Brazilian Dental Science
Ciência Odontológica Brasileira
unesp
UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE

doi: 10.14295/bds.2013.v16i1.854

Influence of glass fiber reinforcement and resin viscosity on the resistance to fracture of Adhesive Partial Fixed Prostheses

Influência do reforço de fibra de vidro e viscosidade da resina sobre a resistência a fratura de Prótese Parciais Fixas Adesivas

Taciana Marco Ferraz CANEPPELE[1], Ingrid Oliveira SILVA[3], Alessandra Buhler BORGES[1], Alexandre Luis Souto BORGES[2], Carlos Rocha Gomes TORRES[1]

1 - Institute of Science and Technology - UNESP – Univ. Estadual Paulista - São José dos Campos (SP) - School of Dentistry - Department of Restorative Dentistry.

2 - Institute of Science and Technology - UNESP – Univ. Estadual Paulista - São José dos Campos (SP) - School of Dentistry - Department of Dental Material and Prothesis.

3 - DDS - Clinician

ABSTRACT

Objective: The aim of this study was to evaluate the influence of glass fiber reinforcement and resin viscosity on the resistance to fracture of adhesive fixed partial prosthesis (AFPP). **Materials & Methods:** A stainless steel molding was constructed simulating oclusal preparation for AFPP on a maxillary first pre-molar (4 x 4 x 2 mm) and molar (6 x 4 x 2 mm), with a proximal slot (2 x 1 x 4 mm) and with 7 mm of distance between them. These moldings were duplicated in polyurethane (n = 60) and divided into two groups according to the resin viscosity: G - Grandio SO (VOCO) (n = 30) and GHF - Grandio SO Heavy flow (VOCO) (n= 30). These groups were subdivided into three subgroups according to the glass fiber reinforcement used (n = 10): Subgroup N - without glass fiber reinforcement; Subgroup V - GRANDTEC (VOCO); subgroup S – everStick C & B (Stick Tech). Four increments divided into 2 layers, 2 in the lower part and 2 in the upper part of the preparations were light-cured according to the manufacturers' instructions. A vertical load was applied on the center of the pieces at a speed of 1mm/min. Data were obtained in Kgf and submitted to two-way ANOVA and Tukey test ($\alpha = 0.05$). **Results:** ANOVA showed significant differences for glass fiber reinforcement. Subgroup N (24.45 ± 3.60)a was significantly different from subgroup S (32.54 ± 6.94) b and subgroup V (37.18 ± 5.33) c. **Conclusion:** The glass fibers tested were capable of improving the resistance to fracture of AFPP. GRANDTEC fiber exhibited the greatest values of resistance to fracture and for the resins studied the viscosity did not influence on the resistance to fracture of AFPP.

KEYWORDS

Glass fiber reinforcement; Adhesive partial fixed prostheses; Resin Composite.

RESUMO

Objetivo: O objetivo deste estudo foi avaliar a influência do reforço com fibra de vidro e viscosidade da resina na resistência à fratura de prótese parcial fixa adesiva (PPFA). **Material e Método:** Um molde de aço inoxidável foi confeccionado simulando preparos oclusais para PPFA em primeiro pré-molar superior (4 x 4 x 2 mm) e molar (6 x 4 x 2 mm), com uma caixa proximal (2 x 1 x 4 mm) e 7 mm de distância entre eles. Esses moldes foram duplicados em poliuretano (n = 60) e divididos em dois grupos de acordo com a viscosidade da resina: G - Grandio SO (VOCO) (n = 30) e GHF - Grandio SO Heavy flow (VOCO) (n = 30). Estes grupos foram subdivididos em três subgrupos de acordo com o reforço de fibra de vidro utilizado (n = 10): Subgrupo N - sem reforço de fibra de vidro; Subgrupo V - GRANDTEC (VOCO); subgrupo S – everStick C & B (Stick Tech). Quatro incrementos divididos em 2 camadas, 2 na parte inferior e 2 na parte superior dos preparos foram fotopolimerizados de acordo com as instruções dos fabricantes. Uma força vertical foi aplicada no centro das peças a uma velocidade de 1 mm/min. Os dados foram obtidos em Kgf e submetidos a ANOVA a 2 fatores e teste de Tukey ($\alpha = 0,05$). **Resultado:** A ANOVA mostrou diferenças significativas para reforço de fibra de vidro. Subgrupo N (24,45 ± 3,60) a foi significativamente diferente do subgrupo S (32,54 ± 6,94)b e subgrupo V (37,18 ± 5,33)c. As fibras de vidro testadas foram capazes de melhorar a resistência à fratura de PPFA. **Conclusão:** A Fibra GRANDTEC apresentou os maiores valores de resistência à fratura e, para as resinas estudadas, a viscosidade não teve influência na resistência à fratura de PPFA .

