Clinical Survival of Indirect, Posterior Fiber-Reinforced Composite Fixed Dental Prosthesis: Up to 15 Years of Prospective Clinical Follow Up

Keywords

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ABSTRACT

This prospective clinical study evaluated the survival of indirect, posterior fiber-reinforced composite fixed dental prosthesis (FRC FDP). Between June-1999 and June-2000, 58 patients received 65 FCR FDPs made of unidirectional E-glass fibers (Vectris) veneered with resin composite (Signum) that were adhesively cemented (Variolink II). The evaluation protocol involved technical (chipping, debonding or fracture of tooth/restoration) and biological failures (caries, endodontic complications). Altogether, 6 technical failures were observed after a mean observation time of 180 months (survival rate: 89.2%, Kaplan-Meier) in the form of fractures (n=2) and partial debondings (n=4). All defective restorations were repaired or recemented. Secondary caries occurred in one patient after 11 years. The 3-unit posterior FRC FDPs showed good clinical survival rate up to 15 years of clinical function. Limited numbers of experienced failures were due to mainly debonding followed by fracture of the veneering composite.g composite.

INTRODUCTION

Improved adhesion of resin-based materials to enamel and dentin along with the developments in resin composites transformed the application of invasive therapy options to minimal invasive ones in reconstructive dentistry. Missing posterior teeth can be restored with a wide range of therapy options such as partial removable dentures, resin-bonded fixed dental prosthesis (FDP) made of metal-ceramic, all ceramic, fiber reinforced composite (FRC), conventional full coverage tooth- or implant-supported FDPs. Each of these techniques has both advantages and disadvantages, and some of the latter may include overall complexity, with biological and financial costs, and cause difficulties in maintaining oral hygiene.[1]

The earlier version of dental fiber-reinforced composites (FRCs) was made of dimethacrylate resin with reinforced glass fibers incorporated in. These composites encountered difficulties with chairside polymerization and indirect restorations, which resulted in hydrolysis and inadequate adhesive stability over time.[1,2] Semi-interpenetrating polymer network (semi-IPN)-based resin matrix technologies were created to increase adhesion. By creating cross-links between linear polymer chains, these systems lessen phase separation and increase the material's resilience to rupture.[3] Contemporary dental FRCs use continuous silanized glass fibers impregnated with resin, forming a semi-IPN during polymerization, improving bond strength, facilitating stress and load transfer, and ensuring clinical success.[4,5]

Studies on clinical performance of indirect FRC FDPs are limited with relatively short follow-up results.[6] Overall survival rate of 75% and functional survival rate of 93% were reported after a follow-up period of 24 to 63 months.[6] In a recent systematic review where nine studies were included, and the follow-up rate ranged from 2 months to 8 years, the survival rate was reported to be 94.5% at 4.8 years. No differences were reported between the survival of anterior and posterior FRC FDPs, and the significant failure type was veneering material fracture.[7] Unfortunately, meta-analysis can still not be performed due to the heterogeneity of the follow-up periods reported in different articles.

The direct and indirect application options and reduced chairside time with simplified application procedures[8] provide a significant advantage for FRC FDPs. Another advantage is that the survival rate of FRC-FDP is not dependent on the material used. The use of different types of composite materials for the build up of pontic presented no significant difference in survival rates.[9] Different resin cements types for bonding procedure also presented no significant results in survival rate.[10] Even the type of framework material has no significant difference on the survival rates. Maelstrom *et al*. reported no significant difference in the survival rate of glass and polyethylene fibers at 2-year follow-up.[11] Despite the short and irregular follow-up period, systematic review found that the operator's experience level had no effect on the survival rate of FRC FDPs. High survival rates were also demonstrated by FRC FDPs, which provided offered mid-term replacement choices for anterior and posterior single teeth.[7] All results ensures flexibility in means of material choice for a successful FRC FDP treatment. Moreover, since the first systematic review on FRC FDPs which rendered the use of these restorations experimental,[12] the following systematic reviews although mentioned the heterogenity of follow-up times presented an increasing survival rates of FRC FDPs,[6,7] further supporting the use of FRC FDPs as a permanent conservative option. However, the heterogeneity in follow-up times of these studies is an impidement for an evidence based clinical desicion making process for FRC FDP application. There is a need for long-term follow-up in the literature to evaluate long-term performance of FRC FDPs.

