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ORIGINAL ARTICLE

Flexural strength of composites: effects of the activation techniques and fiber reinforcement

Resistência à flexão de compósitos: efeitos das técnicas de fotopolimerização e reforço de fibra

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ABSTRACT

Objectives: To evaluate the flexural strength of direct (Charisma) and indirect (Solidex) composites, with or without fiber reinforcements (Ribbond), cured with LED or Stroboscopic Xenon Light. **Material and Methods:** Resin bars made with or without fiber reinforcements, with 25mm x 2mm x 2mm were distributed in groups (n=10): GDL– Direct Resin/LED; GDX–Direct Resin/Stroboscopic Xenon; GDFL– Direct Resin/Fiber/LED; GDFX– Direct Resin/Fiber/Stroboscopic Xenon; GIL– Indirect Resin/LED; GIX– Indirect Resin/Stroboscopic Xenon; GIFL– Indirect Resin/Fiber/LED; GIFX– Indirect Resin/Fiber/Stroboscopic Xenon. The specimens were connected to a universal test machine and submitted to a compression load (2 kN). **Results:** The obtained results were submitted to Analysis of Variance tests ($p < 0.01$), and Tukey (5% significance level) tests. The flexural strength of groups that used polyethylene fiber reinforcement (96.39) was similar ($p = 0.58$) to group without fiber reinforcement (92.47). Direct composites (107.79) showed higher values of flexural strength than indirect composites (81.07), and stroboscopic xenon light curing (108.71) resulted in better flexural strength results than LED (80.15), for both kinds of composites experimented. **Conclusion:** The fiber reinforcement did not improve the composites' flexural strength, direct composites showed higher flexural strength values, and stroboscopic xenon light showed better flexural strength results.

KEYWORDS

Composite resins; Curing lights; Fiber reinforcements; Physical properties.

RESUMO

Objetivo: Avaliar a resistência à flexão de compósitos diretos (Charisma) e indiretos (Solidex), com ou sem reforços de fibra (Ribbond), polimerizados com LED ou Stroboscopic Xenon Light. **Material e métodos:** Barras de resina feitas com ou sem reforços de fibra, com 25 mm x 2 mm x 2 mm foram distribuídas em grupos (n = 10): GDL- Resina Direta / LED; GDX- Resina Direta / Stroboscopic Xenon; GDFL- Resina Direta / Fibra / LED; GDFX- Resina Direta / Fibra / Stroboscopic Xenon; GIL- Resina Indireta / LED; GIX- Resina Indireta / Stroboscopic Xenon; GIFL- Resina Indireta / Fibra / LED; GIFX- Resina Indireta / Fibra / Stroboscopic Xenon. Os espécimes foram conectados a uma máquina de teste universal e submetidos a uma carga de compressão (2 kN). **Resultados:** Os resultados obtidos foram submetidos ao teste de Análise de Variância (nível de significância de 5%) e teste de Tukey ($p < 0,01$). A resistência à flexão dos grupos que utilizaram reforço de fibra de polietileno (96,39) foi semelhante ($p = 0,58$) aos grupos sem reforço de fibras (92,47). Os compósitos diretos (107,79) mostraram maiores valores de resistência à flexão do que os compósitos indiretos (81,07), e a luz e a polimerização com luz stroboscópica de xenônio (108,71) deu melhores resultados de resistência à flexão do que com LED (80,15), para ambos os tipos de compósitos estudados. **Conclusão:** O reforço de fibra não melhorou a resistência à flexão dos compósitos, compósitos diretos apresentaram maiores valores de resistência à flexão, e a luz estroboscópica de xenônio mostrou melhores resultados de resistência à flexão.

PALAVRAS-CHAVE

Resinas compostas; Fotopolimerização; Fibra de reforço; Propriedades físicas.

INTRODUCTION

The functional aesthetic restorative systems can be basically divided in two groups: the direct insertion group, represented by composite resins, and the indirect insertion group, represented by laboratory composite resins and ceramics [1,2]. The indication of each of these materials is associated with the size of the restoration and with the remaining quantity of healthy tooth to be restored [2].

Literature indicates that for smaller reconstitutions, direct restorative materials are more suited because of smaller cost, and the fact that they allow more conservative restorations and faster completion. On the other hand, when facing greater loss of dental structures, indirect procedures like use prosthetic structures are more indicated [1-4].

