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Success, clinical performance and patient satisfaction of direct fibre-reinforced composite fixed partial dentures – a two-year clinical study

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SUMMARY **To evaluate the success, clinical performance and patient satisfaction of directly placed fibre-reinforced composite (FRC) fixed partial dentures (FPDs) in 2 years. One hundred sixty-seven FRC FPDs (120 subjects) were directly fabricated to restore a single missing tooth by six Advanced Education in General Dentistry (AEGD) residents. The FRC FPDs recipients were randomised into two groups according to the fibre materials (pre-impregnated glass or polyethylene). Clinical performance was evaluated at baseline (2 weeks), 6, 12 and 24 months by two calibrated evaluators for prosthesis adaptation, colour match, marginal discoloration, surface roughness, caries and post-operative sensitivity using modified United State Public Health Service (USPHS) criteria. Prosthesis appearance, colour, chewing ability and overall satisfaction were evaluated by patients using a visual analogue scale (VAS). Kaplan–Meier estimation was used to estimate the prosthesis success. Ninety-four patients with 137 FRC FPDs returned (21·67% attrition rate for study subjects, 17·94% for FRC FPDs). Seventeen FRC FPDs failed, due to one-end ($n = 4$) or two-ends ($n = 4$) debonding or pontic fracture ($n = 9$). The cumulative 2-year success rate was 84·32% and survival rate was 92·7%; there were no statistically significant differences between the groups according to different missing tooth location, retention type or fibre materials ($P > 0·05$). Patient satisfaction regarding prosthesis appearance, colour, chewing ability and overall satisfaction was rated high on the VAS (mean >80 mm) for all criteria at all time points. The FRC FPDs (restoring single tooth) fabricated by AEGD residents achieved acceptable success and survival rates in a 2-year follow-up.**

KEYWORDS: **fibre-reinforced composite, fixed partial dentures, success rate**

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Introduction

Resin-bonded fixed partial denture (FPD) is a valid treatment option for the replacement of missing teeth in circumstances when the conservation of the tooth structure is needed or the prosthesis plays a transitional role in the oral cavity (1–3). Despite their disadvantages, such as more frequent rates of debonding than conventionally luted bridges, resin-bonded FPDs have advantages, such as a minimally invasive preparation, reduced cost and good patient acceptance (4). The use of FRC for resin-bonded FPDs is advocated for their favourable elastic modulus compared with metal and better adhesion of the composite luting agent to the framework (5).

Several types of fibres and fibre products have been used as reinforcing materials. Glass fibres are most often used because of their strength and aesthetic characteristics compared with other fibres (6–8).

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The development of fibre products for dental use has resulted in a transition from plain fibres to pre-impregnated fibres, and finally to fully resin-impregnated fibres. Mechanical properties of the materials have improved markedly along with the development. Regarding the fabrication of FRC FPDs, reinforcement with long unidirectional fibres at the tensile side of the construction is recommended (9–11). Fibre-reinforced composite FPDs could be fabricated either directly in the oral cavity or indirectly by a dental technician and cemented in the mouth as a second step. An 8-year follow-up study of 22 indirectly fabricated inlay-retained FRC FPDs reported an overall survival rate of 81·8% (12). A clinical study of 96 indirectly fabricated FRC FPDs placed in posterior areas revealed a 71% success rate and 78% survival rate after 5-year follow-up (13).

The retention types of FRC FPDs include tooth surface retention with no preparation, inlay retention after removal of existing caries, or restoration and hybrid. Vallittu *et al.* reported a tendency for inlay- and hybrid-retained (combinations of wings, inlays and complete coverage crowns) FPDs to have better survival rates than surface-retained FPDs (100% and 89% vs. 75%) after a mean 42-month follow-up. However, the limited number of the inlay- and hybrid-retained FPDs in their study prohibits generalisation of the results (2). van Heumen *et al.* (13) reported no significant differences in the survival rates of inlay-, hybrid- and surface-retained FPDs in 96 indirectly fabricated FRC FPDs. There are controversial reports of the correlation between FRC FPDs survival and location; for example, some studies report lower survival rates for FRC FPDs placed in the mandible (14–16), whereas other studies report similar survival rates between FPDs located in the mandible and the maxilla (17, 18).

