Clinical Survey of Acrylic Resin Removable Denture Repairs with Glass-Fiber Reinforcement

Katja K. Narva, DDS[a]
Pekka K. Vallittu, DDS, PhD, CDT[b]
Hans Helenius, MSc[c]
Antti Yli-Urpo, DDS, PhD[d]

Purpose: The aim of this study was to evaluate clinical usefulness and durability of continuous glass-fiber reinforcement in repair of acrylic resin removable dentures. **Materials and Methods:** Fractured removable dentures without reinforcement, with conventional metal-wire reinforcement, or with mesh reinforcement were collected from two dental schools in Finland. The total number of dentures was 51 and the number of patients was 48. During the repair, the dentures were reinforced with a polymer-preimpregnated E-glass fiber at the region of the fracture. The fibers were used as partial fiber reinforcement, ie, only the weakest part of the denture was reinforced. Follow-up time varied from 4 months to 4.1 years. After the follow-up period, possible fractures and discoloring were visually inspected. Possible irritation of oral mucosa by glass fibers and the general shape of the denture were also evaluated. **Results:** In 88 % of the cases, there was no need for adjustment at the region of partial fiber reinforcement, and the clinical condition of the dentures was good. Glass fibers did not irritate the oral mucosa. In the case of refracture or hairline fracture, positioning of the partial fiber reinforcement was incorrect or the reinforcement had been used incorrectly (the wetting of the reinforcement with denture base resin was inadequate). **Conclusion:** Polymer-preimpregnated partial fiber reinforcement seems to be useful in eliminating fractures of acrylic resin removable dentures. However, this study emphasizes the importance of correct positioning and accurate laboratory technique when partial fiber reinforcement is used. *Int J Prosthodont 2001;14:219–224.*

Damage in the acrylic resin denture base of removable dentures is one of the most common (64%) causes of repair of dentures.[1–5] Theoretically, an edentulous patient could not fracture a complete denture because of relatively high static strength of denture construction and because of low occlusal biting force with removable dentures.[6,7] Smith[8] described flexural fatigue phenomena as a cause of denture fracture. A study[9] of fracture surface characteristics in removable dentures supports the fatigue failure mechanism as a main causative factor for denture fractures. Metal wire or mesh "strengtheners" have not proven to reinforce denture base material effectively.[1–5,8] Clinically, the information obtained is important from the perspective of temporary removable partial dentures (RPD) or those used as "permanent" solutions as well as from the perspective of the need to reinforce tooth- or implant-supported overdentures.

Fatigue resistance is related to the properties of materials; for example, glassy materials have relatively low flexural fatigue resistance. Denture base polymers made from, eg, poly(methyl methacrylate) (PMMA) polymer powder and methyl methaclylate (MMA)–butanediol dimethacrylate (BDMA) monomers, are such glassy materials at room temperature or at the temperature of the oral cavity.[10] To improve material

[a]*Research Associate, Department of Prosthetic Dentistry and Biomaterials Project, University of Turku, Finland.*
[b]*Associate Professor and Docent, Department of Prosthetic Dentistry and Biomaterials Project, University of Turku, Finland.*
[c]*Biostatistician, Department of Biostatistics, University of Turku, Finland.*
[d]*Professor and Head, Department of Prosthetic Dentistry and Biomaterials Project, University of Turku, Finland.*

Reprint requests: *Dr Katja Narva, Institute of Dentistry and Biomaterials Project, University of Turku, Lemminkäisenkatu 2, FIN-20520 Turku, Finland. Fax: + 358-2-333 8390. e-mail: katja.narva@utu.fi*

