A comparative study of the flexural strength of two systems for fiber-reinforced prosthesis*

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ABSTRACT

Continuous fiber-reinforced composites (FRC) have been developed to replace the metal framework in fixed partial dentures (FPD), over which a particulate composite esthetic veneer is applied. The manufactures of these products pledge that this replacement improves the esthetic properties with no compromise of the physical ones. This study evaluates the flexural strength of two pre-impregnated systems of FRC used in FPD: Targis/Vectris (Ivoclar/Vivadent) e Sculpture/Fibrekor (Jeneric/Pentron). Twenty 4mmx4mmx20mm test specimens of each system were made in a stainless steel mold with the fibers in the center along the bars, totally covered by the particulate composite. Specimens were subjected to a three point bending with a MTS testing machine with a constant strain rate of 1mm/min and a 250 KN load. Results were statistically analyzed by the non-parametric Mann-Whitney test. One sample of each system was analyzed in scanning electronic microscope. Targis/Vectris System showed higher flexural strength statistically significant at 5% than the Sculpture/Fibrekor System, therefore the Sculpture/Fibrekor System showed less variation in results.

UNITERMS

Composite resin, fiber-reinforced composites; flexural strength.

MOURA JÚNIOR, J. R. S. et al. Estudo comparativo da resistência flexural de dois sistemas de prótese parcial fixa sem metal. **PGRO – Pós-Grad Rev Odontol**, v.5, n.2,p.6-12 maio/ago. 2002.

RESUMO

Atualmente, foram desenvolvidos alguns sistemas para a confecção das próteses parciais fixas (PPF) onde a estrutura metálica tradicionalmente utilizada como reforço foi substituída por diferentes tipos de fibras associadas a uma matriz resinosa. Sobre este conjunto de fibras uma camada de resina composta é utilizada como material estético de recobrimento. Os fabricantes destes sistemas alegam que esta substituição melhora as propriedades estéticas sem prejuízo às propriedades físicas. Objetivou-se neste estudo avaliar a resistência à flexão de dois destes sistemas: Targis/Vectris (Ivoclar/Vivadent) e Sculpture/Fibrekor (Jeneric/Pentron). Vinte corpos-de-prova de cada sistema foram confeccionados em um molde de aço inoxidável com as dimensões de 4mmx4mmx20mm, sendo que o conjunto de fibras foi totalmente recoberto pela resina composta de revestimento. Os ensaios foram realizados em máquina servo-hidráulica MTS com velocidade de 1mm/min e célula de carga de 250 KN. Os resultados foram analisados estatisticamente pelo método não-paramétrico de Mann-Whitney. Uma amostra de cada sistema foi analisada em Microscópio Eletrônico de Varredura (MEV). O Sistema Targis/Vectris apresentou resistência flexural superior estatísticamente significante a 5%, do que o Sistema Sculpture/Fibrekor, porém o Sistema Sculpture/Fibrekor apresentou menor variação nos resultados.

UNITERMOS

Resinas compostas; resinas reforçadas com fibras; resistência à flexão.

INTRODUCTION

Traditionally metal-ceramic fixed partial dentures (FPD) has been the choice to replace a single missing tooth, and has demonstrated excellent clinical results over the years, however showing some disadvantages. The metallic framework is extremely unaesthetic needing opaque porcelain and a sufficient amount of body porcelain over the structure to mask it, what can't always be properly accomplished. Base metal alloys commonly used in clinical practice may exhibit corrosion and also

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may elicit an allergic reaction from a segment of the patient population. Porcelain is a brittle material and has the potential to fracture and break away from the metal as observed by Freilich et al.[9,11]. In addition, metal-ceramic FPD need extensive preparations in the retainers[21] .

Some systems have been developed where a bundle of long continuous glass or polyethylene fibers impregnated with resin matrix is used to replace the metallic framework from the FPD. This replacement improves the aesthetic characteristics of the FPD, because these fiber-reinforced composites (FRC) are translucent and still maintain the physical properties needed to support masticatory efforts[7].

A layer of particulate covering (veneering) composite is used over the FRC to give the adequate shape to the FPD, similar to natural teeth. Some of these veneering composites are called ceromers (*CERamic Optimized polyMER*) and are made of fine and three-dimensional ceramic particles, specially homogenized, densely packed and impregnated in organic matrix, with an outstanding potential for polymerization by light and heat, allowing better function and aesthetics[2].

