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Five-year survival of 3-unit fiber-reinforced composite fixed partial dentures in the anterior area

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ABSTRACT

Objectives. The purpose of this clinical study was to evaluate the long-term outcome of 3-unit anterior fixed partial dentures (FPDs) made of fiber-reinforced resin composite (FRC), and to identify design factors influencing the survival rate.

Methods. 52 patients (26 females, 26 males) received 60 indirectly made FRC FPDs, using pre-impregnated unidirectional glass fibers, requiring manual wetting, as framework material. FPDs were surface ($n = 48$) or hybrid ($n = 12$) retained and mainly located in the upper jaw. Hybrid FPDs had a combination of retainers; i.e. crown at one and surface retention at the other abutment tooth. Surface FPDs were either purely adhesively retained ($n = 29$) or with additional mechanical retention ($n = 19$). Follow-up period was at minimum 5 years, with check-ups every 1–2 years. Six operators were involved, in three centers in the Netherlands, Finland and Sweden. Survival rates, including repairable defects of FPDs, and success rates were determined.

Results. Kaplan–Meier survival rate at 5 years was 64% (SE 7%). For the level of success, values were 45% (SE 7%) and the estimated median survival time 58 (SE 10.1) months. For surface FPDs, additional mechanical retention did not improve survival significantly. There was a trend towards better survival of surface FPDs over hybrid FPDs, but differences were not significant. Main failure modes were fracture of the FPD and delamination of veneering composite.

Significance. A success rate of 45% and a survival rate of 64% after 5 years was found. Fracture of the framework and delamination are the most prevalent failure modes, especially for surface FPDs.

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1. Introduction

The resin-bonded fixed partial denture (FPD) is a valid treatment option for replacement of missing teeth in selected cases. The main advantage of resin-bonded FPDs over crown retained FPDs is the preservation of dental hard tissues. Clinical survival rates of metal alloy resin-bonded FPDs have been reported to be 60% and higher after 10 years [1,2]. An analysis of 60 publications on resin-bonded bridges reported a survival rate of 74% after 4 years [3].

Traditionally, metal alloy has been used as the material for the framework, but fiber-reinforced composite (FRC) is an alternative today. Inherent advantages are better adhesion of the composite luting agent to the framework, good esthetics and the physiological stiffness of the material. Moreover, restorative composite or fibers can be added to an already functioning FPD, enabling alterations and repair when needed. Various types of fibers and fiber products have been tested as reinforcing materials. Glass fibers are most often used because of their strength and their esthetic character compared to other fibers [4–6]. The development of fiber products available for dental use has led from plain fibers to pre-impregnated fibers and finally fully resin impregnated fibers. Mechanical properties of the materials have improved markedly along with the development. When fabricating FRC prostheses, reinforcement with long unidirectional fibers at the tensile side of the construction is recommended [7–11]. FRC FPDs can be fabricated either directly in the mouth or indirectly by a dental technician. When compared with the direct technique, the indirect technique offers ease of working, a higher degree of composite conversion rate and a better surface finish. Preparation design of abutment teeth in the anterior area is preferably a minimal invasive design (Maryland type) to preserve tooth material.

Although material properties of FRCs have been researched markedly [4,5,7,12–14], clinical research is for the greater part restricted to case-series. From a review of clinical studies it is concluded that the performance of fiber-reinforced constructions cannot compete with FPDs with a metal framework yet [15] in a direct comparison, it has been shown that 3-year survival rates of FRC FPDs were significantly lower than (resin-bonded) metal–ceramic FPDs [16]. Based on similar observations, it has been advocated to limit the indication for FRC FPDs to the anterior region, to short-span distances or to transitional restorations only [17–21]. However, two clinical studies have shown a substantial clinical performance of FRC FPDs with an overall survival rate of 75% after about 5 years, which can be higher than FPDs with a metal framework [22,23].

In this study data were collected of FRC FPDs which were placed in three academic centers in the Netherlands, Sweden and Finland. The purpose was to evaluate the long-term clinical outcome of 3-unit anterior FPDs made of manually resin impregnated glass fiber-reinforced resin composite, and to identify design factors influencing the survival rate. In particular, difference in performance between FRC FPDs with or without additional retention form was analyzed. Service time was minimal 5 years.

