An Alternative Method for Incorporating Fiber Meshes in Complete Upper Dentures

Anthony Prombonas, Efthymia Sklavou, Alexandra Ioannidou, Eleni Kosma, Katerina Orfanou

Division of Dental Technology, Department of Biomedical Sciences, School of Health and Care Sciences, University of West Attica, Athens, Greece

Correspondence to: Anthony Prombonas, aprob@uniwa.gr; Efthymia Sklavou, esklavou@uniwa.gr; Alexandra Ioannidou, aioannidou@uniwa.gr; Eleni Kosma, ekosma@uniwa.gr; Katerina Orfanou, korfanou@uniwa.gr
Keywords: Complete Upper Dentures, Fibers Reinforcement, Fiber Mesh
Received: January 19, 2023 **Accepted:** March 11, 2023 **Published:** March 14, 2023

ABSTRACT

The most commonly used material for constructing complete dentures is polymethyl methacrylate (PMMA). However, the strength characteristics of PMMA, such as impact strength and fatigue strength, are poor, and fracturing of PMMA dentures is a common problem in prosthodontic practice. Reinforcing PMMA with various materials, such as carbon fibers, glass fibers (fiberglass), and ultrahigh modulus polyethylene fibers, has been suggested to strengthen the denture-base material. A common problem encountered when packing the resin on these specimens is fiber slippage beyond the denture edges. The present study proposes an alternative method of incorporating fiber meshes into complete dentures, whereby a thin filament of self-polymerizing resin at the perimeter of the fiber mesh is produced, giving a clear and stable shape to the mesh that fits the upper jaw cast. During placement of the shaped mesh on the cast, a positive-negative relationship is created between the mesh and cast, which immobilizes the mesh during the incorporation process.

1. INTRODUCTION

Good complete dentures are essential to improve the quality of life of completely edentulous patients. The most commonly used material for the construction of complete dentures is polymethyl methacrylate (PMMA) [1-3]. PMMA is commonly used as a denture-base material because it is economical, stable in the oral environment, and easily constructed and repaired without a special primer. However, its strength characteristics, such as impact strength and fatigue strength, are poor, and fracturing of PMMA dentures is a common problem in prosthodontic practice [1].

Fractures in dentures are due to flexural fatigue, which occurs after repeated flexing of the denture base. This type of failure can be explained by the development of microscope cracks in areas of stress concentration [2].

It has been established that maxillary dentures are subject to bending deformation with tensile stresses occurring at the labial aspect and lingually to the incisors on the polished surfaces. The area lingual to the incisors is the most heavily stressed, and the incisal notch represents a weak point in that it might act as a stress raiser and contribute to midline fracturing of maxillary dentures. Although denture bases deform under loading, this deformation may be exacerbated by other factors, such as variations in denture-base contours, changes in supporting tissues and tooth wear [3].

The chemical modification of a denture-base material by, say, copolymerization with a rubber graft copolymer or adding cross-linking agents and the reinforcement of PMMA with other materials such as carbon fibers, glass fibers (fiberglass), and ultrahigh modulus polyethylene fibers have been suggested to strengthen the denture-base material [1, 2].

Among the methods of estimating the reinforcement of complete dentures, some use geometric-rectangular test specimens, whereas others use complete denture specimens [1, 2, 4-9]. Common methods to incorporate fibers into the dentures include the spacer method, the sandwich method, and the stoppers method. A common problem encountered when packing the resin onto these specimens is fiber slippage into a position beyond the denture edges.

The purpose of the present study is to introduce a simple and quick alternative method for incorporating fiber meshes into complete upper dentures (CUD) without the side effect of mesh slippage.

2. SPECIMEN TYPES

Most studies regarding the effect of fiber reinforcement have been conducted with rectangular-shaped specimens made of denture-base resin [1, 4-6].

Given that complete dentures are complicated three-dimensional structures composed of artificial teeth and a denture base, the results with rectangular specimens cannot represent those of dentures because they do not simulate the clinical situation [6, 7].

Some studies have used clinical-shaped specimens and fabricated denture bases to measure the fracture resistance, which better mimics the true clinical situation [2, 5].