Therefore, this clinical study aimed to evaluate the long-term performance of indirect, posterior 3-unit FRC FDPs. The hypothesis was that FRC FDPs would stand the chewing forces and no difference would be found in survival between maxilla and mandible.

MATERIALS AND METHOD

As of January 1999, FRC FDPs are offered as alternative to other conventional therapy options at the of Department of Restorative Dentistry, School of Dentistry, University of Brescia, Italy where the study was conducted. Between June-1999 and June-2000, 58 patients aged between 33 and 62 years old (25 females, 33 males, mean age: 47) received 65 indirect posterior FRC FDPs. Before enrolment in this prospective clinical trial, all patients were provided with a written informed consent. Information was given to each patient regarding the alternative treatment options (ClinicalTrials.gov Identifier: NCT02764463). The study involved people older than 18, years of age, those able to read and sign informed consent, tolerate restorative procedures, have no active pulpal or periodontal diseases, primary caries, allergies, pregnancy, nursing, and have a missing posterior teeth with present antagonist teeth to the FRC FDP, and willing to return for follow-up examinations.

One operator applied all the restorations with experience in adhesive dentistry >10 years since graduation.

In the first session, after an accurate evaluation of spaces and residual dental tissues, the acceptance of this type of treatment by the patient, cavity preparations were made on the abutment teeth not only to remove all carious tissue in some cases but also to create minimum space necessary for the FRC FDP (mesio-distal length: 2 mm; bucco-lingual width: 3.5 mm; occluso-gingival depth: 2.5 mm, divergent proximal boxes, with round internal angles).[13]

A three-step etch and rinse adhesive (Scotchbond Multipurpose, 3M ESPE, St. Paul, USA) was used where cavities were first etched with 37% H_3PO_4 for 30 s, rinsed for 30 s with air-water spray and dried. Adhesive resin was then applied one coat (Scotchbond Multipurpose), air-thinned and photo-polymerized (Astralis 10, Ivoclar Vivadent, Schaan, Liechtenstein; light output: 1200 mW/cm^2) for 40 seconds. Resin composite (Venus, Heraeus-Kulzer, Hanau, Germany) was applied in the cavities in order to eliminate undercuts and increase thickness of thin dentin walls where needed.

Complete arch impressions were made using polyether impression material (Impregum F, 3M ESPE) and provisional restorations were placed using eugenol-free temporary cement (Clip, Voco, Cuxhaven, Germany).

FRC FDPs were made in one dental laboratory on the full arch plaster model. The model was first isolated with two coats of isolation medium. One unidirectional pre-impregnated E-glass fiber bundle (Vectris, Ivoclar Vivadent) was used to reinforce the veneering composite (Signum, Heraeus-Kulzer). Before the fibers were placed on the cast, a thin layer of flowable resin composite (Venus flow, Heraeus-Kulzer) was applied into the cavities on the abutment teeth and the fiber bundle was placed in the bed of the flowable resin using metal instruments. After photo-polymerization of the FRC with a halogen polymerization unit (Astralis 10), the framework was veneered with the resin composite incrementally. The FDP was polymerized for the final time in a heat and photo polymerization unit (Visio Beta, 3M ESPE).

In the second session, after rubber dam placement provisional restorations were removed, the cavities were cleaned with a prophylaxy brush and pumice. After try-in of the FRC FPD for proximal contacts and marginal fit, intaglio surfaces of the FDP were air-abraded (CoJet, 3M-ESPE St. Paul, USA) using 30 µm SiO_2 for 20 s, cleaned with ethanol and air-dried. The cementation surface of the FDP was treated with silane (Monobond S, Ivoclar Vivadent) and resin monomer of the corresponding resin cement accordingly using a microbrush (Heliobond, Ivoclar Vivadent). The resin was left unpolymerized, shielded from light, for 5 minutes to allow the resin to penetrate and activate the interpenetrating polymer network (IPN-phase) of the polymethacrylate polymer matrix of the FRC framework. The cavities were conditioned using a three-step etch and rinse adhesive approach (Scotchbond Multipurpose, 3M ESPE) and FDPs were adhesively cemented using dual polymerized cement (Variolink II, Ivoclar Vivadent). FDPs were photo-polymerized from lingual, labial, mesial, distal, occlusal for 40 s each (Astralis 10, Ivoclar Vivadent, light output: 1200 mW/cm^2).