A reliable restorative material should present mechanical properties that can withstand forces generated during mastication for a long time period without fracturing and damage remaining dental structures [5]. The biggest hesitation during a restorative procedure is to evaluate if the chosen material will be able to withstand these tensions, especially restorations of great loss of dental structures or when making fixed prosthesis [1-4].

Facing these problems, industries are developing products with enhanced mechanical properties, trying to expand their indications [3,4]. For that matter, cutting-edge technology is being used for obtaining more resistant filler particles, as well as better distribution of these particles on the interior of these composites, improving their mechanical resistance.

The use of fiber structures for architecture and the variable composition of the composites which may be associated to synthetic polymers [1-6], and the use of efficient ways of curing (LED or stroboscopic xenon light) for polymer conversion are of fundamental importance for raising flexural strength [4] and attrition resistance of the composites, respectively, according to the literature.

In spite of the great technological advances, there is still not an agreement on the advantages of the utilization of fiber structures on direct (or even indirect) composite resins. Contrasting information about increase in flexural strength of these materials, as well as the influence of curing on mechanic resistance over different curing systems, can be found on the literature [6,7].

Considering that both kinds of restorative composite resins are safe and reliable materials for repairing or replacing dental loss of any nature, and that the aforementioned are of fundamental importance for its success and longevity, the aim of this study is to evaluate the flexural strength of direct and indirect composites, associated or not to reinforcement fibers, varying the curing source.

MATERIAL AND METHODS

The factors in study were: composite resin at 2 levels: direct composite (Charisma A3 - Heraeus Kulzer, Gonsennheumer, Mainz, Germany) and indirect composite (Solidex A3 - Shofu, Higashiyama-Ku, Kyoto, Japan); fiber reinforcement at 2 level: present or absent of polyethylene fibers (Ribbond, Ribbond Inc., Seattle, USA); and the light curing system at 2 levels: LED light (Ultraled, Dabi-Atlante S. A. Indústria Médico-Odontológica Ltda. Ribeirão Preto, Brasil), and stroboscopic xenon light (Strobolux- EDG, São Carlos, SP, Brazil).

Production of the specimens

Using a metallic mold, eighty composite bar shape resin specimens, were made with or without fiber reinforcement. Specimens were made according to ISO 10477 specifications, which regulates tests with polymers: 25.0 mm (length); 2.0mm (width); 2.0mm. Ten bars composed each experimental group (Table 1).

Table 1 - Group distribution according to the factors in study

Groups	Composite	Fiber	Light Curing
Group DL (n = 10)	Charisma	Absent	LED
Group DX (n = 10)	Charisma	Absent	Xenon
Group DFL (n = 10)	Charisma	Present	LED
Group DFX (n = 10)	Charisma	Present	Xenon
Group IL (n = 10)	Solidex	Absent	LED
Group IX (n = 10)	Solidex	Absent	Xenon
Group IFL (n = 10)	Solidex	Present	LED
Group IFX (n = 10)	Solidex	Present	Xenon

A thin layer of an insulating material (Die Isolation, 3M ESPE, St. Paul, Minnesota, USA)) was applied to the inner part of the mold. Next, a polyester strip was positioned at the lower part of the mold, and a first increment of composite resin was condensed (Charisma for groups DL,DX,DFL and DFX ; or Solidex for groups IL, IX, IFL and IFX) filling all the extension of the mold with 1.0 mm of thickness. For groups DL, DFL, IL and IFL, the first layer of composite was cured for 20 s with LED light and potency of 700 mW/cm^2 (Ultraled), with 3 additional sequential curing sessions ranging a length of 10 mm each. For groups DX, DFX, IX and IFX, the first layer of resin was cured for 20 s with Stroboscopic Xenon light (Strobolux), with the whole set being put inside the photopolymerizer of collected energy with very high intensity light and cured only once with potency of 1200 mW/cm^2.

For groups not receiving fiber reinforcement (DL, DX, IL, IX), immediately after the polymerization of the first increment, a second increment was condensed on top of the first, filling the entire mold with little excess. Another polyester strip was positioned above the mold, and a glass plaque was pushed against the composite for leveling the surface of the specimens, for removing the excess of material. Next, the glass plaque was removed, and the curing of the composite was made in the same way as the first increment, respecting the use of LED or stroboscopic light for each group.