Some studies have fabricated denture bases to measure fracture resistance, most of which applied the load directly onto the intaglio surface of the palatal area of the maxillary denture. They measured the fracture strength of the denture acrylic base without artificial teeth. The load was applied on the tissue surface of the denture-base midline in the area that corresponds to the premolar and first molar region. However, this method has several weaknesses because these data may be significantly different from those of intraorally functioning dentures [8, 9].

Recently, a new biomechanical approach was applied to measure the fracture strength of the CUD. This method was based on a hybrid cast, constituting of acrylic in the region along the midline and silicone in the remaining areas, which was the upper loading element of the specimens. This loading element was screwed onto the upper part of the universal testing machine. Each CUD specimen was placed on a hybrid cast (being screwed onto the upper part of the machine) in centric occlusion with an acrylic resin mandibular cast, which acted as the lower loading element of the experiment. Each denture specimen loaded between these two loading elements was subjected to a pure bend, as the midline of the hybrid cast was rigid while its right and left areas were resilient [8].

These methods (*i.e.*, loading a base plate onto the palatal surface or loading complete dentures) simulate the clinical situation, and thus the obtained values may be more relevant clinically compared to the results of rectangular specimens [1, 2, 5, 8, 9]. In addition, a load should be applied to the posterior teeth of a denture, not the palatal area, to ensure the experimental conditions for the denture are approximal to those found in the mouth [4].

3. INCORPORATION METHODS

Several methods have reported on incorporating fiber meshes in complete denture specimens [1-16].

In some of these, the methodology used for incorporating fibers or strengtheners is not outlined in detail [2, 5, 10, 11].

3.1. Spacer Method

The first method is based on the construction of a spacer. The soft spacer (shaped to the pattern of the required reinforcement) is constructed on the master cast using a special pressure-forming machine. After the usual flasking procedures and removal of the wax base pattern, the spacer is placed in the upper half of the mold. The fitting surface (cast) is coated with sodium alginate and packed with acrylic resin, followed by a trial closure with a polyethylene separating sheet to allow for the removal of any excess material. The flask was then kept under pressure for about 60 minutes with the spacer and polyethylene separating sheet still in place. On removing the spacer, a recess should be clearly visible on the surface of the acrylic resin, ready to receive the fiber insert. This must be cut to the required shape using a pair of scissors designed for high-performance fibers [3, 12-14].

3.2. Sandwich Method

According to the sandwich method (second method), after the usual flasking and elimination of the wax base pattern, acrylic dough is prepared according to the manufacturer's recommendations and divided into two parts. Then, an equal amount of the heat cure material mix from the dough stage is placed in both flask halves with a cellophane sheet and trial closure was done. The cellophane sheet divides the mass of acrylic resin into two halves of approximately equal thickness. After trial closure, the cellophane is removed. One layer of woven mat is then cut with specially designed scissors in the same size and shape of the palate, including the ridges of the residual crests of the cast and the properly shaped fiber mesh is placed between the two flask halves, covering the entire palatal surface up to the crest of the ridge. Flasks are pressed under the hydraulic press, bench cured, and processed in an acrylizer. Dentures are then polished according to standard procedures [15].

3.3. Stoppers Method

Wax is used to cover all the denture-bearing areas on the master cast. The wax is then removed for tissue stops in the canine, mid palatal raphe, and molar regions in 4 × 2 mm dimensions and self-cure denture-base resin is then added in the regions where wax was removed. A special pre-impregnated glass-fiber mesh is added to the wax covering the entire denture-base area, which is then placed in vacuum film. The fiber mesh is then adapted to the wax using the vacuum absorber over the master cast and is placed in the light polymerizing unit along with the film and the cast; then, it is cured for three minutes. The mesh can now be used in to create dentures. After dewaxing, the flasks are allowed to cool. Separating media is then applied, and the light cured mesh is placed over the master cast. Dentures are then acrylized following the short curing cycle. The processed dentures are finished and polished [7, 16].

4. FIBER SLIPPAGE

In many studies on incorporating fibers into dentures, a common problem is the fibers slipping outside the denture base when placing the acrylic resin, frequently leading to an uneven distribution and fiber bunching in the resin matrix [17].