After polymerization and rubber dam removal, occlusion was adjusted with fine diamond burs (60- and 40-µm grit) and finally, the restoration was polished with pointed silicon polishers (Astropol, Ivoclar Vivadent) and abrasive polishing brushes (Astrobrush, Ivoclar Vivadent) (*Figure 1A-C*). All patients were then included in 6 months recall program.

The evaluation protocol involved technical (chipping, debonding or fracture of tooth/restoration) and biological failures (caries or endodontic complications). After baseline recordings, patients were followed at 6 months and thereafter annually up to 15 years. During their annual hygiene control appointments, FDPs were evaluated by 2 independent operators. Patients were also instructed to call upon experience of a failure in case a failure occurred until their annual appointment.

Data were analyzed using Kaplan-Meier and Log Rank (Mantel-Cox) tests (SPSS 13.0; SPSS Inc., Chicago, IL, USA) (alpha=0.05).

RESULTS

Mean observation time was 180 months. Minimum observation time was 179 months and maximum 184 months.

Of the 65 FRC FPDs, 35 were placed in the mandible and 30 in the maxilla *(Table 1*). No drop out was experienced until the final observation. Sixty-five FRC FPDs reached the 15-year follow-up *(Figure 2A-C)*.

Altogether, 6 technical failures were observed after a mean observation time of 180 months in the form of pontic fractures without fiber fracture (n=2) *(Figure 3A*) and partial debondings (n=4) *(Figure 3B*). Partial debondings were exclusively adhesive failures between the cement and the enamel/dentin. All defective restorations were repaired or recemented. Endodontic complications or tooth fracture were not observed in any of the restored teeth but secondary caries was observed in one patient on tooth 16 after 11 years.

The cumulative survival rate of indirect FRC FDPs were 89.3% (Kaplan-Meier, CI:95%) *(Figure 3*). No significant difference was found between maxilla and mandible (p>0.05) and molar or premolar (p>0.05) (Cox regression analysis).

Figure 1A-C: Representative photos of A) missing 35, B) indirect FRC FDP replacing the missing tooth at baseline, C) FRC FDP at 15 years follow up.

Table 1. Distribution and location of the indirect posterior FRC FDPs cemented in mandible and in maxilla.

	Pontics		Total
	Molar	Premolar	
Mandible	20	15	35
Maxilla	18	12	30
Total	38	27	65

Figure 2A-B: Representative photos of A) fracture of veneering composite on the lingual side of FRC FDP on 25-27 after 49 months of function. Note that the fiber was intact after veneer fracture. B) debonding of FRC FDP from one retainer (17) after 60 months of function.

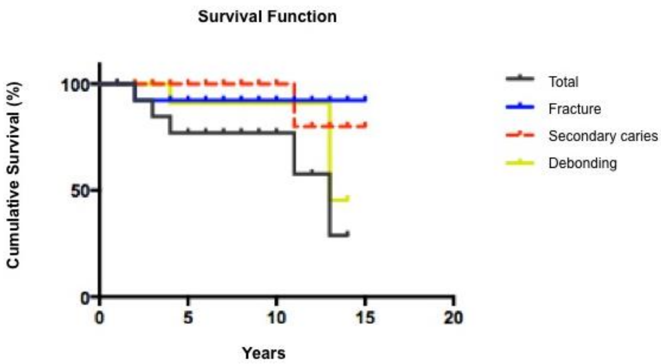

Figure 3: Event-free survival rates of indirect, posterior FRC FDPs in percentage (n=65).

DISCUSSION

According to the results of this study after 180 months, the survival rate of FRC-FDP was 89.2% in 58 patients with 65 restorations, with six technical and one biological failure. No failure was observed the fiber framework in any of the restorations during the follow-up time. The fiber type used in this study was a silanized, pre-impregnated longitudinal E-glass fiber bundle. Each bundle consisted of about 4000 glass fibers (46 wt%), with a diameter of 1.7 mm, embedded in a PMMA/bis-GMA matrix. FDPs were made using only one single bundle in the framework and no additional fibers were placed for the pontic area. Since no fiber fractures were noted, it can be stated that the E-glass fiber used in this study could withstand chewing forces in the posterior region. Since no framework fractures were experienced, and no difference were found between survival in the maxilla and mandible, it can be stated that the FRC FDPs withstood the chewing forces and thus, the hypothesis is accepted.