These systems may be bonded to the retainers, using dental adhesives and resin cements, which is an advantage over the conventionally cemented metal-ceramic FPD. In small prosthetic spaces where the abutment teeth have none or small restorations a minimally invasive (intracoronal) preparation may be done, avoiding unnecessary loss of tooth structure. In addition usually these preparations are supragingival, avoiding damage to the periodontal tissues[7, 19, 21, 27].

Fiber-reinforced materials have been reported in dental literature since early 1960's, although the more recent availability of commercial products is just now leading to recognition and general clinical use. The most widely described clinical application of fibers has been as reinforcement for denture base resins, followed by its use in splints and retainers[17, 22, 25, 26, 28].

Polyethylene or glass fibers have also been described for use in provisional acrylic FPD. Description of fiber-reinforced FPD framework is only recent, even though this has become an important clinical application[10, 13].

Fiber-reinforced composites used as FPD framework are frequently subjected to bending forces during mastication. Even though clinical performance is the final determinant of success, flexural strength is still the mechanical property most related in dental literature and the results of flexural strength tests are useful in selecting and developing materials[11].

Two commercial pre-impregnated fiber-reinforced systems are available for dental laboratories, and even though they have similar indications, they also have differences in their formulations and, specially, variations in handling which may indicate a higher flexural strength of one system over the other.

MATERIALS AND METHODS

Forty test specimens were divided into two groups of twenty samples each, and each group utilized one of the two FRC systems used in FPD: Sculpture/FibreKor (Jeneric/Pentron), called System A, and Targis/Vectris (Vivadent/Ivoclar), called System B.

The samples were made in shape of a rectangular bar with 4mm high, 4mm wide and 20mm long, with the bundles of fibers in the center.

Two 7mmX14mmX27mm stainless steel matrix sets were used to make the test bars. Each set consisted of two plates fixed upon a base plate (Figure 1A). The plate closer to the base showed an opening of 4mm X 20mm and was 1mm thick (1st. Stage), and over it the other plate had the same opening and was 3mm thick (2nd. stage) (Figure 1B). This set allowed one to place a first layer of composite of the correspondent system with 1mm of thickness with just the 1st. stage fixed on the base. Once this layer had been polymerized, the other plate was fixed to the set and the bundle of fibers was placed in the center of the opening onto the previously polymerized composite. Then the whole opening was filled with more composite and polymerized. This procedure allowed a standardization of the making of the test bars with the bundle of fibers in its center, as it is used in FPD (Figure 2).

One of each matrix was sent to different commercial laboratories. Each laboratory was accredited by one of the companies that manufacture the systems used in this study. Just one technician in each laboratory made the bars accordingly to the instructions of the manufacturers.

The test specimens once made were stored in physiological solution at environmental temperature for at least 48 hours before the test[24].

Flexural strength was obtained by subjecting the test bars to fracture in a three point bending test (10mm span - distance between the supports) with a MTS testing machine, model 810.23M, with a constant strain rate of 1mm/min and a 250 KN load.

All test bars were positioned in a way that the first polymerized layer contacted the needle, for test standardization.

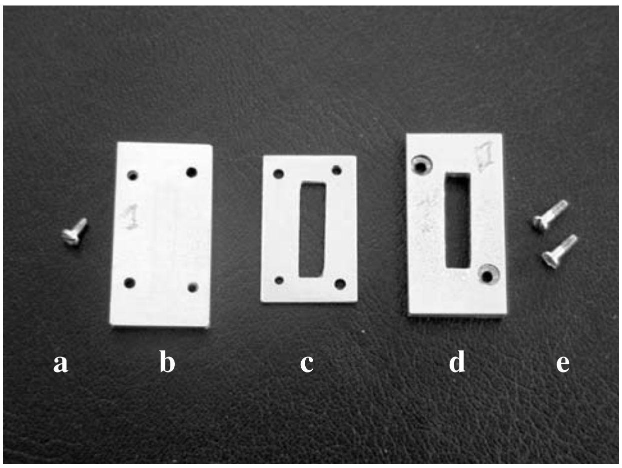

FIGURE 1A – Parts of the matrix:
a– Screw to fixate 1st. stage to base, b– Base plate, c First stage plate, d– Second stage plate, e– Screws to fixate 2nd. stage to the set.