Many researchers admit that, after deflasking, fibers may occasionally be exposed at the peripheral border, in which case trimming should be carried out with diamond burs to avoid delamination of the reinforcement. Lateral spreading of the fibers when packing the acrylic resin results in a rough denture surface with extruded fibers that may cause mucosal irritation and discomfort to the patient [12].

According to many previous studies, it is difficult to increase the concentration of fibers in a polymer matrix to the level where adequate strengthening effect is achieved. The main problem contributing to this is the lateral spreading of fibers when the acrylic resin dough is pressed into the mold, which diminishes the concentration of fibers in the polymer matrix and causes an inhomogeneous fiber distribution in the matrix [14, 17-20].

5. THE PROPOSED METHOD

The proposed method of incorporating fibers into the upper complete denture is described in detail below.

5.1. Preparing the Flask

1) The complete denture is flasked and dewaxed according to known methods.

2) On the upper half of the flask (the half that carries the artificial teeth), medicated cotton is packed up to the neck of the teeth, and, on the lower half (and on the cast), a sheet of wax (1 mm thick) is applied. The labial and buccal vestibula (alveo-labial and alveo-buccal sulcus) are filled with the same wax (**Figure 1**).

3) The surface of the wax is coated with petroleum jelly; a mass of silicone impression putty is prepared and hand pressed into the mold of the upper flask half onto the cotton. The flask is closed and pressed in a hydraulic press under a pressure of 30 - 40 bars.

4) After the polymerization of silicone, the flask is opened and the excess silicone material removed (**Figure 2**).