2. Materials and methods

2.1. *Study design*

Between April 1998 and September 2002, 52 patients (26 females, 26 males) of the departments of Oral Function and the Centre of Special Dental Care Radboud University Nijmegen (the Netherlands), the Institute of Dentistry University of Turku (Finland) and the Dental School Umeå (Sweden). Approval of the universities medical ethical committee was obtained (the joint commission on the ethics of the Turku University and the Turku University Central Hospital, resolution no. 264). Patients were treated with 60 indirect fiber-reinforced fixed partial dentures (FRC FPDs) in the anterior region. Informed consent was obtained. In most cases the patients were treated after referral by their own dentist. The patients' ages ranged from 13 to 64 years, with a mean age of 35 years. All FPDs replaced one missing tooth and two adjacent abutment teeth were used for retention, no cantilever bridges were involved. Forty-three patients received one FPD, five patients received two FRC FPDs. For two patients a new FPD was made after the first failed. For one patient this was repeated after a second failure, resulting in three subsequent FPDs. These FPDs were included as additional cases. Three FPDs were placed in the lower jaw and 57 in the upper jaw. The characteristics of the treated dentitions and FPDs are presented in Table 1. Patients were free of extensive periodontal disease and most of

Table 1 – Distribution of anterior FRC FPDs ($n = 60$).

Variable	n
Jaw	
Maxilla	57
Mandibula	3
Gender of the patient	
Male	26
Female	26
Pontic type	
Central incisor	23
Lateral incisor	28
Canine	9
Operator	
1	25
2	14
3	14
4	4
5	2
6	1
Academic center	
Nijmegen	53
Turku	3
Umeå	4
Material	
Artglass	53
Sinfony	7
Luting cement	
Panavia	17
Twinlook	36
Compolute	7

Table 2 – Distribution of surface retained and hybrid retained FPDs ($n = 60$).

Type of FPD	No preparation	Retention	Preparation	
Surface retained	29	19	0	48
Hybrid retained	0	3	9	12

them had complete dental arches (except the missing tooth). X-rays to exclude periapical disease and loss of periodontal support of the abutment teeth were available.

We aimed for a minimal tooth preparation design and therefore most FPDs included surface retainers (Maryland wing design) but also inlay or onlay retainers in first premolars or complete coverage crowns were made (Table 2). In cases that used a combination of different retainer types, the type of FPD is referred to as 'hybrid' retained, for example, an inlay retainer in one abutment tooth and a surface retainer at the other. FPDs with surface retainers at both sides are referred to as 'surface' retained. Surface retainers can be divided in two groups: (1) retainers that are simply based on the adhesive interface enamel–composite luting cement; or (2) retainers additionally provided with a retention form being approximal grooves and an occlusal rest. Preparation forms were referred to as 'no preparation' (adhesive retention), 'retention' (rests and grooves), or 'preparation' (crown/inlay/onlay preparation) (Table 2). When for example one abutment-site was labeled as 'no preparation' and the other as 'preparation', the overall label was 'preparation'. Allocation of additional retention was based on the preference of the operator.

2.2. *Restorations*

Treatment was performed by 6 experienced dentists, with adequate skills in adhesive techniques, according to a clinical protocol. Treatment was performed during two treatment sessions: (1) tooth preparation, impressions, and if necessary, provisional restorations; and (2) try-in, placement of the FPD and finishing.

In case of occlusal contact the palatal surface was ground to provide enough interocclusal space resulting in a complete surface to be used as a retainer site. Pre-existing restorations were removed and their cavity preparations were used as abutment preparations. If necessary, resin composite was applied in order to provide parallel cavity walls. If proximal grooves were made the positioning of the FPD was directed by their presence. In several cases an optimal approximal contact between abutment teeth and pontic was provided by preparing guiding planes. If no grooves were made, a palatal positioning direction was possible without the need to include guiding planes. After tooth preparation, impressions were made with a polyvinyl siloxane material. In several cases no temporary adhesive restoration was required, since a removable acrylic prostheses was available. If present, cavities were protected with a provisional filling material for the period of the laboratory procedure. Adhesive provisional restorations consisted of a pontic of an acrylic tooth, or an all-composite tooth, or a crown of an extracted tooth, which was retained to the abutment teeth with composite. Retention was mainly created by using the undercut cervical areas.

