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The influence of framework design on the load-bearing capacity of laboratory-made inlay-retained fibre-reinforced composite fixed dental prostheses

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ABSTRACT

Delamination of the veneering composite is frequently encountered with fibre-reinforced composite (FRC) fixed dental prosthesis (FDPs). The aim of this study is to evaluate the influence of framework design on the load-bearing capacity of laboratory-made three-unit inlay-retained FRC-FDPs. Inlay-retained FRC-FDPs replacing a lower first molar were constructed. Seven framework designs were evaluated: PFC, made of particulate filler composite (PFC) without fibre-reinforcement; FRC1, one bundle of unidirectional FRC; FRC2, two bundles of unidirectional FRC; FRC3, two bundles of unidirectional FRC covered by two pieces of short unidirectional FRC placed perpendicular to the main framework; SFRC1, two bundles of unidirectional FRC covered by new experimental short random-orientated FRC (S-FRC) and veneered with 1.5 mm of PFC; SFRC2, completely made of S-FRC; SFRC3, two bundles of unidirectional FRC covered by S-FRC. Load-bearing capacity was determined for two loading conditions ($n = 6$): central fossa loading and buccal cusp loading. FRC-FDPs with a modified framework design made of unidirectional FRC and S-FRC exhibited a significant higher load-bearing capacity ($p < 0.05$) (927 ± 74 N) than FRC-FDPs with a conventional framework design (609 ± 119 N) and PFC-FDPs (702 ± 86 N). Central fossa loading allowed significant higher load-bearing capacities than buccal cusp loading. This study revealed that all S-FRC frameworks exhibited comparable or higher load-bearing capacity in comparison to an already established improved framework design. So S-FRC seems to be a viable material for improving the framework of FRC-FDPs. Highest load-bearing capacity was observed with FRC frameworks made of a combination of unidirectional FRC and S-FRC.

1. Introduction

A fixed dental prosthesis (FDP) is considered as treatment of choice for replacing missing teeth. Since conventional and implant-retained FDPs are invasive, time-consuming, and expensive the dental profession continues the search for alternatives. One such alternative is a fibre-reinforced composite fixed dental prosthesis (FRC-FDP). FRC-FDPs are basically made of a fibre-reinforced composite framework acting as a stress dissipater and are veneered with particulate filler composite (PFC).

Following the introduction of glass fibre-reinforced composites in the early 1990s (Goldberg and Burstone, 1992), their use increased enormously over the last years (Freilich and Meiers, 2004). Limited information is available on their longevity and clinical behaviour, but the available clinical research showed that FRC-FDPs are able to function acceptably for up to five years (Behr et al., 2003; Freilich et al., 2002; Gohring and Roos, 2005; Vallittu, 2004), with reported five year-survival rates between 73% (Gohring and Roos, 2005) and 93% (Vallittu, 2004).

Regardless of the promising results, typical kinds of failures, like delaminating and chipping of veneering composite, were encountered during clinical function (Behr et al., 2003; Freilich et al., 2002; Gohring and Roos, 2005; Monaco et al., 2003). To overcome these failures, the framework design should be modified to support the veneering composite, and the amount of fibres should be increased to improve the rigidity of the FDP (Freilich et al., 2002). The most frequently used FRC framework consists of a bundle of unidirectional FRC placed in the central part of a FDP (Fig. 1B). It seems that the amount of FRC included in such conventional framework is too little to provide the necessary support and rigidity. A high-volume anatomically shaped FRC framework should be able to deal with these shortcomings.

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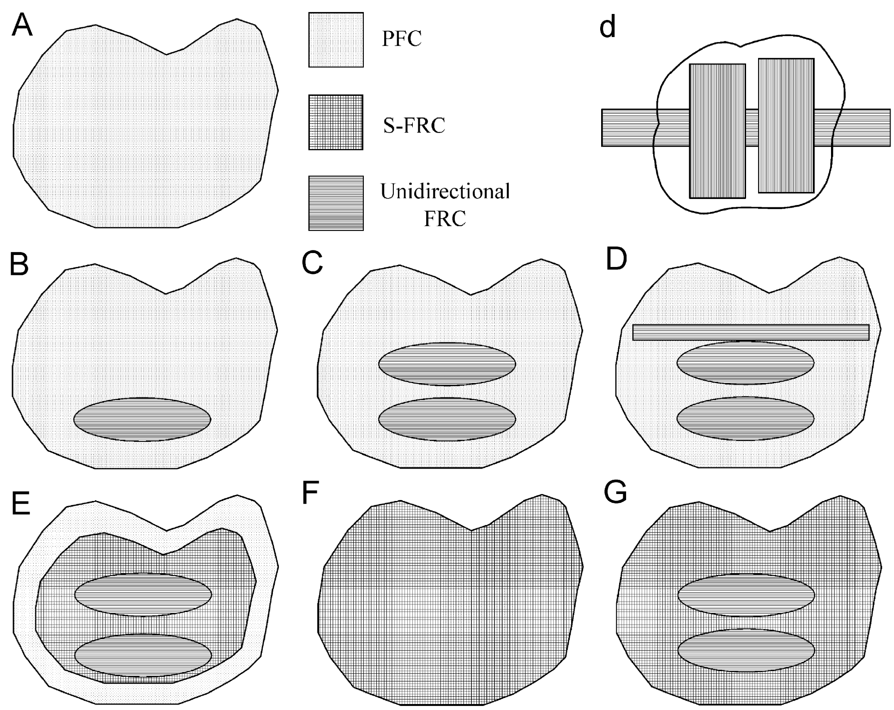