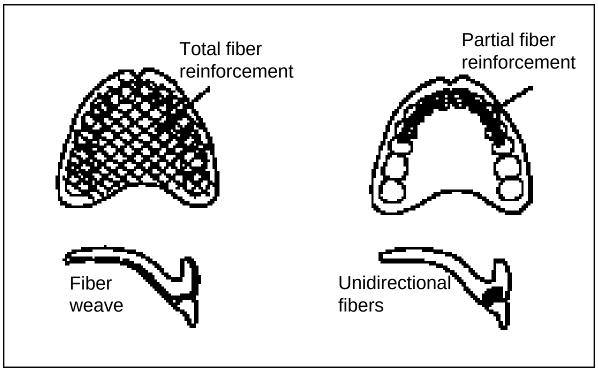


Fig 1 Total fiber reinforcement, *left,* and partial fiber reinforcement, *right,* in maxillary complete denture.

properties in structural engineering applications, fiber-reinforced composites (FRC) are often used. Recently, FRCs have also been used in dentistry as reinforcements of removable and fixed partial dentures.[11–31] FRC has high fatigue resistance.[11] Because fatigue is the main failure mechanism of dentures, the use of FRC as a reinforcement of dentures could be justified. An in vitro study of the flexural fatigue resistance of the acrylic resin of RPDs suggests the clinical usefulness of FRC reinforcement.[12]

The denture base can be reinforced in two ways: the entire denture base can be reinforced, or the fiber reinforcement can be accurately placed in the weak region of the denture. The reinforcements can be defined as a total fiber reinforcement and partial fiber reinforcement (PFR), respectively (Fig 1).[12] Total fiber quantity in denture construction with PFR is low. To obtain a good reinforcing effect with PFR, all of the strength-related factors of FRCs should be carefully taken into consideration.

Several factors influence the mechanical properties of FRC. Adequate adhesion of the fibers to the polymer matrix is one of the most important factors for the strength of FRC. Adhesion requires proper impregnation of the fibers with the matrix, and ideally all of the fibers are embedded in the polymer matrix.[13] Numerous studies have been undertaken to solve the problem of impregnating reinforcing fibers with denture base resin of relatively high viscosity.[14–18] Recently, it was demonstrated that proper impregnation can be obtained by polymer preimpregnation of reinforcing fibers.[19] Fiber orientation also influences properties of FRC. Unidirectional fibers give anisotropic mechanical properties to the composite and are suitable for application in which the direction of the highest stress is known.[32–34]

Different types of fibers have been used to reinforce dentures: glass fibers, ultrahigh–molecular weight polyethylene (UHMWP) fibers, carbon/graphite fibers, and aramide fibers. Fiber type affects the strength of FRC by means of adhesion and mechanical properties of the reinforcing fiber itself.[11–31] Glass fibers have been shown to improve the mechanical properties of acrylic resin, especially fatigue resistance, impact strength, and flexural strength.[11–13,15,18–20,35] This is because of good adhesion of the glass fibers to denture base polymer and a low percentage of elongation at break of glass fibers. UHMWP fibers have relatively good mechanical properties, but the adhesion to the matrix polymers is insufficient, even when plasma treatment of the fiber surface is performed.[36]

Preliminary results of PFRs in removable dentures suggest their clinical usefulness in the short term.[12] The aim of this study was to evaluate the function of PFRs in repair of removable dentures with a two-center clinical survey with up to 4.1 years of follow-up time.

Materials and Methods

The clinical survey was undertaken in two dental schools in Finland: Kuopio University, east Finland and Turku University, southwest Finland. Both complete and removable partial dentures were collected between January 1994 and February 1997. As the patients with fractured dentures appeared at the universities, they were invited to participate in the survey. Denture bases of dentures in Kuopio had fractured a maximum of five times, whereas dentures in Turku had fractured a maximum of three times before the study. The number of previous fractures was obtained from the patient file. The inclusion criterion was existence of a fracture line in the acrylic resin denture base or a fracture of the denture into two pieces. In Kuopio, the same clinical instructor made the clinical examination and the same dental technician made the treatment and repair of all the dentures. In Turku, dental students under the supervision of clinical instructors made the clinical examination and treatment with no previous experience in using PFR in dentures. Technical laboratory work in Turku was done in commercial laboratories where technicians did not have experience in using PFR. The number of dentures was 51. Some of the patients had broken both maxillary and mandibular dentures. The number of patients was 48, 26 men and 22 women.

