treated (ST) sisal fiber with the length of 2 mm at various concentrations, i.e. 2.5, 5.0, 7.5, 10.0 wt %, were compared. The results showed, wt 10% ST sisal fiber reinforced denture base resin had about the same flexural strength with that of denture base resin without fiber reinforcement, and sisal fiber concentrations lower than wt 10% caused reduction of the flexural strength of denture base resin. Flexural modulus increased with sisal fiber reinforcement, what's more, improvement of ST fiber was more obvious.

1 Introduction

At present, denture base resins are used in many types of dental prostheses, including complete or removable partial dentures, transitional prostheses, and implant-supported prostheses. It is superior to other materials in terms of aesthetics, easy manipulation, and inexpensive cost. The material most commonly used for fabricating removable partial or complete dentures is polymethyl methacrylate (PMMA). However, the relatively low mechanical properties of the material1,2, mainly of lower toughness could easily lead to some failures caused by occlusal disharmonies, overload, fatigue, handling, and accidents impacts 3 during its dental applications. Therefore, improvements in the mechanical performances of denture base structures have been sought by adding reinforcing compounds to the PMMA matrix, thus creating a reinforced denture base resins.

To improve toughness, impact resistance, and prevent crack propagation, Cross-linking agents such as glycol dimethacrylate and inclusions of rubber or fibers are added to modify mechanical properties4,5. With the increasing awareness of environment protection, natural fibers appear as low cost, low density and become distinctly environmentally superior alternatives to traditional synthetic fibers in making composites. Due to its high specific strength and modulus, natural fibers are promising reinforcements for fiber reinforced composite materials. Natural fiber reinforced polymers (NFRPs) have raised great attentions and interests among material scientists and engineers in recent decades. Therefore, This research was to develop the dental restorative material having both biocompatibility and environmental adaptability by using plant fiber as reinforcement.

we try to evaluate whether the natural fiber can improve the strength and modulus of denture base resins, and determine the effect of various concentrations of short sisal fiber on the flexural strength and modulus of auto-polymerized denture base resin.

2 Materials and Experimental

Sisal fibers were obtained from Guangxi Province, China. Aminopropyltriethoxysilane was used as coupling agent which was provided by Shanghai Yaohua Chemical Plant, China. Powder (Shanghai Zhangjiang Second Medical Biological Material Co. Ltd., China) and Monomer (Dental Base Resin, Type II, Dental Materials Factory of Shanghai Medical instruments Co. Ltd., China) were mixed as the resin material for making the composites.

According to the test standard ASTM 790-109, a three-point bending test was performed by using a universal testing machine （Changchun, China）with a span distance of 48 mm and at a crosshead speed of 1.28 mm/min. The dimensions of the specimens were 60×13×3 mm^3. Nine test groups (5 specimens for each group) were prepared, i.e. resin without fiber reinforcement, namely control group and resin with untreated or silane treated fiber reinforcement at concentrations of 2.5, 5.0, 7.5, 10.0 wt%, respectively.

3 Results and Discussion

3.1 Fabrication of composites

Untreated long sisal fibers were randomly divided into two groups. One group was cut with scissor to the length of 2 mm, which is shown in figure 1. Then the cut fibers were put into an oven at 115°C for 2 hours, which drove out the water and stored within the plant fibers to improve their mechanical properties6. The other group of untreated long sisal fibers were silanized with γ-Aminopropyltriethoxysilane by being impregnated into the solution, which contained the liquid of silane at a mass ratio of 5%7,8. After 24 hours the impregnated long sisal fiber were taken out from the silane solution and washed with pure acetone to remove the residual silane solution on the surface of sisal fibers. Then the long sisal fibers were placed into the oven at 80°C for 2 hours, by which the acetone volatilized. After being dried the group of silane treated long sisal fibers was also cut with scissor to the length of 2 mm, like the first group.

Fig. 1 Short sisal fiber

Fig. 2 Sisal fiber impregnated in the monomer liquid

Powder and Monomer were weighted respectively at a P/L ratio of 10g / 8ml, which required a little more monomer than it usually needed in the conventional fabrication at the P/L ratio of about 10g / 6.6ml, to ensure a good liquidity of the mixture, considering the addition of fibers.