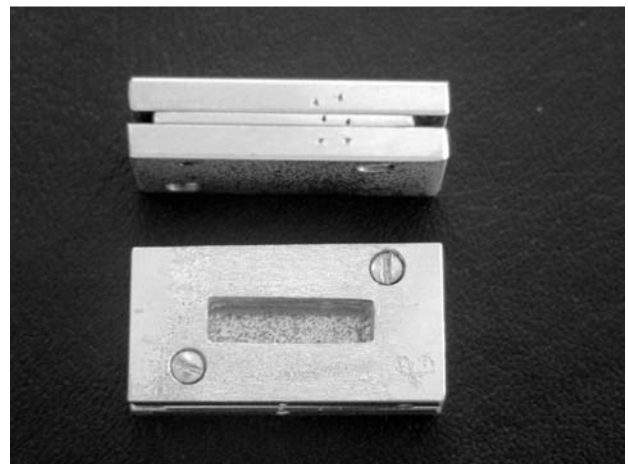

FIGURE 1B – Matrices after mounting in lateral and frontal view.

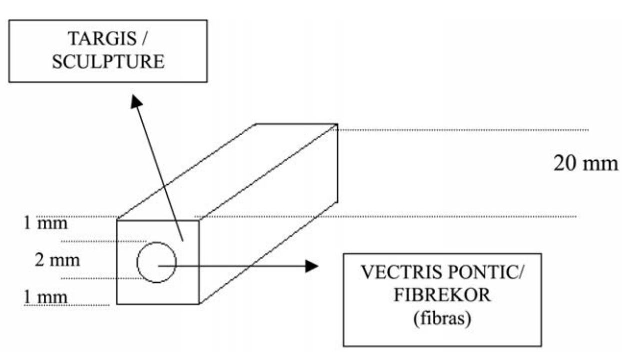

FIGURE 2 – Schematic representation of a test specimen.

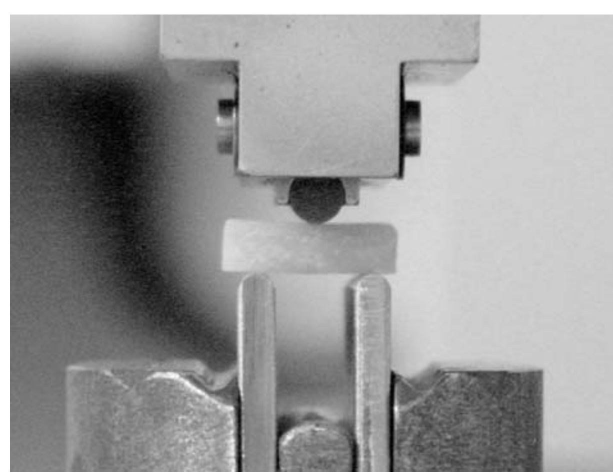

FIGURE 3 – Flexural test where the needle presses the test speci men placed over the supports in the test machine, until the lower surface fractures.

The mathematical equation suggested by Phillips[23] in 1993 to calculate the flexural strength was:

$$S = \frac{3\,WL}{2\,bd^2}$$

Where: W= maximum load before fracturing (Newton); L= distance between the supports (meters); b= width of the test bar (meters); d= depth or thickness of the test bar (meters); and S= Flexural resistance (Pascal).

The results were analyzed by the "U" test of Mann-Whitney.

One sample from each group was randomly chosen to be transversally sectioned, polished and analyzed in the scanning electronic microscope (SEM) to check the interface of the fibers with the resin matrix and of the fiber bundle with the veneering resin.

Results

The mean values of flexural strength and standard deviation of the two systems are shown on Table 1.

The "U" test of Mann-Whitney showed that there is a statistically significant difference at 5%, meaning the mean values are different.

The SEM analyzed samples showed adhesion between the bundle of fibers and the veneering composite, which is due to the compatibility of the resin matrices[3] (Figures 4 and 5).