Many *in vitro* studies have been conducted to test the laboratory load-bearing properties of FRC FPDs fabricated with different fibre materials, pontics and designs. Clinical studies have examined the survival of indirectly fabricated FRC FPDs. However, prospectively designed clinical studies to investigate the survival and clinical performance of directly placed FRC FPDs are scarce (15, 19). In addition, most of the existing reports have small numbers of subjects, and providers who were experienced clinicians, and none of the current studies evaluated patient satisfaction. With consideration of the above issues, the aims of this study were to evaluate the success, survival, clinical performance and patient satisfaction of directly placed FRC FPDs with a two-year follow-up period in a relatively large sample of 167 restorations. The null hypothesis was that there is no difference in the success rates between FRC FPDs fabricated with different fibre materials (pre-impregnated glass or polyethylene). We also examined other factors which could affect the success rate, including missing tooth locations, FRC FPDS retention type (surface, inlay and hybrid retention) and operator experience.

Materials and methods

The study protocol was approved by the Research Subject Review Board of the University of Rochester, USA (RSRB #31176). One hundred twenty subjects who met the following inclusion criteria were recruited into the study: (i) aged 18–80 years; (ii) had missing tooth/teeth in the maxilla or mandible; (iii) were indicated for the open-space closure; (iv) had no obvious untreated caries; (v) had no untreated periodontal disease; (vi) had no sign or history of general occlusal wear due to bruxism of parafunctions; (vii) good or moderate oral hygiene; (viii) agreed with the trial protocol (reviewed and signed the consent form); and (ix) after a discussion with the patient of alternative treatment options, such as fixed bridge or implant, the patient decided to proceed with the FRC FPDs treatment option before entering the study. Subjects who met the following exclusion criteria were excluded from participation: (i) considerable horizontal and/or vertical mobility of abutment teeth, a tooth mobility index score of 2 or 3, and (ii) span length of more than one molar/premolar, or one maxillary incisor or two mandibular incisors, depending on the location of the missing tooth.

Direct FRC FPDs fabrication

One hundred and sixty-seven FRC FPDs were directly fabricated in the patients' mouths by six AEGD residents following standard procedure protocols. One of the AEGD residents had greater experience with composite procedures before entering the AEGD residency and was rated as 'proficient' according to the *Chambers et al.'s* (20), five-point novice to expert scale (novice, beginner, confident, proficient and expert); the remaining five residents were rated as 'beginner'.

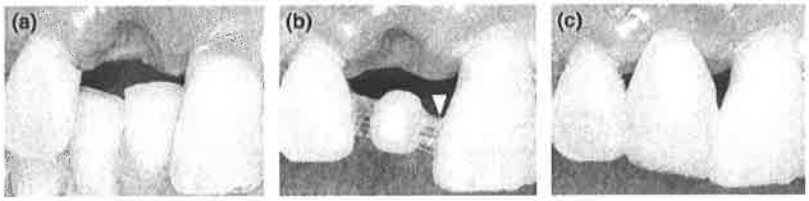

Fig. 1. Schematic design of FRC FPD (retention type – surface retention). (a) Before restoration. (b) Fibre (yellow arrow) is placed between the teeth by surface retention only. (c) Final restoration.

Study subjects were randomised into groups of different fibre materials, namely pre-impregnated glass fibre everSTICK C&B*[†] and polyethylene fibre Ribbond[‡]. Different retention types (surface, inlay and hybrid) were used based on the abutment tooth condition: surface retention was used if both abutment teeth were free of caries or restorations, schematic design shown in Fig. 1; inlay retention was used if both abutment teeth had existing caries or restoration, fibres were placed in internally in the prepared cavity box. Hybrid retention was used if either or both abutment teeth had existing caries or restorations, and fibres were placed internally and on the buccal/lingual surface of the teeth. Photographs were taken at the FRC FPDs fabrication appointment and follow-ups.