Numbers of fractures of the dentures, age of the dentures, follow-up time, and age of the patients before the study are given in Table 1. There were seven mandibular dentures and 44 maxillary dentures in the study, and of those, 28 were complete dentures and 23 were RPDs. Ten of the antagonist teeth were natural teeth or FPDs and 41 were RPDs or complete dentures.

All of the dentures were repaired with normal dental laboratory techniques, with the exception of insertion of the PFR. No restrictions were made on the use of the dentures. The PFR used was an experimental polymer-preimpregnated glass-fiber reinforcement. The fibers of the PFR were continuous, unidirectional E-glass fibers (composition SiO_2 55 wt%, CaO 22 wt%, Al_2O_3 15 wt%, B_2O_3 6 wt%) that had a porous prepolymer matrix. The fibers were silanated with gamma-methacryloxypropyltrimethoxysilane (A174, Union Carbide) before preimpregnating the fibers to obtain adhesion between the fibers and denture base polymer.

The PFR was placed into the region of the fracture of the denture base at a 90-degree angle to the fracture line. The PFR was wetted with a small amount of monomer liquid of mainly MMA (eg, Palapress, Heraeus Kulzer) and embedded with a mixture of polymer powder and monomer liquid. The resin was polymerized in warm water in a pneumatic curing unit for 15 minutes.

In Kuopio, no occlusal adjustment or rebasing/relining was done to the dentures. The patients were asked to contact the dental clinic in case of fracture or crack in the dentures, and they were asked to participate in the follow-up examinations after each 12-month period. In Turku, the treatment consisted in some cases of also rebasing/relining or occlusally adjusting dentures. The patients were asked to contact the dental clinic in case of fracture or crack in the denture. All patients were examined at the end of the follow-up period. Possible rerepairs were retrospectively analyzed from the patient file.

In the examination of general shape of the denture, possible fractures, hairline fractures, and discoloring of PFR were visually inspected. Possible protrusion of the fibers and irritation of the oral mucosa were also evaluated.

The statistical computations were made with SPSS (Statistical Package for the Social Sciences for Windows), release 8.0, 1997. To evaluate the results, the mean number of rerepairs in each denture per year was calculated before and after the insertion of the PFR. The number of repairs was compared by nonparametric Wilcoxon's signed ranks tests. Kaplan-Meier survival curves were calculated for time of fracture as an endpoint. P values less than .05 were interpreted as statistically significant.

Results

There was a significant difference in the survival rate of the RPDs left unreinforced or reinforced with the conventional methods and those reinforced with the experimental PFR ($P < .001$). Six of 51 dentures needed rerepair during or after the follow-up period, one in Kuopio and five in Turku. Kaplan-Meier survival curves visually showed the difference between survival of dentures before and after insertion of PFR (Fig 2). By combining data of Turku and Kuopio, it was found that in 12% of the cases, there was need for rerepair of dentures at the region of PFR, including cases with a hairline fracture that had not been found by the patient. During the recall clinical examination, no signs of irritation of oral mucosa were found. In one denture, the PFR was slightly discolored.

Table 1 Summary Statistics

	Minimum	Maximum	Mean	Standard deviation
Turku (n = 30)				
Age of dentures before PFR (y)	1.5	16.9	6.1	4.1
Follow-up time (y)	1.0	2.6	2.0	0.5
No. of fractures before PFR	1	3		
Age of patients before PFR (y)	54.5	88.4	71.8	7.7
Kuopio (n = 21)				
Age of dentures before PFR (y)	2.2	15.8	6.1	3.4
Follow-up time (y)	0.3	4.1	2.6	0.8
No. of fractures before PFR	1	5		
Age of patients before PFR (y)	48	88.4	70.5	10.1