PALAVRAS-CHAVE

Reforço por fibra de vidro; Prótese parcial fixa adesiva; Resina composta.

INTRODUCTION

With the advancement of dentinal adhesives and the aesthetical evolution in Dentistry, the composites were largely used in posterior restorations. The significant improvements of many materials are observed in the new generation of them. However, two main concerns are still present: the mechanical resistance and the polymerization contraction [1-3].

Additionally to the use for the construction of single restorations, because of the growing aesthetical challenge and relatively low cost, resin composites have been used to construct adhesive fixed prostheses both in the anterior and posterior areas, therefore increasing the risk of failures because of a greater mechanical need [4,5]. To adequate to this situation, reinforcement fibers were associated with resin composites aiming to provide a higher mechanical behavior, resulting in a better clinical performance, mainly regarding to flexure and marginal infiltration [2,6-11]. The efficacy of fiber reinforcement depends on several variables, including the resin used, the amount of fibers in the resin matrix [12], length, shape and orientation [13], their adhesion to the matrix polymer and impregnation of the fibers by the resin [14]. The Law of Mixtures indicates that with the increase of the proportion of the fiber content of a specimen, the attribute of the composite performance is closer to that of the fiber component [15]. Moreover, the fiber geometry inside a structure can influence the modulus of elasticity and the hardness [13].

The development of the technology of the composites reinforced with fiber opened the way of manufacturing metal-free restorations, single crowns, and fixed partial dentures with durability and good aesthetics, especially in the anterior area [7,9], which could replace the approach employing ceramic materials exhibiting disadvantages such as need of removing a greater amount of sound dental structure and higher cost [16]. However, the literature reports fracture occurrence or composite delamination when a fiber-reinforced prosthesis is used in high stress areas, such as the posterior region [4,17]. With the advent and creation of new generations of glass fiber-based materials and the appearance of new experimental composites would result in improvements in the longevity of more conservative and lower cost treatments.

The aim of this study was to compare the flexural strength of AFPP simulated in resin composite, with or without glass fiber reinforcement, evaluating the influence of the fiber reinforcement and the resin type employed. The null hypotheses tested were:

- The use of resins of different viscosities would not interfere on the flexural strength of the AFPP;
- The use of different types of reinforcement fibers did not interfere on the flexural strength of the AFPP.

MATERIAL AND METHOD

Matrix construction

Firstly, a testing situation simulating a type of AFPP infrastructure was idealized. Through using a stainless steel matrix which simulated occlusal and approximal preparations comprising: a pontic space of 7 mm; approximal slots of 1 x 4 x 2 mm^3 at both sides; direct right occlusal preparation of 4 x 4 mm^2; direct left occlusal preparation of 6 x4 mm^2 and with a thickness of 2 mm (Figure 1), a silicon impression (Odorsil - Artigos Odontologicos Classico S.A., São Paulo-SP, Brazil) was made following the manufacturers' instructions and resulting in 60 polyurethane matrixes (F16 – Axson, Cergy, France).