A rubber dam was applied in all of the cases. The abutment teeth were properly cleaned with prophy paste and microabrasion (50 μm aluminium oxide). The surface of the abutment tooth to be bonded was etched with 35% phosphoric acid for 30 s on the enamel and 15 s on the dentin, rinsed and gently air-dried for 5 s. The bonding agent OptiBond solo[§] was applied on the abutment teeth surface. everSTICK C&B glass fibre or Ribbond polyethylene fibre was placed on the appropriate portion with Tetric flowable composite[¶] and light-cured in place for 20 s, then the pontic and retainers were built up with Tetric Ceram[¶] or Esthet•X** resin composite. After polymerisation, the FRC FPDs restoration margins and occlusion were adjusted, polished and finished with flame and football-shaped carbide burs, soflex discs[††], Jiffy rubber polishing cups[‡‡] and/or Enhance and Pogo**. Patients received individualised instructions to maintain plaque control.

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[†]GC-America, Tokyo, Japan.
[‡]Ribbond Inc., Seattle, WA, USA.
[§]Kerr corporation, Orange, CA, USA.
[¶]Ivoclar Vivadent, Schaan, Liechtenstein.
**Dentsply–Caulk, Milford, DE, USA.
[††]3M, Minneapolis, MN, USA.
[‡‡]Ultradent, South Jordan, UT, USA.

Clinical performance

The clinical performance of the FRC FPDs was evaluated by two calibrated examiners using the slightly modified United State Public Health Service (USPHS) criteria from van Dijken *et al.* (21) (Detail presented in Table 1). Inter- and intra-examiner agreement for the evaluated criteria exceeded 87% at the calibration. The evaluated parameters included adaptation of prosthesis to the abutment tooth, colour match, marginal discoloration, surface roughness and occurrence of caries.

Failure determination

Subjects returned for 2-week, 6-, 12- and 24-month follow-ups. Subjects were aware of the need to notify the dentists whether they experienced discomfort or suspected failure during periods other than at their regular follow-ups. The following conditions were defined as failure in this study: (i) debond from one end, (ii) debond from both ends, (iii) fracture/delamination of veneering composite, (iv) fracture of GF-frame, (v) fracture of abutment tooth, (vi) decay of abutment tooth or (vii) other conditions that prevent the clinical function of the FRC FPDs. The survival probability was analysed at two different levels: success (without any failures described above), survive (success cases + failed cases but repaired and are in full clinical function).

Patient satisfaction

At the baseline (2-week), 6-, 12- and 24-month follow-ups, patient self-satisfaction evaluation of the FRC FPDs prosthesis was performed regarding prosthesis appearance, colour, chewing ability and general satisfaction. Each category was rated on a visual analogue scale (VAS) of 100 mm with 'extremely

Table 1. Evaluation criteria* for clinical performance of FRC prosthesis

Category	Score	Criteria
Adaptation to the abutment tooth	0	All margins closed or possess minor voids or defects (enamel exposed)
	1	Obvious crevice at margin, dentin or base exposed
	2	Debond from one end
	3	Debond from both ends
Colour match	0	Very good colour match
	1	Good colour match
	2	Slight mismatch in colour or shade
	3	Obvious mismatch, outside the normal range
	4	Gross mismatch
Marginal discoloration	0	No discoloration evident
	1	Slight staining, can be polished away
	2	Obvious staining, cannot be polished away
	3	Gross staining
Surface roughness	0	Smooth surface
	1	Slightly rough or pitted
	2	Rough, cannot be refinished
	3	Surface deeply pitted, irregular grooves
Caries	0	No evidence of caries adjacent to the margin of the restoration
	1	Caries evident adjacent to the margin of the restoration

*Modified from van Dijken *et al.* (21).

dissatisfied' at 0 mm and 'extremely satisfied' at 100 mm. Higher scores represent greater patient satisfaction with the prosthesis.