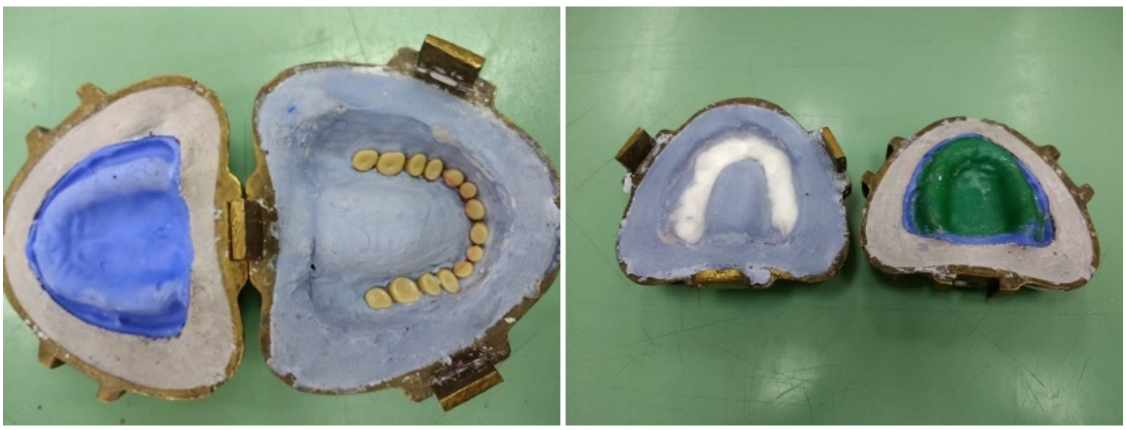

Figure 1. **Preparation of the upper half of the mold with medicated cotton.**

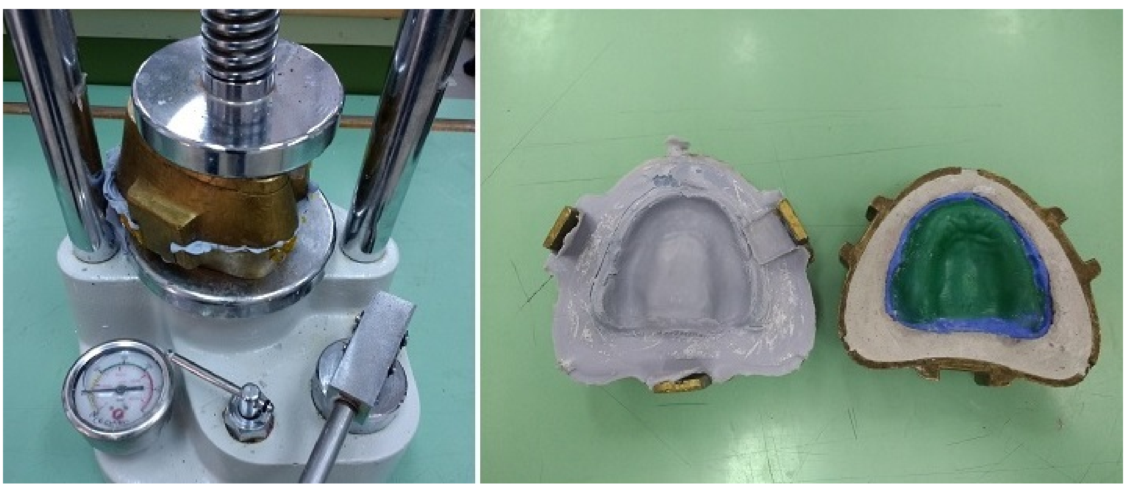

Figure 2. **Modification of the upper half of the mold with silicone impression putty.**

5.2. Shaping the Fiber Mesh

5) On the lower half of the flask and on top of the wax sheet, a piece of cellophane sheet is laid after wetting with water and draining.

6) Small amounts of self-polymerizing resin are kept in the fridge for 15 minutes to reduce their temperature and delay the polymerization. Using these materials, a fluid mass of self-polymerizing resin is prepared.

7) Some fluid resin is placed on to the cellophane using a metallic spatula, along the labial and buccal vestibula as well as the palatal border.

8) A piece of mesh is cut to the shape of the tissue surface of the cast, and, after wetting its perimeter with monomer, it is placed on the cellophane of the lower half of the flask. The flask is closed by applying a pressure of 40 bars (**Figure 3**).

9) After the polymerization of the self-polymerizing resin, the flask is opened and the mesh removed. The mesh has now taken the shape of the cast, which remains stable due to the hard resin around its inner perimeter (**Figure 4**).

10) With the help of a thin metal disk for forming interdental spaces of acrylic bridges, the excess mesh is cut off at a distance of 2 mm from the bottom of the labial and buccal vestibula (**Figure 5**).

11) After cutting off the excess, the mesh is repositioned on the wax of the lower half of the flask, fluid self-curing resin is applied along the outer perimeter of the mesh (with the same methodology as before), and the flask is closed and compressed with the press at the same pressure above. In this way, a hard self-polymerizing resin is placed around the perimeter of the mesh, both internally and externally. The new excess resin is cut off with the help of the same metal disc as before (**Figure 6**).

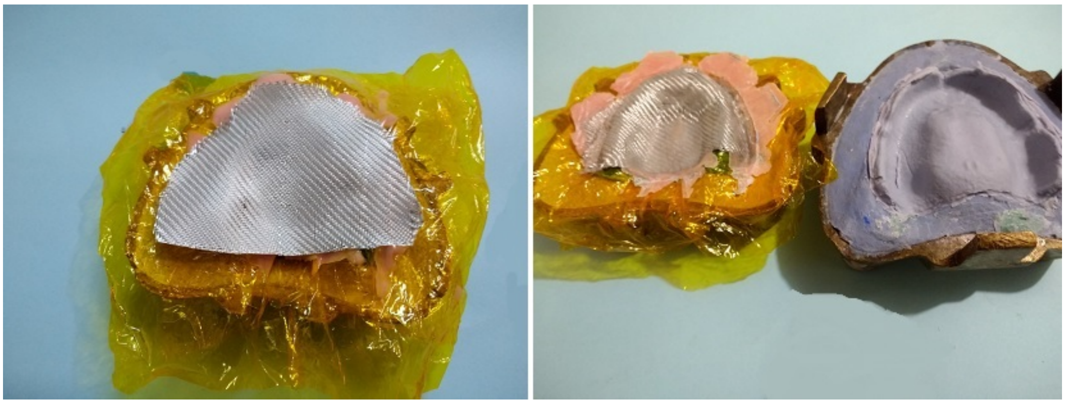

Figure 3. Contouring of the fiber mesh with self-polymerizing resin under pressure in the modified mold.