FPDs were made in dental laboratories on a full arch stone cast which was isolated with separating agent. The fiber framework consisted of manual resin wetting requiring unidirectional pre-impregnated glass fiber bundles (StickTM; StickTech Ltd., Finland). Each bundle consists of about 4000 glass fibers, with a diameter of 17 μm, embedded in a PMMA/BisGMA matrix. A bidirectional fiber mat (fiber diameter 10 μm) was used for additional reinforcement of the retainers (Sticknet; StickTech Ltd., Finland). Glass fiber reinforcements were manually impregnated with BisGMA-TEGDMA based light polymerizing monomer resin (Stick Resin; StickTech Ltd., Finland) to form a PMMA–dimethacrylate inter-polymer network (IPN) [24] before use. Before the fibers were placed on the cast, a thin layer of flowable composite was applied at the retainer area. After light polymerization, the framework was veneered with composite resin (in Nijmegen: Artglass (Hereaus Kulzer, Germany), in Turku and Umeå: Sinfony (3M ESPE, Germany)). Sometimes an opaquer was used to aid in an esthetic restoration. The composite resin was built incrementally using a heat-light polymerization oven (in Nijmegen: Heraflash (Hereaus Kulzer, Germany), in Turku and Umeå: Visio Beta (3M ESPE, Germany)).

In the second treatment session, the provisional restoration was removed and the abutment teeth were cleaned with pumice. The fit of the FPD was checked using a silicon material (Fit Checker, GC, Japan); if needed the fit was adapted using diamond burs.

Rubberdam was applied in about 50% of the cases. Meanwhile, the bonding surface of the FPD was treated with monomer resin. The resin was left unpolymerized, shielded from light, for at least 3 min to allow the resin to penetrate and activate the IPN-phase of the polymethacrylate polymer matrix of the FRC framework. The bonding surface of the abutment teeth was acid-etched with 37% phosphoric acid gel for 20 s, rinsed and gently air dried for 5 s. FPDs were luted with a resin composite cement (in Nijmegen: Twinlook (Hereaus Kulzer, Germany) or Panavia (Kuraray, Japan), in Turku and Umeå: Compolute (3M ESPE, Germany)) according to the manufacturer's instructions. After removal of excess material, the resin composite cement was light cured for 20 s per surface. After polymerization, restoration margins were finished. Occlusion was adjusted with fine diamond-burs and the restoration was polished using rubbers and polishing discs. Patients received individual instructions to maintain plaque control.

2.3. *Evaluation*

Most of the patients were included in a care program that included 6 or 12 months general dental health check-ups, in the majority performed by their own dentist. Besides these check-ups, patients were advised to contact the dentist from the university clinic if any abnormality or event occurred concerning their FPD. For specific evaluation of the FRC FPDs, patients were invited for check-ups every 1–2 years. The performance of the restorations was evaluated by clinical examination. Caries and periodontal status, wear of the restoration, discoloration, fractures and dislodgements were recorded. After minimal 5 years, all patients whose records did not already indicate the failure or removal