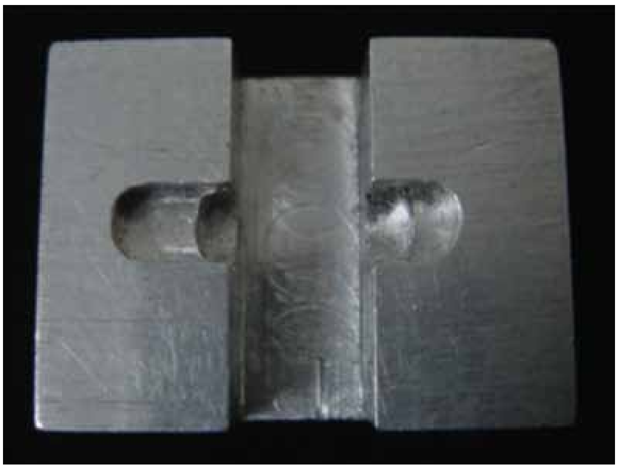


Figure 1 - Stainless steel matrix simulating preparations for adhesive fixed partial prosthesis.

Construction of the specimens

The polyurethane matrixes were divided into 2 groups (N = 30) according with the resin composite used: Group GHF: Low-viscosity resin composite - Grandio Heavy Flow (VOCO, Cuxhaven/Germany) and Group G: Conventional Resin Composite - Grandio SO (VOCO, Cuxhaven/ Germany).

Each group was subdivided into 3 subgroups according to the reinforcement fiber employed (n = 10): Subgroup N – without reinforcement fiber; Subgroup V – GrandTEC glass fiber (VOCO); Subgroup S –everStickC&B glass fiber (Stick Tech Ltd., Turku, Finland).

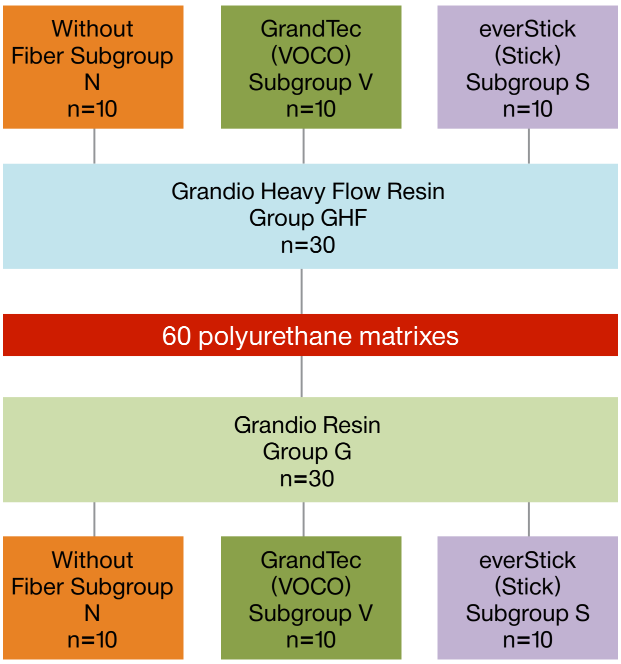


Figure 2 - Illustrates the division of the groups.

In the subgroups that did not receive glass fiber reinforcement (G-N; GHF-N) the resin was applied in 5 increments, each one light-cured for 40s with energy of at least 550 mJ/cm^2. Onto the last resin layer, a polyether strip was placed to standardize the surface roughness, and light-cured. In the subgroups receiving glass fiber reinforcement (G-V; G-S; GHF-V; GHF-S), the application of the resin composite followed the same aforementioned procedure, except that the glass fiber was placed and light-cured after the application of the first resin increment, following the manufacturer's instructions. Next, the same procedure as described above was performed. After the construction of the specimens, they were stored into distilled water at 37° C, for 24 h, prior to the execution of the flexural strength testing.

Flexural strength test

The specimens placed into their respective matrixes were test regarding their flexural strength in a universal testing machine (EMIC model DL2000 - EMIC Equipamentos e Sistemas de Ensaio LTDA, São José dos Pinhais-PR, Brazil) characterizing a three-point flexural strength test at crosshead speed of 1 mm/min and load cell of 50 Kgf. When the fracture occurred, the values were recorded in Kgf. The tests were performed with the specimens immersed into distilled water.