Fig. 1. Graphical representation showing the cross sections of the different framework designs used in this study. (A) PFC: PFC without fibre-reinforcement; (B) FRC1: PFC reinforced with one bundle of unidirectional FRC; (C) FRC2: PFC reinforced with two bundles of unidirectional FRC; (D) FRC3: PFC reinforced with two bundles of unidirectional FRC and two pieces placed perpendicular to the main framework; (d) FRC3: occlusal view; (E) SFRC1: anatomically shaped FRC framework; (F) SRC2: experimental S-FRC; and (G) SRC3: experimental S-FRC and two bundles of unidirectional FRC.

Already some evidence, *in vitro* as well as *in vivo*, is available in the literature on framework design of FRC-FDPs. Behr et al. (2005) tested simulated three-unit FRC-FDPs with one anatomical framework and two conventional framework designs and obtained significant higher fracture resistance for an anatomically shaped framework (902 N) in comparison to conventional frameworks (694 and 737 N). Also Xie et al. (2007) tested the fracture resistance of inlay-retained FRC-FDPs with different framework designs. A framework which supported the pontic area in buccolingual direction showed significant higher fracture resistance compared to conventional and high-volume designs.

Freilich et al. (2002) evaluated the clinical performance of short-span FRC-FDPs and changed during the course of the study, the framework design. The original low-volume framework design, suffered veneer fractures in an early stage. Therefore a high-volume design, which was more rigid and offered more support for the veneering composite, was introduced. The high-volume design showed a 95% survival rate instead 62% for the low-volume design after a mean observation time of 3.75 years. Monaco et al. (2003) investigated the clinical behaviour of inlay-retained FRC-FDPs with conventional and modified framework designs over a period of 12–48 months. The conventional framework design showed a higher failure rate than the modified framework design. In the group of FDPs with a conventional framework design delamination occurred in three cases (16%), while in the modified framework group only one FDP (5%) suffered from chipping.

Short glass-fibres containing fibre-reinforced composite (S-FRC), with semi-interpenetrating polymer network matrix, was recently introduced to dentistry (Garoushi et al., 2007a). Random-orientated S-FRC exhibit isotropic properties in comparison to the anisotropic properties of unidirectional fibres. S-FRC exhibit improved mechanical properties with regard to flexural strength and toughness in comparison to PFC (Garoushi et al., 2007a; Petersen, 2005). Both properties make S-FRC a possible alternative to easily fabricate a high-volume anatomically shaped FRC framework. Garoushi et al. (2007b) showed that short-span FRC-FDPs made of S-FRC exhibited similar load-bearing capacity as conventional FRC-FDPs.

The aim of the present study was to evaluate *in vitro* the influence of framework design on the load-bearing capacity of laboratory-made inlay-retained FRC-FDPs. The null-hypothesis to be tested was that incorporation of S-FRC to FRC frameworks of FRC-FDPs improves their load-bearing capacity and generates a more favourable fracture pattern.

2. Materials and methods

Eighty-four laboratory-made three-unit inlay-retained FRC-FDPs replacing a lower first molar were constructed. The FRC frameworks were made of a commercially available unidirectional E-glass-containing FRC (Everstick C&B, Stick Tech Ltd., Turku, Finland) and a new experimental S-FRC. S-FRC was prepared as described previously (Garoushi et al., 2007a). The FRC frameworks were veneered with hybrid PFC for indirect use (Gradia-dentine A3, GC Corporation, Tokyo, Japan). The materials used in this study and their composition are listed in Table 1.

2.1. FDP preparation

A zirconia model (Ice Zirconia, Zirconzahn, Bruneck, Italy) of a mandibular second premolar, a missing first molar and second molar, prepared to accommodate a three-unit inlay-retained FDP, was created. The inter-abutment distance of 11 mm corresponds with the mesial–distal dimensions of a mandibular first molar. The second premolar received a disto-occlusal inlay preparation (step: 3.0×2.0 mm; box: 1.5×3.5 mm; depth: 2.0 mm) and the second molar a mesio-occlusal inlay preparation (step: 4.0×3.0 mm; box: 1.5×5.0 mm; depth: 2.0 mm) according to the guidelines for composite inlay restorations. Preparations were made with conventional diamond burs (set 4278, Komet, Lemgo, Germany) in a water-cooled airrotor.

The FRC-FDPs were fabricated according to seven different framework designs (Fig. 1):

PFC: made of PFC without fibre-reinforcement.
FRC1: made of PFC reinforced with one bundle of unidirectional FRC.