Table 1 – Values obtained from statistical analysis (MPa = Pa x10^6)

	Mean (MPa)	Standard Deviation (MPa)
System A *Sculpture/Fibrekor*	113,16	22,68
System B *Targis/Vectris*	185,29	47,82

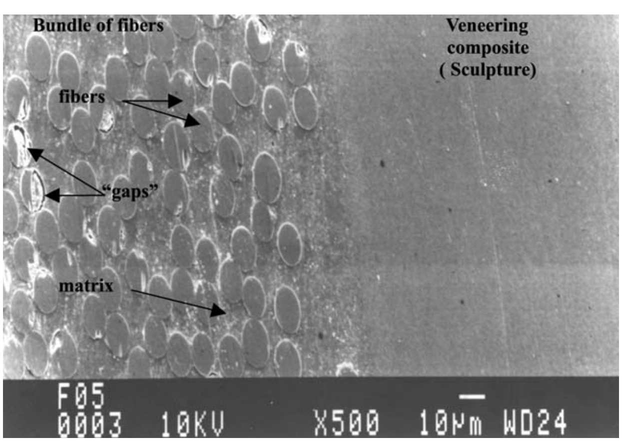

FIGURE 4 – Adhesion of the bundle of fibers to the veneering composite of Sculpture/Fibrekor (500X).

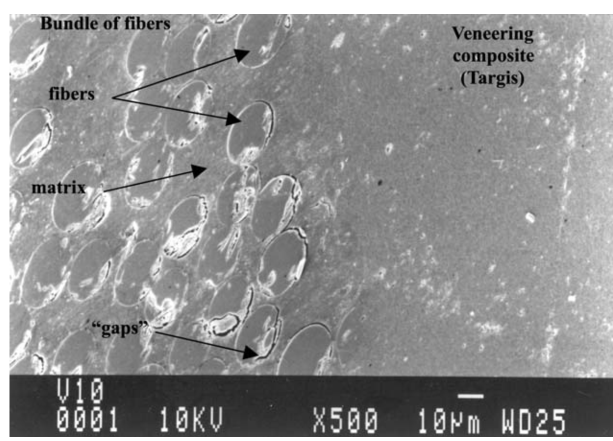

FIGURE 5 – Adhesion of the bundle of fibers to the veneering composite of Targis/Vectris (500X).

Discussion

The statistical analysis of the values obtained in the flexural test showed a significant difference between the mean values of the systems used in this study. Some factors such as variations in their formulations and in handling might have had a role in these results.

System A (Sculpture/Fibrekor) needs its bundle of fibers to be condensed manually up to the desired thickness, and then light-initiated. However, System B already comes with the fibers in the desired thickness from the manufacturer and the technician only needs to light initiate it under pressure in vacuum, which results in a larger content of fibers[18]. According to Freilich et al.[11] the resistance of the FRC depends on the properties and volume of the fibers. Behr et al.[1], on the other hand said that the greater volume of fibers won't lead necessarily to a higher flexural strength, what differs from our findings.

Behr et al.[1], Dyer & Sorensen[5] and Harlow et al.[16], in their studies used just the bundle of fibers in a resin matrix, which doesn't reflect the way these materials are used in dentistry, as they should be completely covered by the veneering composite. It's not recommended for these fibers to be exposed to the oral environment, because according to Giordano[12] it may cause gingival irritation and plaque retention.

Karmaker et al.[18] stated that the position of the fibers in the test specimens that shows the highest resistance values is when they are under traction. This situation occurs when during the flexural test, the needle presses the test bar causing compression on the side of the bar it touches, and causing tension on the opposite side. These authors used as test specimens bars with the veneering composite laminated over the bundle of fibers, but we chose to use a test specimen with the veneering composite all around the fibers, which represents more likely a clinical situation.

During the test we found that the first fracture happened in the veneering composite surface opposing the needle, and not in the bundle of fibers. That was expected because of the test bar we used, with the fibers completely surrounded by the composite, showing inferior values in this type of test than those obtained by Dyer & Sorensen[5], Goldberg et al.[14] and Harlow et al.[16], where they used just the bundle of fiber with no veneering composite.

Comparatively, the results obtained by Lysak et al.[20], using just the composite without fibers in a flexure test were inferior to ours. As stated by Ramos Júnior et al.[24], the fiber-reinforcement within the composite offers resistance to fracture and prevent from fragment separation.

The fibers in both systems are unidirectional and parallel, and according to Bottino et al, *apud* Gorab & Feller[15], implies in higher flexural strength. The fibers may be spaced while being handled which may be an advantage or a disadvantage depending on the technique. In spite of a higher volume of fibers offering greater resistance, too many fibers may cause a lack of matrix impregnation, leading to less resistance of the system.