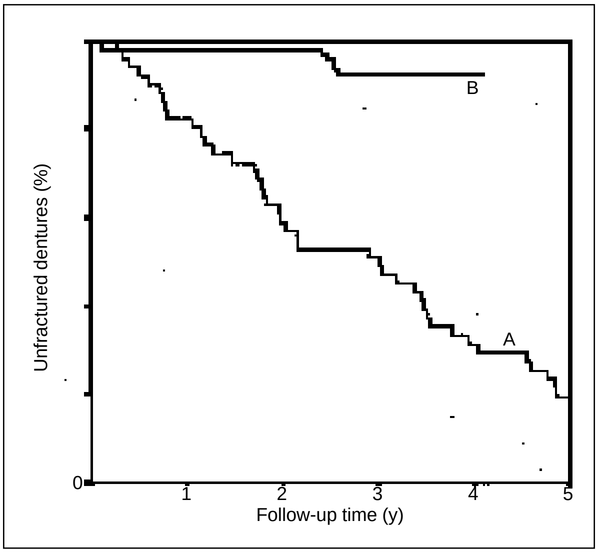


Fig 2 Kaplan-Meier survival curves for dentures before *(A)* and after *(B)* insertion of PFR. Curve A represents the first 5 years of survival of the dentures without PFR, with a maximum 16.9-year wearing period.

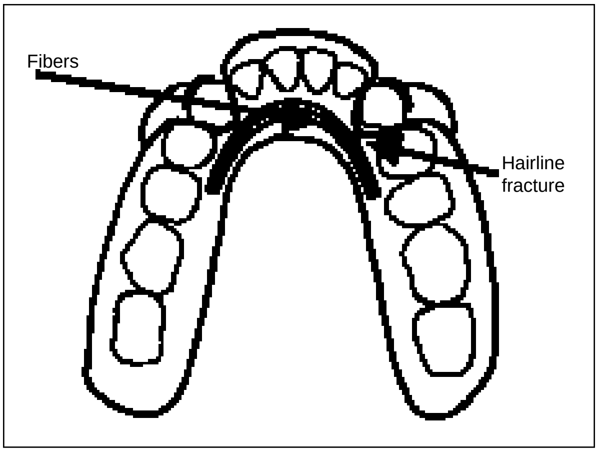


Fig 3a Mandibular RPD with hairline fracture found at the recall checkup.

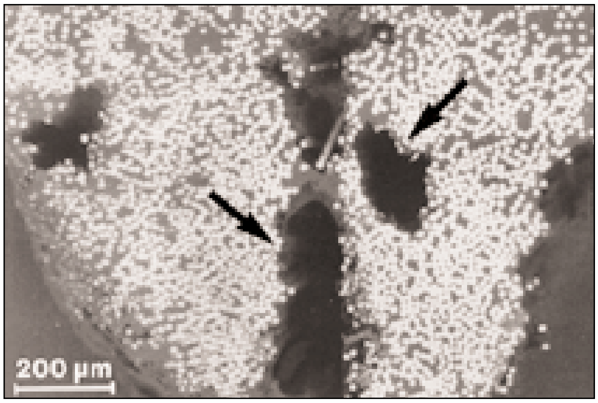


Fig 3b SEM view of cross section of the PFR shows some polymerization-shrinkage voids in the well-impregnated FRC structure *(arrows).* Importance of high-quality PFR is emphasized in the parts of dentures with small dimensions. (Original magnification × 100.)