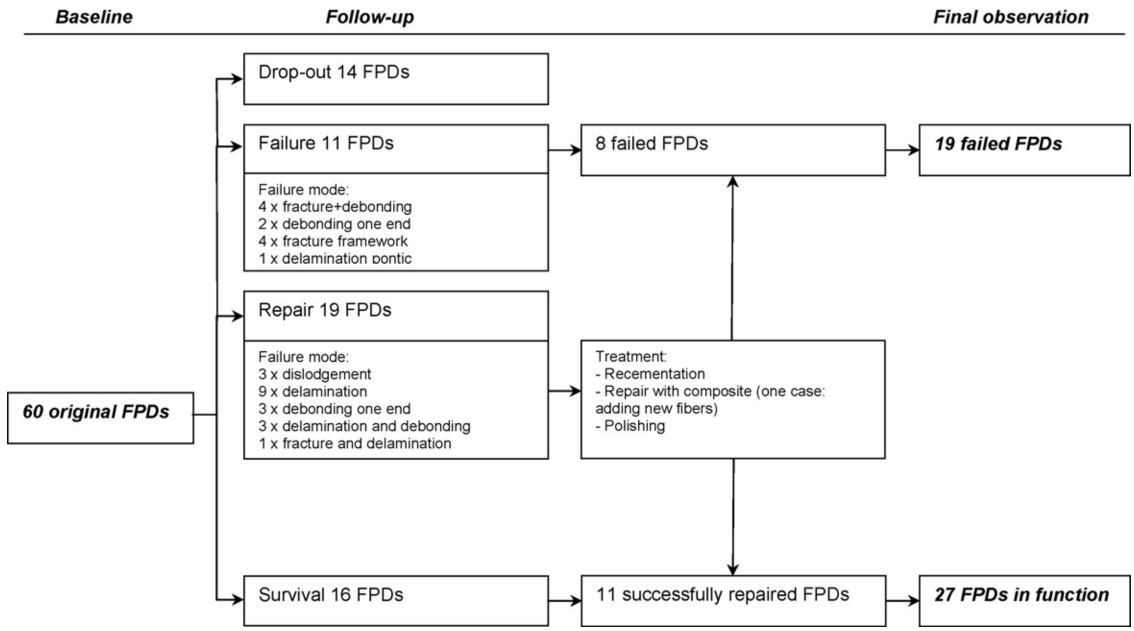

Fig. 1 – Lifecycle of anterior FRC FPDs during the follow-up period (5–9 years).

of the restoration were invited to participate in a clinical examination.

During the follow-up period, all interventions were recorded. Interventions may vary from finishing in case of chip fractures through repair by adding resin composite to renewal of the restoration. When records indicated interventions, the date and type of repair were recorded. If FPDs were repaired more than once, the first date of repair was used. The FPDs that could be rebonded after dislodgement, were rebonded using the same procedure as had been used originally.

Modes of failure were recorded as: (1) fracture of framework; (2) debonding one end; (3) dislodgement; (4) delamination; (5) combination of problems; (6) replacement. Fracture of the pontic, while the framework was still intact, was recorded as delamination.

2.4. *Analysis*

All restorations were included as individual cases with the following survival categorization:

2.4.1. *Survival*

FPDs were considered to have survived when no loss of retention or fracture was detected by the observers or patients. Also FPDs with small defects, such as wear or chipping were considered to have survived. No intervention was needed during service time.

2.4.2. *Repaired*

Interventions, such as polishing and finishing after chipping of small fragments of the veneering resin composite, repair of small delaminations with restorative resin composite, or adding fibers at the connector area of the fiber framework, were needed during follow-up. Also rebonding of FPD after dislodgement or debonding of one retainer was considered a repair.

2.4.3. *Failure*

An FPD was considered failed, when problems, such as fracture of the restoration, unrepairable delamination of the veneering resin composite, and combination of problems, that could not be repaired with the FPD in situ, occurred during follow-up.

The survival probability was analyzed at different levels: on the level of ‘success’ ($S_{success}$) and on the level of ‘survival’ ($S_{survival}$). Endpoints for the $S_{success}$ were the categories “failure” or “repaired” and were consequently recorded as censored. Endpoint for $S_{survival}$ was “failure”. Data of drop-out patients were censored upon the last date that information of the FPD was available. Reasons for drop-out were traced.

Kaplan–Meier survival analyses were done for the complete group of FPDs and discriminated according to retainer type and preparation form. The 95% confidence intervals for survival probability at 5 years were calculated. Correlations between variables were crosschecked and possibilities for Cox regression analyses were researched, but appeared to be irrelevant. The analyses were performed with SPSS version 14.0 (SPSS Inc., Chigaco, IL, USA).