Each group of weighted sisal fibers was pre-impregnated in the monomer liquid for 10 minutes to improve the interfacial bonding between fiber and resin10-12, as shown in figure 2. Then the weighted powders were mixed into the monomer liquid and stirred till no bubbles appeared. The resin-sisal fiber mixture was poured into a stainless steel mould, which was pre-smeared with acetone to clean out the impurities and then smeared with parting agent. Besides, two pieces of narrow rectangular bars with the thickness of 3 mm were placed into the mould to ensure the accuracy of the depth of the specimens. When the mixture became dough, the steel mould was covered and placed into a hot-press machine under the pressure of 2 MPa13 at room temperature 23°C, for 30 minutes. Finally, after being taken out from the steel mould the plate was cut and polished to the dimension of 60×13×3 mm, with #1200 SiC paper.

3 Results and Discussion

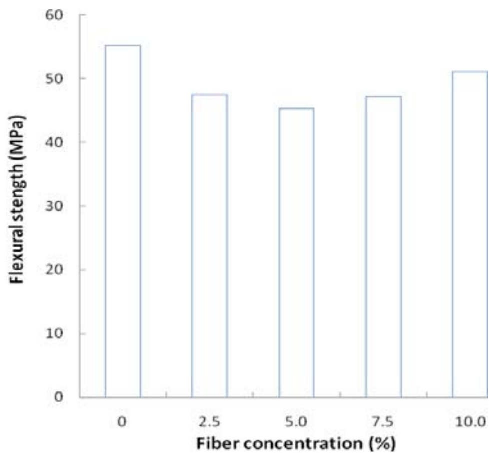


Fig. 3 Flexural strength of denture base resin reinforced with various fiber concentrations

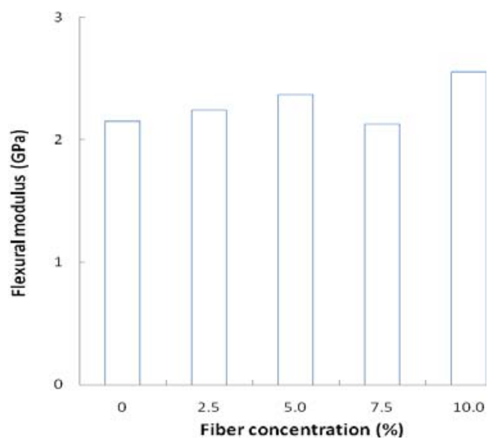


Fig. 4 Flexural modulus of denture base resin reinforced with various fiber concentrations

The flexural strength and modulus of PMMA-resin reinforced with various fiber concentrations are shown in Figure 3 and 4, respectively.

The results showed that 2 mm sisal fiber (less than 10 wt%) reduced the flexural strength but increased the flexural modulus of PMMA-resin. The influences in both situations were not significantly

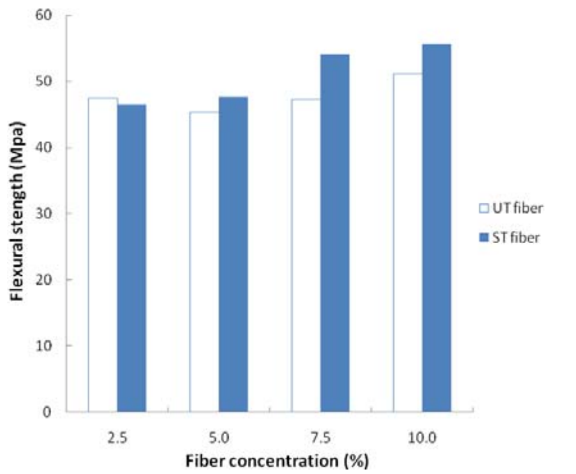


Fig. 5 Comparison of flexural strength of PMMA-resin with UT and ST sisal fiber reinforcement