Statistical analysis

The data obtained were analyzed regarding to their normality and homogeneity through two-way ANOVA and Tukey test. The level of significance adopted was 5%.

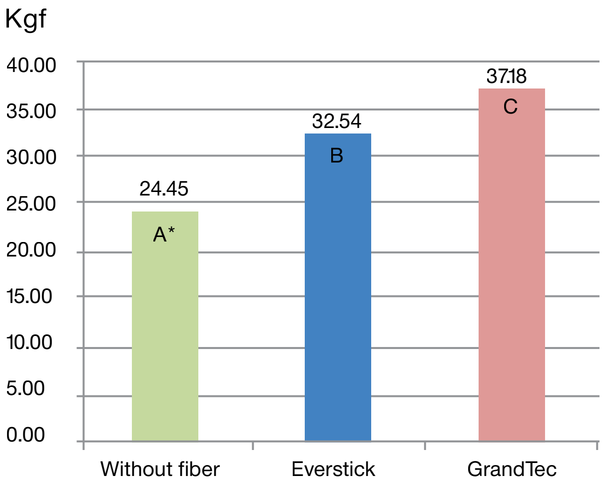
RESULTS

The values of the flexural strength for all the experimental conditions are shown in Table 1.

ANOVA showed significant differences only for the variable Glass Fiber. Tukey test was applied and the result is seen in Figure 3.

Table 1 – Mean (standard-deviation) values of the flexural strength (Kgf) for all the experimental conditions

	Conventional Resin Grandio SO	Low-viscosity resin Grandio Heavy Flow
Without fiber	25.36 (4.51)	23.55 (2.27)
Grandtec fiber	35.08 (6.41)	39.28 (3.03)
EverStick fiber	30.49 (7.33)	34.59 (6.22)



*Different letters mean statistically significant differences. ($p<0.05$)

Figure 3 – Result of Tukey test.

DISCUSSION

The null hypothesis tested in which the use of resins of different viscosities would not interfere on the flexural resistance of AFPP was accepted because there was no significant difference between the resins tested. On the other hand, the null hypothesis that the use of different reinforcement fibers would not interfere on the flexural resistance of AFPP was rejected because there was significant differences between the resins with and without fiber reinforcement and between the fiber types.

In this present study, resins of different viscosities were tested. However, both presented high filler content. To characterize better the resins studied and also to help in the understanding of the results, some mechanical properties of Grandio SO (conventional resin) and Grandio Heavy flow (Low-viscosity resin), were analyzed, finding that modulus of elasticity values of 21.62 GPa and 12.85 GPa, respectively. Concerning to microhardness, the conventional resin displayed higher values (93.19 HK) than the low-viscosity resin (40.27 HK). Even with better mechanical properties than the conventional resin, the low-viscosity resin showed a similar behavior regarding to the flexural strength in the conditions tested by this present study.

According to Anusavice [1], the mean force exerted during mastication at the pre-molar area ranges from 221.4 N to 444.9 N. In this present study, the groups reinforced by glass fiber exhibited adequate values to support the masticatory forces. The maximum force values measured in this study was closer to, but did not exceed the masticatory forces mentioned by Anusavice for the pre-molar area.