These systems were chosen because they're resin matrix pre-impregnated by the manufacturer, resulting in a more homogeneous material allowing it to support two or three times more load than those manually impregnated as stated by Freilich et al.[10].

The bonding between the fibers with the matrix resin could be observed in the SEM, as well as the bonding between the bundle of fibers and the veneering composite, which may result in a material with flexural properties similar to the most common alloys used in FPD[8].

On the other hand, some gaps within the bundle of fibers could also be observed, which may lead to diminishing the resistance. A larger diameter of the fibers in the System B was also visualized.

On Figure 6 a statistical analysis of the results may be found, with a greater variation of values on System B. Even though system B showed a higher mean value than System A, the greater variation of its results around the mean value inspires doubts towards its clinical performance. We wonder if a system with such a range of results could be reliable, as some of its values are similar to System A.

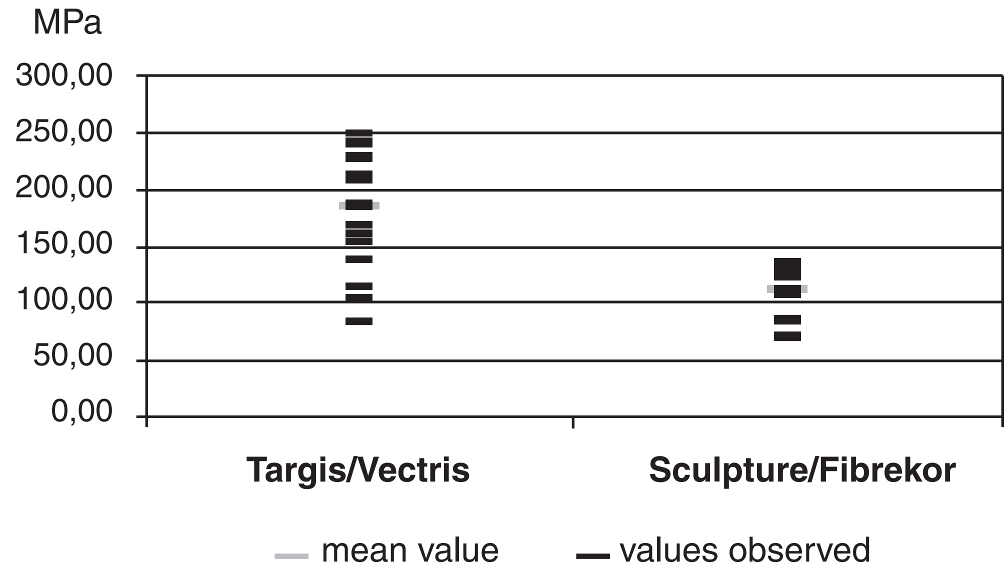

FIGURE 6 – Frequency of the values obtained in the flexural test.

The behavior of System A seems more consistent, with less variation, even with a mean value inferior to System B.

The use of FRC as substitutes of the metallic framework of FPD inspires caution, as the longevity of these systems is still not established. The Dental Advisor[4], mentioned some concerns regarding the use of these systems, such as resin discoloration, displacement after cementation and possible post-operative sensitivity caused by masticatory forces, as these materials are not rigid as ceramics. Other observations and studies, as well as clinical analysis, are necessary to establish long-term resistance of these materials.

For now, it seems reasonable to keep the use of FRC limited to three-unit FPD with a small prosthetic space, in a situation where an osseo integrated implant can't be used, and specially when the abutment teeth are unrestored or have modest intracoronal restorations. However, it is important during intracoronal preparation to allow enough space at the connector area to a significative volume of material, because it's in this area that most of the tension is concentrated in the FPD[6].

Another advantage of these systems is the possibility of repairing them intraorally in case of small cracks or fracture, as frequently they don't fail completely. As in this study, usually the fractures only happen in the veneering composite, with the fibers maintaining the fragments in place and bonded to the abutment teeth.

Conclusions

The study carried as shown allowed to the following conclusions:

- System B Targis/Vectris showed a higher flexural resistance than System A Sculpture/Fibrekor.
- System A Sculpture/Fibrekor showed less variation in results when compared to those of System B Targis/Vectris.

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