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Review

Fiber-reinforced dental composites in beam testing

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ABSTRACT

Objectives. The purpose of this study was to systematically review current literature on *in vitro* tests of fiber-reinforced composite (FRC) beams, with regard to studies that followed criteria described in an International Standard. The reported reinforcing effects of various fibers on the flexural strength and elastic modulus of composite resin beams were analyzed.

Sources. Original, peer reviewed papers, selected using Medline from 1950 to 2007, on *in vitro* testing of FRC beams in comparison to non-reinforced composite beams. Also information from conference abstracts (IADR) was included.

Data. With the keywords (fiber or fibre) and (resin or composite) and (fixed partial denture or FPD), the literature search revealed 1427 titles. Using this strategy a broad view of the clinical and non-clinical literature on fiber-reinforced FPDs was obtained. Restricting to three-point bending tests, 7 articles and 1 abstract (out of 126) were included. Finally, the data of 363 composite beams were analyzed. The differences in mean flexural strength and/or modulus between reinforced and unreinforced beams were set out in a forest plot. Meta-regression analyses were performed (single and multiple regression models).

Conclusions. Under specific conditions we have been able to show that fibers do reinforce resin composite beams. The flexural modulus not always seems to increase with polyethylene-reinforcement, even when fibers are located at the tensile side. Besides, fiber architecture (woven vs. unidirectional) seems to be more important than the type of fiber for flexural strength and flexural modulus.

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1. Introduction

Fiber-reinforced composites (FRCs) are generally being used in engineering applications. An important feature of composites is their ability to tailor the material until it meets the design requirements, which makes FRC highly suitable for a wide range of dental applications like removable dentures, root canal posts, provisional restorations and fixed partial dentures (FPDs) [1]. Although the use of the material is growing, the clinical behavior is not fully understood. A systematic review on scientific documentation of commercially available FRCs shows poor evidence to support their clinical use as an alternative for conventional materials [2].

Laboratory findings, however, point at a justified use of FRCs for specific applications. Generally, mechanical properties of FRC structures have been found to be superior to that of non-reinforced composites *in vitro* [3,4]. In high stress bearing areas a material with high flexural strength, high elastic modulus and low deformation as well as high impact and fatigue resistance is required. The mechanical behavior of FRCs has been researched extensively, but studies in this area have been conducted with many different materials and performed with different aims [4–7].

The mechanical behavior of FRC is complex compared to particulate filler composite. Properties of FRCs can range from isotropic to anisotropic and the behavior of the construction is influenced by the volume, location and direction of the fibers [4,8–10]. Laboratory investigations on FRC FPDs have favored the use of long continuous fibers located in the tensile area of the construction, with strands perpendicular to the direction of the applied load [1,9].

Three-point bending tests specifically simulate the loading of an overlying bridge construction, such as an FPD. Several studies have investigated properties like the flexural strength of FRC beams on the basis of these tests [11–13]. However, test conditions vary in construction design, span length and geometry of the beams, and loading speed and geometry of the loading apparatus. The same materials have been used with various amounts of incorporated fibers leading to different results [14,15]. A standard three-point bending test has been published by the International Standards Organization (e.g. ISO 4049). The ISO 4049 describes the preparation of a test specimen and the use of a universal test apparatus for bending tests on composite beams [16]. Several studies have been published using this standard test, but an overall view of the reinforcing effect of FRC in particulate composite beams is lacking.

It can be hypothesized that fiber-reinforcement increases both flexural strength and modulus of resin composite. Also it is expected that there is a difference in the effect of fiber-reinforcement on the mechanical properties between glass fibers or polyethylene fibers, the most commonly used fibers in dentistry, and other relevant characteristics. With respect to this hypothesis the objective of this study is to evaluate the *in vitro* reinforcing effects of fiber material on the flexural strength and elastic modulus of composite resin beams (FRC beams). A structured review is performed on the dental literature with regard to the criteria as described in the ISO test 4049.

2. Materials and methods

This review consisted of: literature search and selection, conference abstract search and selection, inclusion/exclusion of papers, extraction of data and statistical analysis. The literature was searched with an electronic database (Medline) with the year limits 1950 to December 2006 as well as the Cochrane Library of Clinical Trials. Keywords used were (fiber or fibre) and (resin or composite or fixed partial denture or FPD). The electronic search was carried out to obtain a broad view on FRCs in fixed partial denture applications. The result of this search was used as a 'pool' to select studies on bending tests with composite beams. Two independent readers (CvH and CK) carried out a selection of the references found on the basis of abstracts as published in Medline. If no abstract was available in Medline the selection was done on the basis of the title of the article. The emphasis of this first step in the review procedure was on inclusion of references using the criteria shown in Table 1. For this step, and also for subsequent steps, disagreements were resolved by discussion.

The second selection step was carried out on the basis of the Materials and Methods sections of full text copies of the selected references by the two readers. *In vitro* studies in which FRC beams were subject of the study were selected. Moreover, reference lists of the selected papers were handsearched to identify additional *in vitro* studies on composite beams. Criteria as shown in Table 1 were used for inclusion. Additionally, the search for conference abstracts, specifically on *in vitro* beam testing, was carried out by the two independent readers, by searching the IADR abstracts on the website of the *Journal of Dental Research*, with year limits 2000–2007. Keywords used were fiber, composite, strength, fixed partial denture and three-point bending test.

The selection procedure in step 3 specifically identified some predetermined test conditions as described in ISO 4049