E-glass has also been the most commonly used frameworks in FRC FDP studies.[10,14-17] Previous studies reported no significant difference in survival rates of FRC FDPs due to use of different frameworks.[7,11] On the other hand, Izgi *et al.* reported increased survival rates with polyethylene fibers (3.3 years) compared to glass fibers (2.9 years). Yet, the authors also acknowledge the difficulty of framework comparison due to heterogenity in follow-up times and small sample sizes.[18]

In another study, Khan *et al.* evaluated the effect of different primers used at different treatment times to condition the surface of semi-IPN FRC surfaces, where they successfully presented a dependent relationship between the application time of the primer and the tensile bond strength of the luting agent to the FRC surface and concluded that a five-minute application is optimal for high bond strength between the FRC surface and the luting agent.[1] In the present study, a five-minute monomer application was also adopted for optimal adhesion between the FRC surface and the luting agent. However, it was also demonstrated that the type of primers does not affect the degree of the monomer conversion of the luting cement.[4]

The most commonly used material for the pontic were microhybrid composite as reported in different studies.[10,11,14,15,17,18] Two studies reported the use of microfilled composites.[9,19] However, no difference was reported between different microfilled composites.[9] Commonly reported failure of FRC FDPs were the fracture of the veneering material.[7] The fracture of the veneering composite could be attributed to the unsupported areas under the composite yielding to cohesive fracture. One other reason could be due to the cohesive strength of the veneering composite itself that was methacrylate based with 78 w% filler content. Future studies should observe the fracture phenomena of FRC FDPs by adding more fibers in the pontic area.

Although excellent adhesion is achieved on enamel, it seemed that shear and torque forces exceeded the adhesive forces between the cement and the enamel/dentin. Interestingly however, after secondary cementation no failures were observed up until final observation period. One reason for debonding could be due to better polymerization and improved degree of conversion of the veneering composite on the FDP in the laboratory polymerization unit.[20] This kind of polymerization would decrease the amount of free monomers that would react with the methacrylate based resin cement. Failure types in the form of debonding at the interface between the abutment teeth and the retainer presents also a major mode of failure, in metal-ceramic[21] or all ceramic resin-bonded FDPs.[22]

The retainer type used in this study was inlay type retainer. Surface, inlay or hybrid (surface and inlay) retainers were used in different studies.[14-16,18,19] No preparation on abutment teeth was also reported previously.[10] However, although inlay preparations were slightly better than surface preparations and no preparation, no significant difference was observed between any preparation type.[11,14,15] The majority of the similar studies on FRC FDPs with mechanical retention with cavities presented a survival rate of ≥ 72% after 2 to 5 years.[6]

One comparable treatment option is metal-ceramic resin-bonded FDPs. An analysis of 60 studies on resin-bonded metal-ceramic FDPs revealed a survival rate of 74% after 4 years[8] while the survival rate for all-ceramic resin-bonded FDPs with two retainers was reported to be 73.9% and one retainer 94.4%.[22] The authors acknowledges that although the present study provides comparable results to previous studies, the small size of the study group with 58 patients, is a limitation for a generalized interpretation of the outcome.

In clinical situations where implant prognosis is questionable and economical limitations are present for other materials, FRC FDPs could be offered as an alternative therapy option.

CONCLUSIONS

Limited numbers of experienced failures with the indirect posterior fiber reinforced composite FDPs up to 15 years in function were due to mainly debonding followed by fracture of the veneering composite.