Discussion

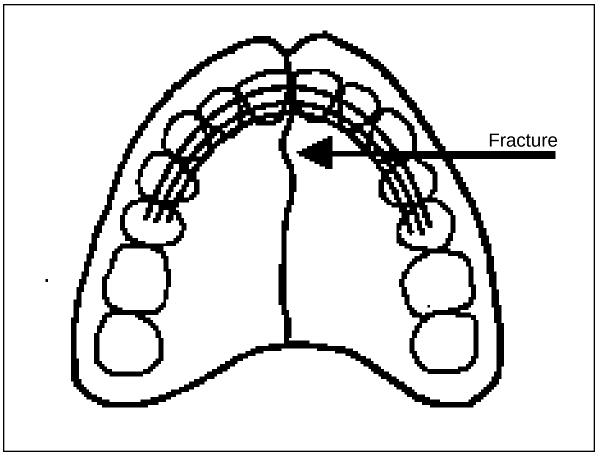
This survey examined the elimination of recurrent fractures in acrylic resin denture bases by using PFR made from glass fibers. Preliminary clinical results of the use of PFRs in removable dentures suggest their usefulness in reinforcing acrylic resin dentures.[12] In that study, some factors, like incorrect placement and insufficient length of PFR, were found to relate to the refractures, and they were eliminated during the rerepair of those removable dentures. The two-center survey examined those removable dentures for a longer period as well as evaluated the function of PFRs in another study center. The importance of the technical factors related to the strength of the fiber composite material and the occurrence of refractures was also emphasized in the present study.

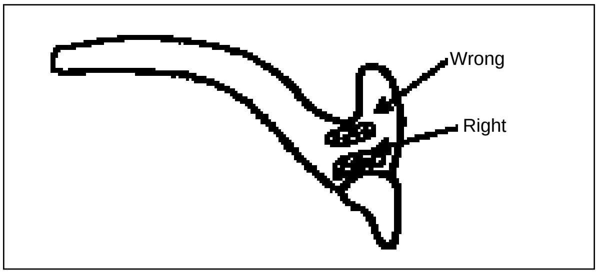
A short hairline fracture was found at the recall examination in the same region as the previous fracture in one mandibular RPD after it had been worn for 2 years and 4 months (Fig 3a). The distance from the margin of the denture to the fiber-rich region was approximately 3 mm, and the hairline fracture initiated in this region and stopped at the fibers. One explanation for this fracture is that the fibers were not placed to the margin of the denture. Scanning electron microscopic (SEM) examination of the PFR of this case showed voids in the well-impregnated structure of the PFR (Fig 3b). The voids were likely caused by polymerization shrinkage of the monomers of the denture base resin and could have weakened the PFR. This phenomenon has been discussed previously.[14,15,17] The problem occurred with the prototype of the PFR used in the present case because the polymer-preimpregnated PFR was wetted with an excess of monomer liquid. The ratio of monomer liquid to the quantity of prepolymer matrix between glass fibers resulted in an excess of monomer liquid between the fibers. Another reason for the failure in this RPD might have been the existence of an old metal wire in the denture base that had not been removed in the repair with PFR. It has been demonstrated that the influence of metal wires of low rigidity is limited with regard to the flexural strength of denture constructions.[11] To eliminate the polymer-shrinkage voids, excess amounts of polymerizable monomers should be reduced to a minimum. This could be done by wetting the polymer-preimpregnated PFR with a mixture of polymer powder and monomer liquid instead of plain monomer liquid.[19]

The importance of high-quality PFR is emphasized in the parts of dentures with small dimensions. For example, maxillary complete dentures with a great volume of polymer or FRC can tolerate poorly impregnated regions better than dentures with small dimensions (Fig 3b).

In another RPD repaired in Turku, there was a hairline fracture in the region of the previous fracture 2.5 years after the insertion of the first PFR. The denture was one of the first dentures in which PFR was used in Turku, and the reason for the hairline fracture might have been the placement of too short a piece of PFR and mishandling of the insertion of the PFR during the repair. The condition of the rerepaired denture was good when the new PFR was evaluated after 6 months.

The importance of correct location was also emphasized in maxillary complete denture shown in Fig 4. The denture was 3 years and 5 months old and had fractured once before the placement of the first PFR. The reason for the refracture after only 4 months was most likely the faulty placement of the PFR. The PFR was placed close to the oral mucosa in the denture





Figs 4a and 4b Importance of the right location of the PFR can been seen in this maxillary complete denture; it fractured because the reinforcing fibers were placed too close to the alveolar crest, ie, on the compression side of the denture during mastication. The region of the highest tensile stress is located between the incisors, where the midline fracture began.