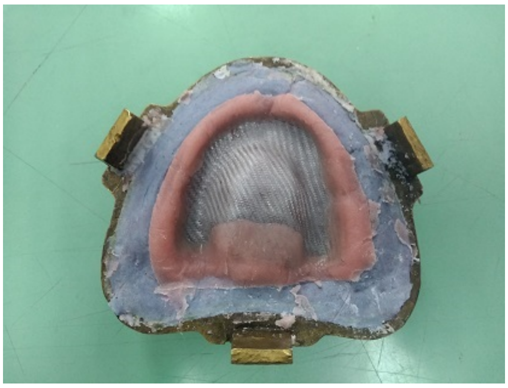

Figure 4. The molded acrylic border on the mesh perimeter.

Figure 5. **The cutting of the excess mesh using a thin metal disk.**

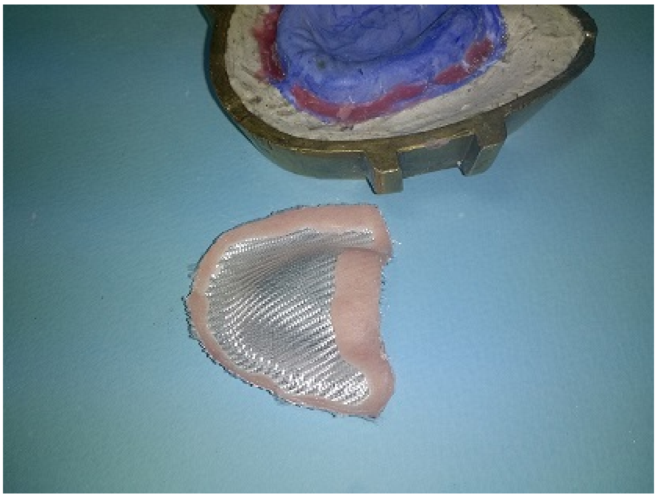

Figure 6. **The addition of self-polymerizing resin along the outer perimeter of the mesh.**

5.3. Incorporating the Mesh into the Denture

12) The flask is opened and the thick silicone layer and cotton are removed from the upper half of the mold, leaving the wax sheet on the lower half.

13) Acrylic resin dough is prepared (heat-cured resin) in accordance with the manufacturer directions. A new sheet of cellophane is laid on top of the wax of the lower flask half, and the shaped mesh, after wetting with a dilute monomer–polymer solution, is placed on the cellophane to fully adjust on cast. Subsequently, the resin dough is hand pressed onto the upper half of the mold in the teeth area; the flask is closed and compressed in the press at a pressure of 100 bars.

14) The flask is opened and excess acrylic removed. The mesh has now been incorporated into the acrylic resin of the upper half of the mold 1 mm from the cast surface (**Figure 7**).

15) The wax sheet (spacer) is removed from the cast, the mesh is wetted with a monomer–polymer solution, a thin layer of heat-cured resin is placed on the mesh being incorporated into the resin, a new sheet of wetted cellophane is placed on the resin, and the flask is closed and compressed under the same pressure as above.

16) The flask is opened, the excess acrylic is removed, the tissue surface of the cast is painted with a tinfoil substitute, and the flask is closed and compressed under the same pressure as above (**Figure 8**).

Figure 7. **The incorporation of the mesh into the acrylic resin of the upper half.**

Figure 8. **The flask and the complete denture before the final closure.**

17) The flask is transferred to a spring clamp and both are placed in a curing unit.
18) The final denture processing is done as usual.

6. DISCUSSION

As mentioned previously, the main problem in incorporating fiber mesh into the upper complete denture is fiber slippage. This side effect often occurs in the denture-base specimens rather than the rectangular ones. The shapes shown in **Figure 9** and **Figure 10** illustrates why this occurs.