Statistical analysis

The success curve was estimated using the Kaplan–Meier method. Patient satisfaction data were analysed by paired *t*-tests to examine the difference between different time points. Differences between the marginal adaptation, colour match, marginal discoloration and surface roughness scores of the acceptable restorations at 2-year follow-up were tested with the chi-squared test. Statistical significance level was set at 0·05.

Results

This study recruited 120 patients at initial FRC FPDs placement, with 167 prostheses directly placed in the patients' mouths to restore a single missing tooth, and a mean abutment number of 2 for all prostheses. During the two-year follow-up period, 94 patients (32 males and 62 females) with 137 FRC FPDs returned for follow-up appointments. Twenty-six patients with 30 FRC FPDs dropped out of the study, resulting in an attrition rate of 21·67% for study subjects and 17·94% for FRC FPDs prostheses. Patients who had dropped out could not be reached with three attempts of telephone calls or mail. A description of the patients and prostheses is shown in Table 2. Of patients who returned for follow-up, 99 restorations were placed in the maxilla and 38 were placed in the mandible. Restorations placed were in the anterior, pre-molar and molar areas in 63, 44 and 30 FRC FPDs, respectively. In terms of retention type, 63 restorations were fabricated with surface retention, 29 with inlay retention and 45 with hybrid retention. Pre-impregnated glass fibre everSTICK C&B was used in 66 cases, and Ribbond polyethylene fibre was applied to 71 cases.

Table 2. Description of patients and prostheses ($N_{patients}$ = 94, $N_{FRC\ FPDs}$ = 137)

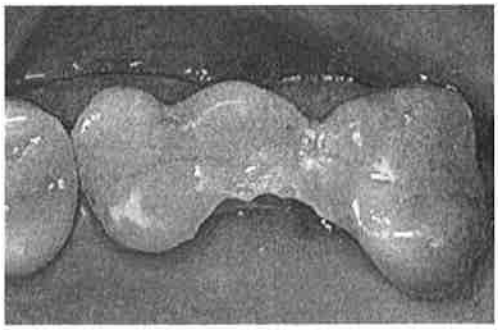
Variable	Anterior	Pre-molar	Molar	Total
Gender				
Male				32
Female				62
Race				
African American				23
Caucasian				58
Hispanic				12
Other				1
Location				
Maxilla	51	34	14	99
Mandible	12	10	16	38
Total	63	44	30	137
Type of retainer				
Surface retained	47	14	2	63
Inlay retained	7	7	15	29
Hybrid retained	9	23	13	45
Fibre material				
Pre-impregnated glass fibre (Stick-tech)	31	21	14	66
Polyethylene fibre (Ribbond)	32	23	16	71

Seventeen FRC FPDs failed during the two-year follow-up period, resulting in a cumulative success rate of 84·32%. Four restorations debonded from one end, four restorations debonded from two ends, and nine FRC FPDs had fractured pontics or delaminated composites (Fig. 2). Fracture/delamination of the composite was the most prevalent failure type (52·94%). The

Distribution of failures

(*N* = 17)