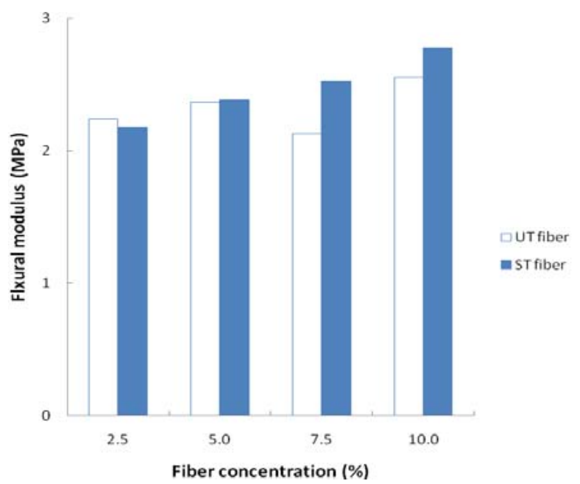


Fig. 6 Comparison of flexural modulus of denture base resin with UT and ST sisal fiber reinforcement

Figure 5 and 6 showed the comparative flexural strength and modulus of untreated (UT) and silane treated (ST) sisal fiber reinforced PMMA-resin.

At the fiber concentration of 2.5 wt%, both the flexural strength and modulus of ST group were a little lower that those of UT group, but with the fiber concentrations increasing, the two properties of ST group exceeded those of UT group and became higher, specially at the fiber concentrations of 7.5% and 10%.

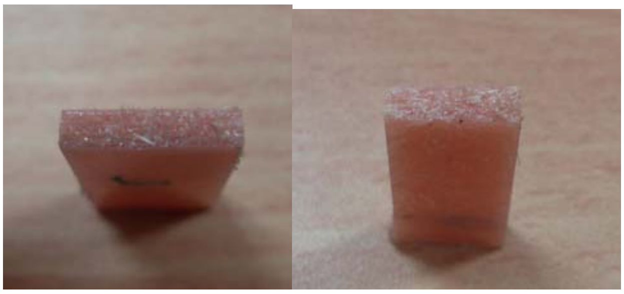
Besides, within the ST group the flexural strength and modulus increased obviously, with the fiber concentrations increasing.

PMMA resin is the material of choice for the fabrication of denture bases. However, fracture of the base may occur because of the low flexural strength and modulus of PMMA. One of the most common causes for crack of dentures is fatigue . This fracture stems from the initiation and propagation of a crack, and it requires the presence of a stress raiser or localized stress.

This study compared the flexural strength and modulus of short sisal fiber reinforced denture base resin with various concentrations. In the concentrations tested we found the flexural strength of short sisal fiber reinforced denture base resin was reduced when the fiber concentration was raised from 0wt% to 5wt%,whereas from 5wt% to 10wt%, it was enhanced. The results also demonstrated that when the concentration of fibers was increased, the modulus increased approximately 35%.

For the short sisal fiber, the fibers are oriented randomly in the matrix, which has a continuous phase. The quantity of sisal fiber in the denture base is relative to concentrations fluidity. If the fibers were greater than 10 wt% in concentration, manipulation became difficult. In this study, we suggested that10 wt% was a suitable short sisal fiber concentration.

The flexural strength and modulus of sisal fiber reinforced denture base is relative to silane treatment. The flexural strength and modulus with standard deviations are shown in Figure 3 and 4, respectively. And the results showed that fiber concentration and silane treatment have a significant effect on the flexural strength and modulus. It is necessary to provide good adhesion between the fiber and the polymer matrix for the reinforcement of resins with fiber. Fibers without silane added to the resin act a as foreign body. Fibers without silane may spoil the homogenous structure of the matrix. Silane agents chemically combining sisal fibers to resin matrix may alter the mixture to a more homogenous state and may exceeded the normal strength values of denture base.



(a) **(b)**

Fig. 6 Fracture modes of (a) untreated and (b) silane treated composites.

4 Conclusion

Within the limitations of this in vitro study, 2-mm wt 10% ST sisal fiber reinforced denture base resin had about the same flexural strength with that of denture base resin without fiber reinforcement, and sisal fiber concentrations lower than wt 10% caused reduction of the flexural strength of denture base resin. Flexural modulus increased with sisal fiber reinforcement, what’s more, improvement of ST fiber was more obvious.

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