In the case of the rectangular specimen, the forces acting on the fiber mesh when pressing the resin dough act perpendicular to the surface of the mesh. These forces nail-stabilize the mesh on the surface of the resin (**Figure 9**).

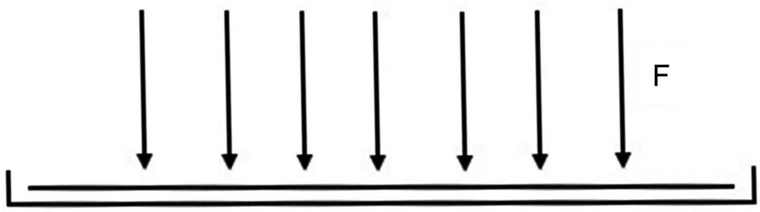

Figure 9. Forces acting on the mesh in a rectangular specimen.

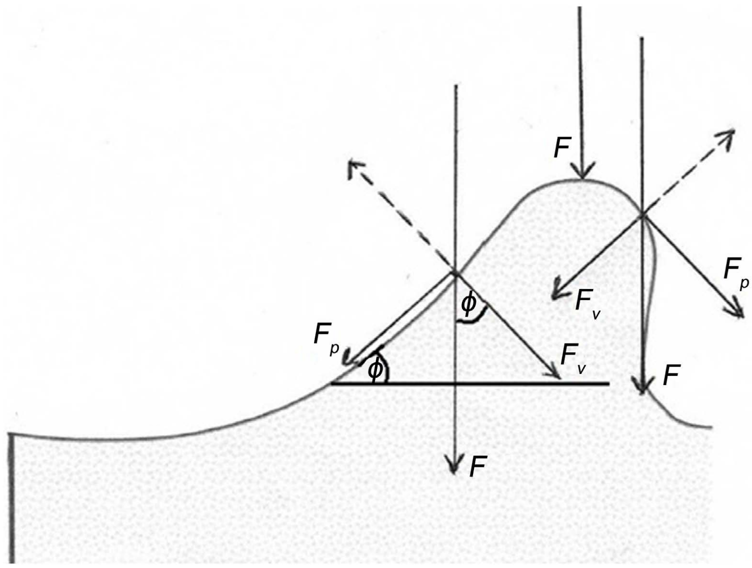

Figure 10. Analysis of forces acting on a mesh in a complete denture specimen.

In the case of complete denture specimens, the vertical force F (compressive force) acting on the lateral surfaces (inclined planes) of the residual ridges (labial and buccal) is broken down into two components. The F_v is vertical to the surface of the ridge, whereas the other component F_p is parallel to the ridge surface. If angle ϕ is assumed to be the slope of the plane, then the parallel component is equal to the product of the sine of the angle ϕ to the vertical component (**Figure 10**).

The following equation holds:

$$F_p = \sin(\phi) \times F$$

The vertical components (F_v) are neutralized by the surface resistance of the cast (action equals reaction). It is obvious that all parallel components of the left side give a resultant parallel force, while, in the same way, a total parallel force is created on the right (lip) side of the ridge. In practice, the resultant parallel force of one side is never equal to the resultant parallel force of the other side. For this reason, the parallel resultant force causes of mesh slippage when pressing the resin dough. As a result, the mesh slips toward the side with the largest resultant parallel force. The greater the slope of the ridge surface, the greater the parallel component and the greater the possibility of the slippage phenomenon occurring. At the top of the ridge where angle ϕ equals zero, sin (ϕ) equals zero and the parallel component vanishes.

The proposed method shapes the fiber mesh into the shape of the upper edentulous jaw, creating a hard perimeter on the mesh. The resulting benefits are as follows:

1) The shape of the mesh remains stable when packing the acrylic dough.

2) A relation of positive to negative (male to female) is created between the cast and the fiber mesh. This relation ensures the mesh is incorporated precisely and securely into the denture base and avoids the slippage phenomenon.