Failure type	Number (%)	Average longevity (month)	Location	Retainer type	Fiber material
Debond from one end	4 (23·5%)	21	8	Surface	Polyethylene (Ribbond)
			9	Surface	Polyethylene (Ribbond)
			18	Inlay	Polyethylene (Ribbond)
			28	Hybrid	Polyethylene (Ribbond)
Debond from two ends	4 (23·5%)	18	5	Surface	Polyethylene (Ribbond)
			12	Hybrid	Polyethylene (Ribbond)
			12	Surface	Glass (Stick-tech)
			19	Surface	Glass (Stick-tech)
Fracture/delamination of composite	9 (53·0%)	24	3	Inlay	Polyethylene (Ribbond)
			8	Surface	Polyethylene (Ribbond)
			8	Surface	Glass (Stick-tech)
			9	Hybrid	Glass (Stick-tech)
			11	Surface	Polyethylene (Ribbond)
			12	Surface	Polyethylene (Ribbond)
			12	Hybrid	Glass (Stick-tech)
			13	Hybrid	Polyethylene (Ribbond)
			22	Hybrid	Glass (Stick-tech)
Fracture of the fiber frame	0				
Fracture of the abutment tooth	0				
Decay of the abutment tooth	0				
Others	0				



Failure of an inlay-retained FRC FPD (Pontic #3) restored with glass fiber (Stick-tech). The prosthesis was determined as a failure at the 24-month follow-up with delamination of the composite at the pontic area.

Fig. 2. Distribution of FRC FPDs failures during 2-year follow-up.

lower left photo in Fig. 2 illustrates the failure of an inlay-retained FRC FPDs restored with everSTICK C&B. The restoration was determined as a failure at the 24-month follow-up with delamination of the composite on the pontic. Seven FRC FPDs were repaired and in clinical function up to 2 years, which resulted in a 92·70% 2-year clinical survival rate.

There were no statistically significant differences among groups with different missing tooth location, retention type, fibre materials or operator experience (the *P*-values obtained from log-rank test >0·05), as shown in Fig. 3.

The FRC FPDs were associated with satisfactory prosthesis adaptation, colour match, marginal discoloration and surface roughness after 24 months (shown in Fig. 4). Evaluation of restoration adaptation to the abutment tooth showed that 95·45% of the restorations were scored as 0% and 4·55% of the restorations were scored as 1, indicating obvious crevice at the margin or dentin/base exposure. Interestedly, all of the cases scored as 1 were from the anterior region. All prostheses were rated as 0 (very good) for colour match at the 24-month follow-up. More prostheses in the molar (20%) and pre-molar (40%) regions were rated as 1 (slightly rough or pitted) for surface roughness than those in the anterior region (8·33%). One case in the anterior region had secondary caries in the abutment tooth.

Patient satisfaction (shown in Fig. 5) was rated high on the VAS (mean >80 mm) for all criteria at baseline, 6, 12 and 24 months. There was no statistically significant difference between the different time points (all $P > 0·05$).

Discussion

Clinical data on FRC FPDs have been published during the past 15 years. However, most of the