3. Results

The lifecycle of the FRC FPDs included in this study is shown in Fig. 1. During the follow-up period 14 FPDs were lost to follow-up (22%). These drop-out patients could not be contacted or were not able to participate in follow-up examination mostly because of travel distance. One of the restorations was replaced with an implant-supported crown without being registered as failure and one was replaced with a full coverage FPD by another dentist for unknown reasons. Nineteen FPDs failed because of fracture, delamination or debonding, but were regarded as reparable by the operator. Reparable failures

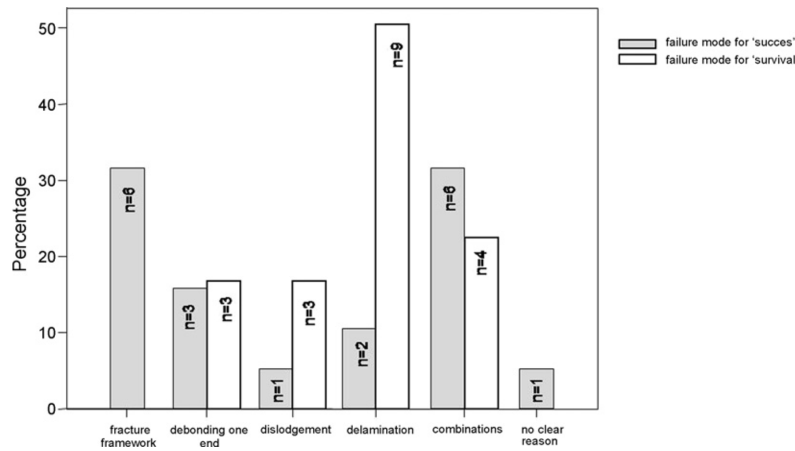

Fig. 2 – Failure mode in categories at $S_{success}$ and $S_{survival}$.

occurred at a mean follow-up of 27 months. The rebonded or repaired FPDs failed again in 8 cases within 3–19 months. Twelve failures were observed at a mean follow-up of 31 months.

The percentage distribution of failure modes is shown in Fig. 2. For reparable failures delamination was the most commonly seen problem (47%). Fracture and combinations of problems were the main causes for total failure (both 33%). Fracture of the framework concerned in the majority of cases the connector area (Fig. 3). Combined problems always included debonding and fracture of the surface retainers. Debonding mainly involved surface retained FPDs, with or without additional retention. One hybrid retained FPD, debonded after 2.8 years, was successfully replaced, while another one, debonded after 2.5 years, debonded and fractured again after 4.2 years. Focusing on failure modes of surface retained FPDs, it appeared that debonding occurred in 30% of the failed cases.

Overall survival curves for $S_{success}$ and $S_{survival}$ until 5 years are shown in Fig. 4. Kaplan–Meier survival probability at 5 years was 45% (SE 7%) for 'success' and 64% (SE 7%) for 'survival'. The estimated median survival time is 58 months (SE 10.1 months) for 'success'. Obviously, including repaired FPDs increases the survival rate.

Fig. 3 – Failure of a surface retained FPD. Connector area is fractured, after delamination/wear.

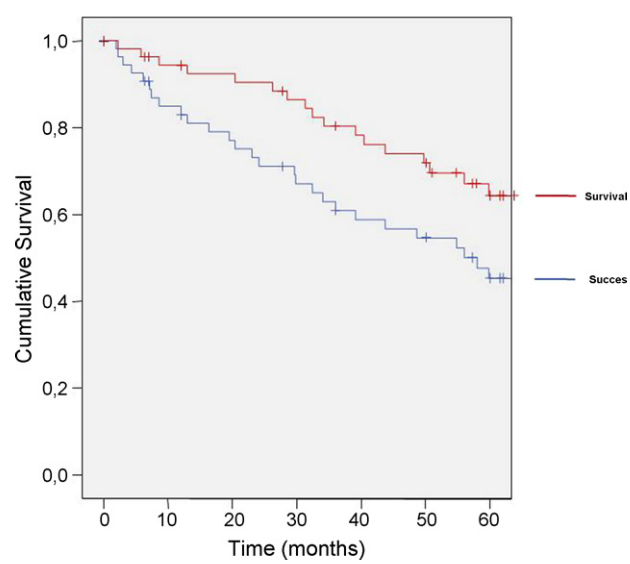

Fig. 4 – Restoration survival probability as a function of time for FRC FPDs ($n = 60$).