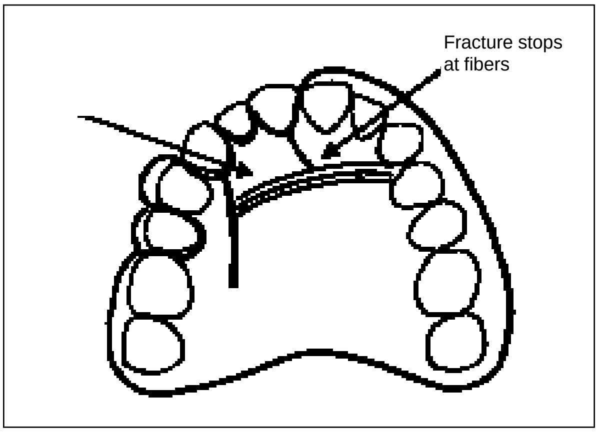


Fig 5a Maxillary RPD that refractured after 2 years and 3 months. Reasons for the fractures might be that the fibers were not in the anterior margin of the denture and the PFR was too short to stop the new fracture.

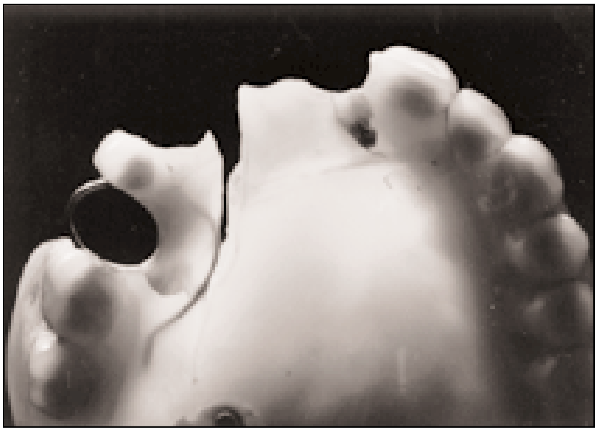


Fig 5b Maxillary RPD that refractured after 2 years and 3 months.

base, even though the region of highest tensile stress was located between the incisors, where the midline fracture began (Fig 4b). After the new PFR was inserted in the correct region, ie, close to the ridge-lap surface of the incisors, there have been no fractures in the denture base for 2 years and 8 months. Another example of the same type of incorrect placement of PFR was in a complete denture made in Turku. There was the beginning of a hairline fracture in the midline that the patient had not noticed. It was rerepaired during the recall examination. As in the previous complete denture, the fibers had been placed too close to the oral mucosa.

Another type of incorrect placement of PFR is shown in Fig 5. A maxillary RPD with a fracture was repaired with PFR. After the denture had been worn for 2 years and 3 months, new fractures were found. There were two obvious reasons for the recurrent fracture: *(1)* fibers were not in the anterior margin of the denture, and the new fracture propagated until it reached the fibers; and *(2)* the PFR was too short, which resulted in propagation of the new fracture posteriorly.

A small amount of glass fibers can strengthen the denture if they are placed correctly, are well impregnated with the surrounding polymer matrix, are perpendicular to the possible fracture line, and are long enough. Using monomer liquid to wet the PFR appeared to cause void formation inside the PFR. It is essential to use a mixture of acrylic resin powder and liquid to wet the PFR to avoid an excess of monomer in the PFR. Taking into account these aspects, polymer-preimpregnated glass-fiber PFRs seem to be useful in eliminating fractures of acrylic resin RPDs.

Conclusions

With the limitations of the study, the following conclusions were made:

1. The new PFR can prevent recurrent fractures in acrylic resin dentures.
2. This study emphasizes the importance of correct positioning of the PFR on the tension side during mastication, perpendicular orientation to the possible fracture line, length of the PFR, and accurate laboratory technique.
3. The quality of the PFR is especially important in constructions of small size.

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