By comparing the proposed method with existing ones, it is evident that the former creates meshes with a stable immobilizing shape, leading to precise incorporation. Meshes with a stable shape could be produced by the method of stoppers applied either in the case of stoppers method or the case of the metallic mesh [7, 16]. The difference is that, in the stoppers method, extra equipment is necessary. In particular, additional materials and devices are needed such as a special vacuum device, air compressor, photopolymerization device and pre-impregnated fibers or liquid photopolymerizable resin. In the present method, none of the above is needed except a small amount of silicone impression putty and a small amount of self-polymerizing resin with infinitesimal cost. In addition, the present method uses dry fibers which are wetted during the incorporation process. This increases the range of type of fibers that can be used, since only glass and polyethylene fibers are commercially available pre-impregnated. The methods of spacer and sandwich do not ensure the stabilization and immobilization of the meshes, as they do not have the fixed shape of the cast as they remain soft and flexible, and, they are therefore prone to the action of sliding forces [5, 7, 12-15].

A possible side effect of the present method may be the incomplete impregnation of dry fibers, which are not commercially available as pre-impregnated fibers.

7. CONCLUSIONS

1) With the proposed method, the fiber mesh acquires the clear shape of the upper jaw cast due to a thin filament of self-polymerizing resin at the perimeter.

2) When placing the shaped mesh on the cast, a positive-negative relationship is created between them (mesh and cast), ensuring that the precise and secure mesh incorporation has taken place.

3) The proposed method is fast and economical and does not need extra equipment.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

REFERENCES

1. Prasad, H., Kalavathy, M. and Mohammed, S. (2011) Effect of Glass Fiber and Silane Treated Glass Fiber Reinforcement on Impact Strength of Maxillary Complete Denture. *Annals and Essences of Dentistry*, **4**, 7-12. https://doi.org/10.5368/aedj.2011.3.4.1.2

2. Hirajima, Y., Takahashi, H. and MinakuchI, S. (2009) Influence of a Denture Strengthener on the Deformation of a Maxillary Complete Denture. *Dental Materials Journal*, **28**, 507-512. https://doi.org/10.4012/dmj.28.507

3. Karacaer, O., Dogan, O.M., Tincer, T. and Dogan, A. (2001) Reinforcement of Maxillary Dentures with Silane-Treated Ultra High Modulus Polyethylene Fibers. *Journal of Oral Science*, **43**, 103-107. https://doi.org/10.2334/josnusd.43.103

4. Yu, S.H., Oh, S., Cho, H.W. and Bae, J.M. (2017) Reinforcing Effect of Glass-Fiber Mesh on Complete Dentures in a Test Model with a Simulated Oral Mucosa. *Journal of Prosthetic Dentistry*, **118**, 650-657. https://doi.org/10.1016/j.prosdent.2017.03.018

5. Kim, S.H. and Watts, D.C. (2004) The Effect of Reinforcement with Woven E-Glass Fibers on the Impact Strength of Complete Dentures Fabricated with High-Impact Acrylic Resin. *The Journal of Prosthetic Dentistry*, **91**, 274-280. https://doi.org/10.1016/j.prosdent.2003.12.023

6. Yu, S.H., Cho, H.W., Oh, S. and Bae, J.M. (2015) Effects of Glass Fiber Mesh with Different Fiber Content and Structures on the Compressive Properties of Complete Dentures. *The Journal of Prosthetic Dentistry*, **113**, 636-644. https://doi.org/10.1016/j.prosdent.2014.10.013

7. Komala, J., Kumar, S., Bheri, S. and Deepyi, G.S.G.M. (2018) To Evaluate the Fracture Resistance of Maxillary Complete Dentures Reinforced with Full and Partial Glass Fibre Mesh: An *in Vitro* Study. *International Journal*

of Medical and Health Research, **4**, 181-187. https://doi.org/10.22271/ijmhr.2018.v4.i8.36