Survival rates for surface retained FPDs compared to hybrid retained FPDs are not significantly different for both $S_{success}$ and $S_{survival}$ (Fig. 5; log rank test $p > 0.05$). However, survival rates at 5 years seemed to be higher for surface retained FPDs ('success' 50% vs. 28%; 'survival' 68% vs. 52%). Focusing on surface retained FPDs it showed that the survival rates of $S_{success}$ without preparation was 45% (SE 10%), while this was 57% (SE 13%) for these FPDs with retention (Fig. 6). For $S_{survival}$ rates were 66% (SE 10%) for FPDs without preparation and 71% (SE 12%) when retention was used. These differences in survival percentages were not statistically different ($p > 0.05$). The survival plots for FPDs with and without retention are quite congruent.

Interaction between independent variables such as operator, patient age, preparation, type of FPD and luting cement, hampers a valid regression analysis.

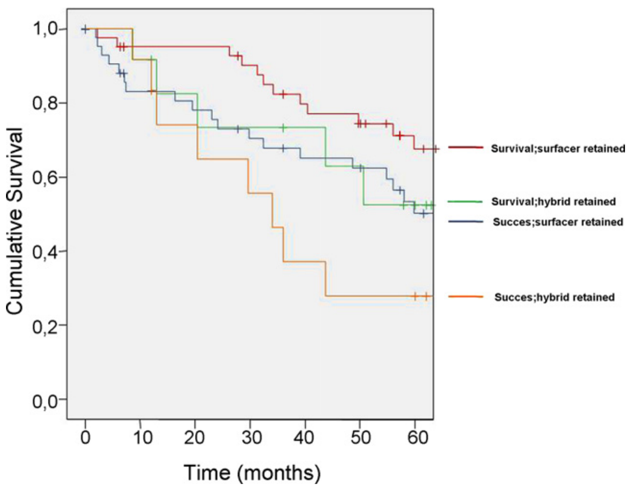

Fig. 5 – Restoration survival probability as a function of time for surface retained ($n = 48$) and hybrid retained FPDs ($n = 12$).

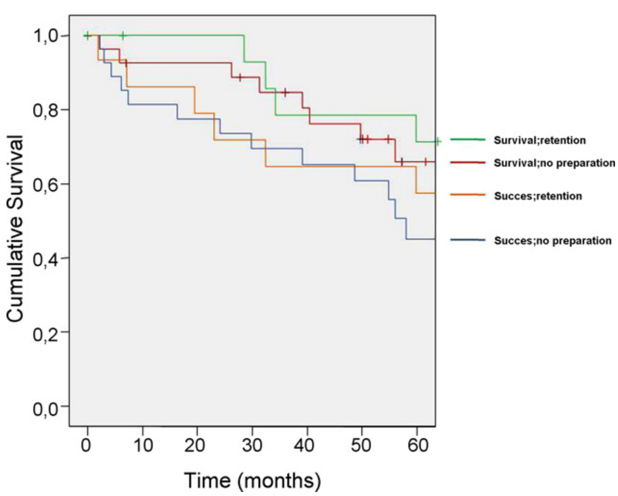

Fig. 6 – Restoration survival probability as a function of time for surface retained FPDs for 'no preparation' ($n = 29$) and 'retention' ($n = 19$).

4. Discussion

This study reports on indirect anterior FRC FPDs. To our knowledge, no long-term results have been published so far. The 45% success rate after 5 years in this study is a modest result for restorations that have a permanent character. The result is better compared to the 50% success rate for comparable restorations found earlier after just 12 months [28]. Considering the 64% survival rate after repair of the present restorations, the result is nearly as good as the 75% survival rate for surface retained FPDs at a follow-up of approximately 60 months [27]. Compared to metal resin-bonded FPDs, with reported 5-year survival rates up to 87.7% [29], the attractive features of the FRC FPDs are the esthetic nature of the framework and the easier possibility of repair and adjustment of the construction. Delaminations of resin composite can be repaired relatively easily by adding material after appropriate preparation of the fractured surface. Repair may also include adding fibers in situ, but the structural strength may be at risk. The 5 years success and survival rates were clearly different, which implies that repair of the FPD is beneficial to restoration survival time.

The laboratory fabricated FPDs of this study were made of partially pre-impregnated glass fiber bundles and were developed in the late 1990s. Of the three kinds of dental fiber products available today (plain, partially and fully resin impregnated fibers) the first two require manual impregnation of the fiber bundles by the operator. It is known that manual resin impregnation results in lower fiber fractions than what can be obtained by modern fully resin impregnated glass FRCs (30% vs. 65 wt%) and strength of the construction is related to the relative fiber quantity in the cross-section of the material [25,26]. Accordingly, static flexural strength of manually impregnated FRCs range from 250 to 350 MPa, while the range is 750–1200 MPa for fully resin impregnated glass FRCs [27–29].