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DISCLOSURE

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REFERENCES

1. Khan, A.A., Zafar, M.S., Fareed, M.A., *et al.* Fiber-reinforced composites in dentistry - An insight into adhesion aspects of the material and the restored tooth construct. *Dent Mater* 2023; **39**:141-151.
2. Heikkinen, T.T., Matinlinna, J.P., Vallittu, P.K. and Lassila, L.V. Long term water storage deteriorates bonding of composite resin to alumina and zirconia short communication. *Open Dent J* 2013; **30**:123-125.
3. Khan, A.A., Mohamed, B.A., Al-Shamrani, S.S., *et al.* Influence of monomer systems on the bond strength between resin composites and polymerized fiber-reinforced composite upon aging. *J Adhes Dent* 2019; **21**:509-516.
4. Khan, A.A., Al-Kheraif, A.A., Mohamed, B.A., *et al.* Influence of primers on the properties of the adhesive interface between resin composite luting cement and fiber-reinforced composite. *J Mech Behav Biomed Mater* 2018; **88**:281-287.
5. Basavarajappa, S., Perea-Lowery, L., Aati, S., *et al.* The effect of ethanol on surface of semi-interpenetrating polymer network (IPN) polymer matrix of glass-fibre reinforced composite. *J Mech Behav Biomed Mater* 2019; **98**:1-10.
6. van Heumen, C.C., Kreulen, C.M., Creugers, N.H.J. Clinical studies of fiber-reinforced resin-bonded fixed partial dentures: a systematic review. *Eur J Oral Sci* 2009; **117**:1-6.
7. Ahmed, K.E., Li, K.Y. and Murray, C.A, Longevity of fiber-reinforced composite fixed partial dentures (FRC FPD)-Systematic review. *J Dent* 2017; **61**:1-11.
8. Gonzalez, A.M., Piedra-Cascón, W., Zandinejad, A. and Revilla-León, M. Fiber-reinforced composite fixed dental prosthesis using an additive manufactured silicone index. *J Esthet Restor Dent* 2020; **32**:626-633.
9. Cenci, M.S., Rodolpho, P.A.dR., Pereira-Cenci, T., Del Bel Cury, A.A. and Demarco, F.F. Fixed partial dentures in an up to 8-year follow-up. *J Appl Oral Sci* 2010; **18**:364-371.
10. Kumbuloglu, O. and Özcan, M. Clinical survival of indirect, anterior 3-unit surfaceretained fibre-reinforced composite fixed dental prosthesis: up to 7.5-years follow-up. *J Dent* 2015; **43**:656-663.
11. Malmstrom, H. ADellanzo-Savu, A., Xiao, J., *et al.*, Success, clinical performance and patient satisfaction of direct fibrereinforced composite fixed partial dentures—a two-year clinical study, *J Oral Rehabil* 2015; **42**:906-913.
12. Jokstad, A., Gokce, M. and Hjortsjo, C. A systematic review of the scientific documentation of fixed partial dentures made from fiber-reinforced polymer to replace missing teeth. *Int J Prosthodont* 2005; **18**:489-496.
13. Ellakwa, A.E., Shortall, A.C., Shehata, M.K. and Marquis, P.M. The influence of fiber placement and position on the efficiency of reinforcement of fiber reinforced composite bridgework. *J Oral Rehabil* 2001; **28**:785-791.
14. Heumen, C.C.M., van Dijken, J.W.V., Tanner, J., *et al.* Five-year survival of 3-unit fiber-reinforced composite fixed partial dentures in the anterior area. *Dent Mater* 2009; **25**: 820-827.
15. van Heumen, C.C.M., Tanner, J., van Dijken, J.W.V., *et al.* Five-year survival of 3-unit fiber-reinforced composite fixed partial dentures in the posterior area. *Dent Mater* 2010; **26**:954-960.
16. Wolff, D., Schach, C., Kraus, T., *et al.* Fiber-reinforced composite fixed dental prostheses: a retrospective clinical examination. *J Adhes Dent* 2011; **13**:187-194.
17. Frese, C., Schiller, P., Staehle, H.J. and Wolff, D. Fiber-reinforced composite fixed dental prostheses in the anterior area: a 4.5-year follow-up. *J Prosthet Dent* 2014; **112**:143-149.
18. Izgi, A.D., Eskimez, S., Kale, E. and Deger, Y. Directly fabricated inlay-retained glass and polyethylene fiber-reinforced composite fixed dental prostheses in posterior single missing teeth: a short-term clinical observation. *J Adhes Dent* 2011; **13**:383-391.
19. Spinas, E., Aresu, M. and Canargiu, F. Prosthetic rehabilitation interventions in adolescents with fixed bridges: a 5-year observational study. *Eur J Paediatr Dent* 2013;b14:59-62.
20. Souza, R.O., Özcan, M., Michida, S.M., *et al.* Conversion degree of indirect resin composites and effect of thermocycling on their physical properties. *J Prosthodont* 2010; **19**:218-225.
21. Creugers, N.H.J. and Hof van't, M.A. An analysis of clinical studies on resin-bonded bridges. *J Dent Res* 1991; **70**:146-149.
22. Kern, M. and Sasse, M. Ten-year survival of anterior all-ceramic resin-bonded fixed dental prostheses. *J Adhes Dent* 2011; **13**:407-410.