By analyzing the effect of the glass fiber reinforcement in AFPP, an increase in the resistance to fracture was found due to the addition of the glass fiber reinforcement. The fibers used in this study are composed by glass fiber structures impregnated with resin composite and indicated for direct use in dental office. The impregnation of reinforcement fibers with resin enables that the fibers be in closer contact with the polymeric matrix. This is a pre-requisite for the bonding of the fibers to the polymer matrix and therefore for the resistance of the set. In the application of the load onto the occlusal surface, the occlusal side of the AFPP underwent compression stress [18] and the gingival surface maximum tensile stress concentrated in the connection areas, the most critical regions [19]. The efficient location for fiber reinforcement is at the tensile points, such as the pontic base [19,20]. The reinforcement with fiber inclusion enables a better tension distribution and dissipation of the structure in which it was incorporated, therefore decreasing the stress transmission and stress homogenization including the pontic teeth [19,21]. Theoretically, the effect of the fiber reinforcement is not only based on the stress transference from the matrix to the fibers, but also on the individual behavior of the fibers as paralyzing units of the cracks [22]. The capacity of the glass fiber of either delaying or stopping the crack propagation [13] is another reason that may result in an increase of the resistance to fracture of AFPP. It is important to emphasize that the system success depends on the cohesion among the fibers and the surrounding resin matrix, which must assure the uniformity of the stress transference from the matrix to the fibers.

In this study the specimens were constructed simulating an infrastructure of an adhesive fixed partial prosthesis with occlusal and approximal preparations and a pontic space of 7 mm. However, it is known that such analogy is a simplification of a complex loading which is not easily replicated in the laboratory. Notwithstanding, such approach has the advantage of the standardization of the specimens and loading conditions. The placement of the fiber reinforcement inside the specimens must be commented. To be able to achieve an optimum reinforcement by the fibers, these should be placed at the tensile stress side of the specimen [23] which is the weakest point. However, the exposure of the fibers may lead to the weakening of the fiber/matrix set, increasing the risk of premature failures [23,24]. Because of these aforementioned reasons, and in agreement with other studies [23], this present study placed the fibers at the center of the prosthesis completely surrounded by the fiber [23].

Concerning to the orientation of the fibers, all fibers used were perpendicular to the direction of the load applied and parallel to the stress direction. Such geometry of the test optimizes the mechanical properties, in contrast with the fibers placed in a parallel orientation to the load applied [9]. This study employed a three-point flexural test to evaluate the flexural properties of the materials. According to Ellakwa et al. [23], the stress types (tensile, shear, compression) and their distributions are capable of mimicking those found in fixed prostheses.

Further studies are necessary to evaluate the effect of water or saliva aging on glass fiber reinforcement. Further studies should also focus on the determination of the effect of the inclusion of unidirectional fibers in the area of most tensile stress on the resistance of AFPP.

CONCLUSION

Within the limits of this study, it can be concluded that the glass fibers tested were capable of increasing the resistance to fracture of the simulated AFPP, and GrandTEC exhibited the highest values regarding to the resistance to fracture of these resins. The viscosity did not influence on the resistance to fracture of the adhesive FPP.