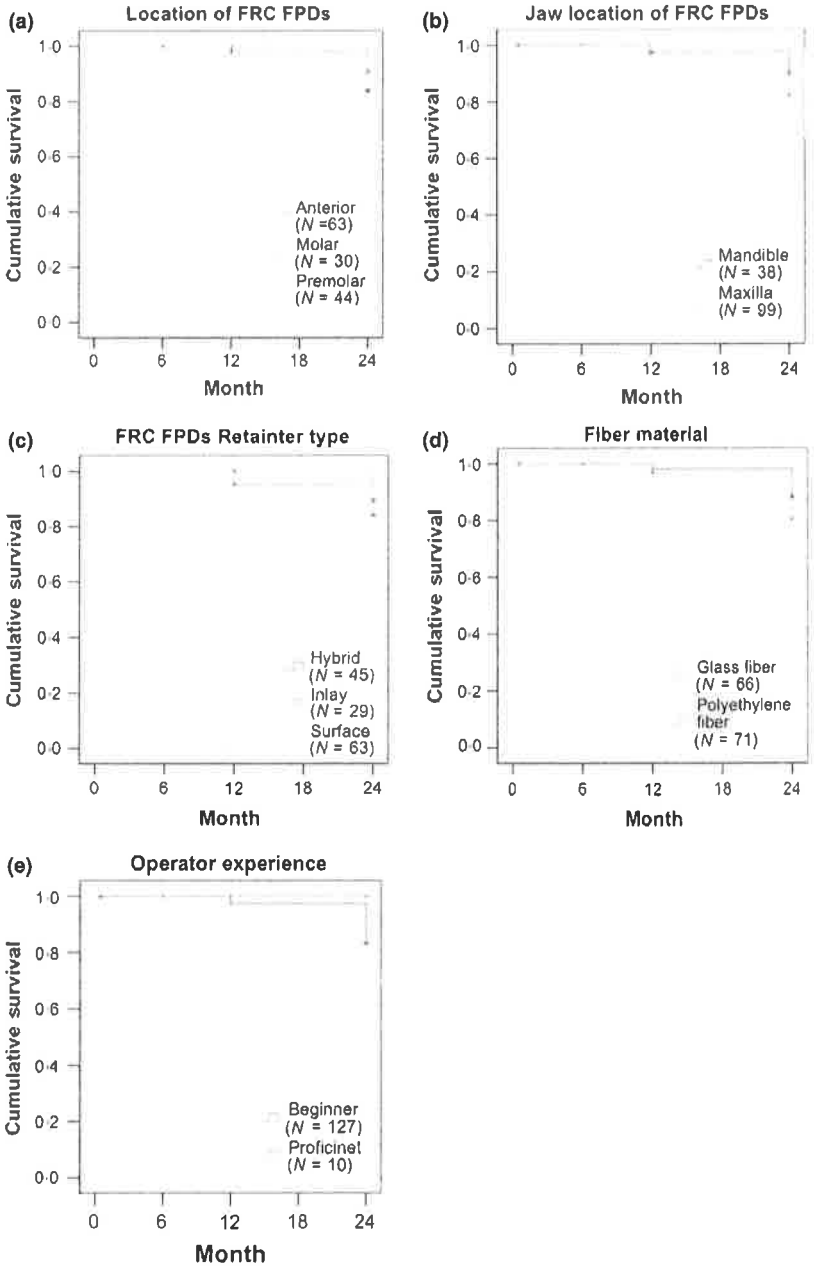


Fig. 3. Success of the FRC FPDs. No statistically significant difference was found between the FRC FPDs in terms of location, retainer type, fibre materials and operator experience (all $P > 0{\cdot}05$). (a–e) show the cumulative survival rate of the bridges dependent on position in the jaw, in which jaw, retainer type, fibre type and operator experience.

publications are case reports or case series. Few clinical studies in directly placed FRC FPDs have been published. A retrospective clinical examination study of 32 directly placed FRC FPDs found a 74·4% survival rate after a mean follow-up of 18·2 months (19). A 3-year clinical evaluation of directly placed FRC FPDs using prefabricated pontics reported 91·3% survival at 2 years and 78·3% at 3 years.(15) A 2-year clinical study of polyethylene FRC inlay-retained FPDs reported 100% survival rate for all 28 prostheses (14). The 2-year success rate of the FRC FPDs in our study is 84·32% and survival rate is 92·7%, which is comparable to that of other studies. Regarding the functional survival rate, some patients did not wish to repair debonded or fractured FRC FPDs, although the prostheses were repairable. These patients chose alternative treatment options instead, such as implants or conventional FPDs. For other patients with repairable failures, we repaired the seven FRC FPDs according to the patient's preference.