8. Prombonas, A.E., Poulis, N.A. and Yiannikakis, S.A. (2019) The Impact of Notches on the Fracture Strength of Complete Upper Dentures: A Novel Biomechanical Approach. *ESJ*: *European Scientific Journal*, **15**, 433-448. . https://doi.org/10.19044/esj.2019.v15n24p433genju
9. Polyzois, G.L., Andreopoulos, A.G. and Lagouvardos, P.E. (1996) Acrylic Resin Denture Repair with Adhesive Resin and Metal Wires: Effects on Strength Parameters. *The Journal of Prosthetic Dentistry*, **75**, 381-387. https://doi.org/10.1016/S0022-3913(96)90029-3
10. Duymus, Z.Y., Akyils, S. and Denizoglu, S. (2006) An Investigation of Fracture Loads of Acrylic Base Plates Reinforced, Non-Reinforced and Prepared in Different Palatal Shapes. *Atatürk Üniversitesi*, *Dis Hekimligi Fakültesi*, *Protetik Dis Tedavisi Anabilim Dals*, *ÖJretim Üyesi*, **16**, 18-24.
11. Andrei, O.C., Margarit, B., Bisoc, A., Bunget, A.M., Farcasiu, C., Dina, M.N. and Tanasescu, L.A. (2019) Comparison of Classic and Metal Reinforced Maxillary Acrylic Complete Dentures Fracture Resistance. *Materiale Plastice*, **56**, 923-930. https://doi.org/10.37358/MP.19.4.5285
12. Clarke, D.A., Ladizesky, N.H. and Chow, T.W. (1992) Acrylic Resins Reinforced with Highly Drawn Linear Polyethylene Woven Fibres. 1. Construction of Upper Denture Bases. *Australian Dental Journal*, **37**, 394-399. https://doi.org/10.1111/j.1834-7819.1992.tb00766.x
13. Kattimani, P.T., Shah, T., Pareek, V., Parmar, P.M., Nigam, H. and Shah, P. (2019) A Comparative Study of Palatal Shapes and Flexural Properties of Edentulous Maxillary Conventional Heat Polymerised Acrylic Resin Denture Bases with Glass Fibre/Metal Mesh Reinforced Bases. *Journal of Dental and Medical Sciences*, **18**, 51-70.
14. Vallittu, P.K., Lassila, V.P. and Lappalainen, R. (1994) Transverse Strength and Fatigue of Denture Acrylic-Glass Fiber Composite. *Dental Materials*, **10**, 116-121. https://doi.org/10.1016/0109-5641(94)90051-5
15. Murthy, H.B.M., Shaik, S.S.H., Khare, S., Haralur, S.B. and Roopa, K.T. (2015) Effect of Reinforcement Using Stainless Steel Mesh, Glass Fibers, and Polyethylene on the Impact Strength of Heat Cure Denture Base Resin-An *in Vitro* Study. *Journal of International Oral Health*, **7**, 71-79.
16. Im, S.M., Huh, Y.H., Cho, L.R. and Park, C.J. (2017) Comparison of the Fracture Resistances of Glass Fiber Mesh- and Metal Mesh-Reinforced Maxillary Complete Denture under Dynamic Fatigue Loading. *The Journal of Advanced Prosthodontics*, **9**, 22-30. https://doi.org/10.4047/jap.2017.9.1.22
17. Nair, V.V., Kumar, P.C., Ram Mohan, K.N., Nair, K.N.V., Nair, K.C. and Harshakumar, K. (2013) A Comparative Study of Different Laboratory Techniques to Control Posterior Palatal Shrinkage in Maxillary Complete Dentures. *Health Sciences*, **2**, 1-14.
18. Uzun, G., Hersek, N., and Tinçer, T. (1999) Effect of Five Woven Fiber Reinforcements on the Impact and Transverse Strength of a Denture Base Resin. *The Journal of Prosthetic Dentistry*, **81**, 616-20. https://doi.org/10.1016/S0022-3913(99)70218-0
19. Yazdanie, N. and Mahood, M. (1985) Carbon Fiber Acrylic Resin Composite: An Investigation of Transverse Strength. *The Journal of Prosthetic Dentistry*, **54**, 543-547. https://doi.org/10.1016/0022-3913(85)90431-7
20. Vallittu, P.K., Lassila, V.P. and Lappalainen, R. (1994) Acrylic Resin-Fiber Composite—Part I: The Effect of Fiber Concentration on Fracture Resistance. *Journal of Prosthetic Dentistry*, **71**, 607-612. https://doi.org/10.1016/0022-3913(94)90446-4