REFERENCES

1. Anusavice KJ. Phillips Science of Dental Materials. 11 th ed. Philadelphia: W.B. Saunders Company; 2005.
2. Fabre HSC, Pereira WB, Martelli Junior H, Lopes MB, Gonini Junior A. Prótese adesiva em resina composta reforçada por fibras para dentes posteriores. Rev Assoc Paul Cir Dent. 2009;63(2):124-9.
3. Scherrer SS, Botsis J, Studer M, Pini M, Wiskott HW, Belser UC. Fracture toughness of aged dental composites in combined mode I and mode II loading. J Biomed Mater Res. 2000;53(4):362-70.
4. Rappelli G, Coccia E. Fiber-reinforced composite fixed partial denture to restore missing posterior teeth: a case report. J Contemp Dent Pract. 2005 Nov 15;6(4):168-77.
5. Zhang L, Xie QF, Feng HL, Wang Y. Influence of fiber framework design on fracture strength of posterior glass fiber-reinforced-composite resin-bonded fixed partial dentures. Zhonghua Kou Qiang Yi Xue Za Zhi. 2007 Jan;42(1):52-6.
6. Freilich MA, Karmaker AC, Burstone CJ, Goldberg AJ. Development and clinical applications of a light-polymerized fiber-reinforced composite. J Prosthet Dent. 1998 Sep;80(3):311-8.
7. Freilich MA, Meiers JC, Duncan JP, Eckrote KA, Goldberg AJ. Clinical evaluation of fiber-reinforced fixed bridges. J Am Dent Assoc. 2002 Nov;133(11):1524-34; quiz 40-1.
8. Kolbeck C, Rosentritt M, Behr M, Lang R, Handel G. In vitro study of fracture strength and marginal adaptation of polyethylene-fibre-reinforced-composite versus glass-fibre-reinforced-composite fixed partial dentures. J Oral Rehabil. 2002 Jul;29(7):668-74.
9. Vallittu PK. Survival rates of resin-bonded, glass fiber-reinforced composite fixed partial dentures with a mean follow-up of 42 months: a pilot study. J Prosthet Dent. 2004 Mar;91(3):241-6.
10. Braga NM, Souza-Gabriel AE, Messias DC, Rached-Junior FJ, Oliveira CF, Silva RG, et al. Flexural properties, morphology and bond strength of fiber-reinforced posts: influence of post pretreatment. Braz Dent J.23(6):679-85.
11. Bottino MA, Bondioli IR. A comparative study of flexural strength using two composite resins fiber reinforced. Braz Dent Sci. 2001;4(3):5-12.
12. Stipho HD. Repair of acrylic resin denture base reinforced with glass fiber. J Prosthet Dent. 1998 Nov;80(5):546-50.
13. Dyer SR, Lassila LV, Jokinen M, Vallittu PK. Effect of fiber position and orientation on fracture load of fiber-reinforced composite. Dent Mater. 2004 Dec;20(10):947-55.
14. Goldberg AJ, Burstone CJ. The use of continuous fiber reinforcement in dentistry. Dent Mater. 1992 May;8(3):197-202.

15. Herakovich C. Mechanics of fiber composites. New York: John Wiley; 1998.

16. Feinman RA, Smidt A. A combination porcelain/fiber-reinforced composite bridge: a case report. Pract Periodontics Aesthet Dent. 1997 Oct;9(8):925-9; quiz 30.

17. Gohring TN, Roos M. Inlay-fixed partial dentures adhesively retained and reinforced by glass fibers: clinical and scanning electron microscopy analysis after five years. Eur J Oral Sci. 2005 Feb;113(1):60-9.

18. Vallittu PK. The effect of glass fiber reinforcement on the fracture resistance of a provisional fixed partial denture. J Prosthet Dent. 1998 Feb;79(2):125-30.

19. Magne P, Perakis N, Belser UC, Krejci I. Stress distribution of inlay-anchored adhesive fixed partial dentures: a finite element analysis of the influence of restorative materials and abutment preparation design. J Prosthet Dent. 2002 May;87(5):516-27.

20. Rosentritt M, Behr M, Lang R, Handel G. Experimental design of FPD made of all-ceramics and fibre-reinforced composite. Dent Mater. 2000 May;16(3):159-65.

21. Nagata K, Takahashi H, Ona M, Hosomi H, Wakabayashi N, Igarashi Y. Reinforcement effects of fiberglass on telescopic dentures using a three-dimensional finite element analysis and fracture test. Dent Mater J. 2009 Sep;28(5):649-56.

22. Garoushi S, Vallittu PK, Lassila LV. Fracture resistance of short, randomly oriented, glass fiber-reinforced composite premolar crowns. Acta biomaterialia. 2007 Sep;3(5):779-84.

23. Ellakwa AE, Shortall AC, Shehata MK, Marquis PM. The influence of fibre placement and position on the efficiency of reinforcement of fibre reinforced composite bridgework. J Oral Rehabil. 2001 Aug;28(8):785-91.

24. Gohring TN, Schmidlin PR, Lutz F. Two-year clinical and SEM evaluation of glass-fiber-reinforced inlay fixed partial dentures. Am J Dent. 2002 Feb;15(1):35-40.

Taciana Marco Ferraz Caneppele
(Corresponding author)
Av. Eng. Francisco José Longo, nº 777,
Jardim São Dimas, São José dos Campos – SP
12245-000

Received: 2013 Jan 16

Accepted: 2013 Mar 05