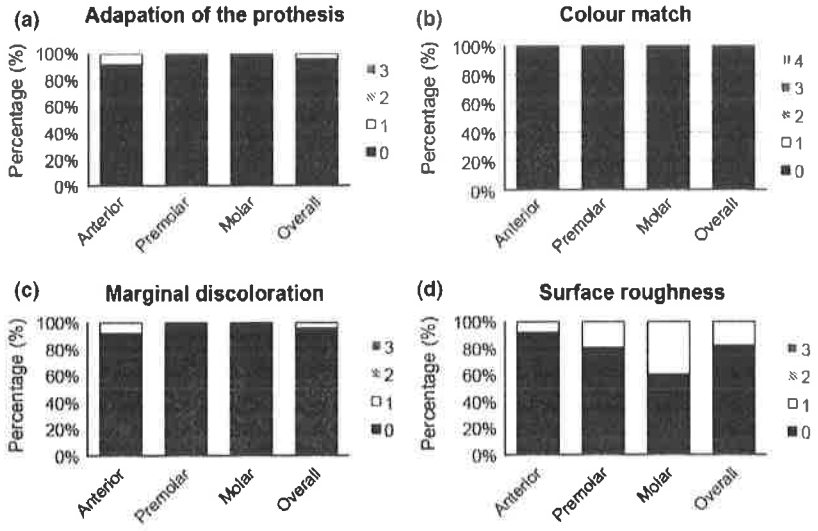


Fig. 4. Clinical performance of FRC FPDs at 2-year follow-up. (a–d) show the result of the following USPHS criteria that were evaluated; adaption of prosthesis, colour match, marginal discoloration and surface roughness.

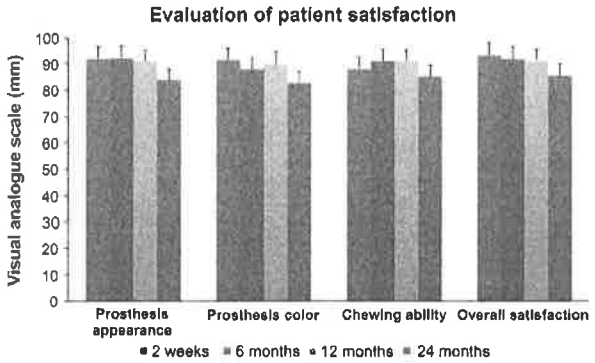


Fig. 5. Evaluation of patient satisfaction of the FRC FPDs.

Compared with the published FRC FPDs studies (14, 15), one of the strengths of our study is its relatively large sample size. The sample sizes of previous studies were 20–50 at initial placement, while in this study, 167 FRC FPDs were directly placed in 120 subjects, and 137 FRC FPDs in 94 patients returned for the 2-year follow-up.

Our prospective clinical study included comparisons between different fibre materials, retention type, missing tooth location and operator experience. Although there was no statistically significant difference detected between groups, the distribution of different variables was within a small number of 17 complications and was analysed with Kaplan–Meier survival curves and multiple log-rank tests, which could affect the outcome when one variable is predominantly an effect of small statistical power and consequently unable to prove that one of these variables is irrelevant for the prognosis of FRC FPDs. Nevertheless, an interesting finding was related to AEGD residents' experience. In this study, in which all failed bridges were fabricated by inexperienced providers, the Kaplan-Meier success estimation did not reveal statistically significant differences between residents with different experience levels. The limitation is that there is only one operator at proficient level. In the published literature, most FRC FPDs were fabricated by dentists experienced in restorative dentistry (1, 22). More research needs to be carried out to investigate the operator experience-related FRC FPDs success.

In our study, the dropout rate was around 20% within 2 years, which could potentially reduce the power of the study. The acceptable success and survival rate in this study over 2 years does support the use of FRC FPDs as a short-term option for replacing a missing tooth, especially if finances are of concern.

Conclusions

In this study, the FRC FPDs (for replacing a single tooth) fabricated by AEGD residents were associated with acceptable success and survival rates in a two-year follow-up period. FRC FPDs success was not affected by missing tooth location, retention type or fibre materials. However, more long-term follow-up is desirable in future studies.

Disclosure/Acknowledgments

The study protocol was approved by the Research Subject Review Board of the University of Rochester,

USA (RSRB #31176). This research was carried out without funding.

Conflict of interests

No conflict of interests declared.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Data S1. Fiber Reinforced Bridge. Patient Satisfaction Survey.