The fabrication of FRC FPDs in this study consisted of a single longitudinal fiber bundle in the framework and additionally woven fibers in the retainer area. No supporting fibers for the pontic were added. Freilich et al. showed *in vivo* and Xie et al. *in vitro* that a higher quantity of fibers in the pontic prevents veneer delaminations in that area [23]. This may put our results into light regarding the most common reasons of failure, being delamination and frame fracture. Although those reasons are in agreement with others [27–29], adaptation of the framework design might improve performance of the FPDs. Recent data on FEM modeled FRC FPDs suggests ways to optimize the design and provide better support for the pontic with lower interfacial stress between veneer and fiber framework [30]. Furthermore, in bridge constructions the connector areas have to resist the highest tensile and shear forces [31,32]. Strengthening of this part of the construction may be obtained by changing preparation protocols and create more materials volume for the resin composite or fiber material.

This study was a mix of a prospective trial and a retrospective evaluation. Generally accepted limitations of retrospective studies, like their non-protocolized design, are not applicable to this study. Operators worked according to a clinical protocol and the restoration design was restricted to 3-unit FPDs. This study forms part of a trial including posterior FPDs. Unfortunately the sample proportions were not equally distributed between centers, being the major part of restorations made in Nijmegen. The laboratory procedures deviated on details. For example, the three clinical centers chose two different resin composite veneering materials which depended on their experience with the materials. It has been stated that resin materials with a higher elastic modulus may perform better under clinical conditions [33]. However, a comparison between used materials cannot be made because of the difference in group sizes. The indications for tooth replacement in the study varied from a temporary solution in younger patients with multiple ageneses to (semi)permanent restorations to save costs, both biologically and financially. It can be anticipated that patient selection influences the results but it is not clear to what extent.

The detailed preparation design of the FPD abutment teeth varied. Surface and hybrid retained FPDs can be discerned, which is the consequence of the variation in the dental status of subjects. Hybrid retained FPDs include combinations of a surface retainer, an inlay or a crown. We did not observe a substantial difference in survival rates for surface and hybrid retained FPDs. This gives reasons to suppose that anterior FPDs with retainers that have inherent retentive capacity (inlay, crown) did not inevitably lead to better results compared to purely adhesive retained FPDs. Restricted to the surface retained FRC restorations, additional retention (grooves, rests) of the retainer hardly improved survival, but merely prevented debonding, since fracture of the framework and delamination was seen more often than with purely adhesive retention. It was shown that metal resin-bonded FPDs with approximal grooves were more retentive than without grooves [34]. It is interesting to note that resin extensions (into grooves) of the FPDs, that technically cannot be fiber reinforced, did not show cohesive fracture.

Failures can be traced to several causes. Possible reasons for the observed failures are: (1) degradation of the luting agent, (2) disintegration of the interface between framework and veneering resin composite [35,36], (3) fracture of thin connector areas and the low bulk retainers, (4) stress induced by dynamic occlusion, loading the FPD not perpendicular to the fiber direction. Since the adhesive surface of the FRCs was resin composite, one would expect debonding or dislodgement from the resin composite luting agent to be a minor problem. Despite we found debondings or dislodgements. To note, the predominant reason for failure of surface retained metallic resin-bonded FPDs is known to be debonding [37]. Wear was never recorded as a reason for failure or repair, although wear of resin composite was seen in several cases. It is possible, however, that delamination and wear are two phenomena that are hardly discernible. The surface retainer was in most instances only a thin layer of glass fibers embedded in resin composite and wear of the superficial layer exposes the fibers which increases risk of delamination or fracture.

5. Conclusions

The 3-unit anterior resin-bonded FRC FPDs in this study showed a clinical survival rate of 64% after 5 years. For indirect FRC FPDs with manually impregnated glass fibers, fracture of the framework and delamination of veneering composite were the most prevalent failure modes, especially for surface retained FPDs.

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