For the groups which received fiber reinforcement (DFL, DFX, IFL, IFX), immediately after the polymerization of the first increment, a segment of Ribbond® polyethylene fiber, with length of 22 mm and width of 2 mm, was saturated with the “bond” of the Scotch Bond Multipurpose Plus adhesive system, and positioned over the first composite increment. After its compression and adaptation, the adhesive was cured for 20 s with LED light and potency of 700 mw/cm^2, with 3 additional sequential curing sessions ranging a length of 10 mm each. The second composite increment was inserted and cured as previously described, respecting the use of LED or stroboscopic light for each group.

Next, the specimens were removed from their molds and the excess removed with a 15° razor attached to a scalpel, and fine finishing made with Norton sandpaper, with 1200 granulation.

It is interesting to note that after the specimens were made, their dimensions were measured using an electronic caliper rule (Starrett Indústria e Comércio Ltda, Itu, São Paulo, Brazil). Specimens that did not match the defined dimensions weren’t used in this experiment. Next, the specimens were stored in individual containers filled with distilled water, at ambient temperature without any kind of light, for 7 days, when they were then submitted to flexural strength tests.

Flexural strength tests

According to ISO 10477 specifications for flexural tests, a EMIC universal test machine (model DL-1000, EMIC Equipamentos e Sistemas LTDA., São José dos Pinhais, Paraná, Brazil) with a constant speed of 0.5 mm/min and load of 2 kN. The specimens were positioned over two parallel holders with 2 mm of diameter, with 20 mm of distance between their centers. A third holder also with 2 mm of diameter, situated between the other two, attached to the upper part of the testing machine, so that the load may be applied centrally to the point of permanent deformation of complete fracture of the specimens.

The obtained results were submitted to Analysis of Variance tests ($p < 0.01$), and Tukey (5% significance level) tests.

RESULTS

Tables show means and the standard deviations of the flexural strength (measured in MPa) of specimens of each group and the mean of studied factors (Direct or indirect resin – Table 1; presence of fiber reinforcement –Table 2; light curing – Table 3)

The ANOVA test showed statistically significant differences among groups ($p < 0.01$). For identifying this difference, the Tukey test at a 5% significance level was used. The groups with fiber or without fiber showed similar results of flexural strength ($p = 0.58$), while the Charisma group had better results than the Solidex group ($p < 0.001$). A significant difference was found between the curing groups, where those that were cured by Xenon Stroboscopic light showed better results of flexural strength than those which were cured by LED light ($p < 0.001$).

There was no interaction of variables (Composite x Fiber: $p = 0.78$; Composite x Curing: $p = 0.80$; Fiber x Curing: $p = 0.54$; Composite x Fiber x Curing: $p = 0.77$)

Table 2 - Mean (standard deviations) of flexural strength (in MPa) of each group, and statistic decision considering the composite resin factor

	Direct Resin (Charisma)	Indirect resin (Solidex)
LED	89.14 (13.46) A	63.67 (27.91) B
Stroboscopic Xenon	123.80 (22.82) A	93.25 (19.33) B
LED + Fiber	96.70 (19.56) A	71.07(24.10) B
Stroboscopic Xenon + Fiber	121.50 (21.36) A	96.27 (18.47) B
Mean	107.79	81.07

Mean followed by different letter in the rows are statistically diferent ($p < 0.05$).

Table 3 - Mean (standard deviations) of flexural strength (in MPa) of each group, and statistic decision considering the fiber reinforcement factor

	Without fiber reinforcement	With fiber reinforcement
Direct Resin + Led	89.14 (13.46) A	63.67 (27.91) B
Direct Resin + Stroboscopic Xenon	123.80(22.82) A	93.25 (19.33) B
Indirect Resin + Led	96.70 (19.56) A	71.07(24.10) B
Indirect Resin + Stroboscopic Xenon	121.50 (21.36) A	96.27 (18.47) B
Mean	107.79	81.07

The groups with fiber or without fiber showed similar results of flexural strength ($p = 0.58$).

Table 4 - Mean (standard deviations) of flexural strength (in MPa) of each group, and statistic decision considering the curing factor

	LED	Stroboscopic Xenon
Direct Resin	89.14 (13.46) B	123.80(22.82) A
Direct Resin + Fiber	96.70 (19.56) B	121.50 (21.36) A
Indirect Resin	63.67 (27.91) B	93.25 (19.33) A
Indirect Resin + Fiber	71.07(24.10) B	96.27 (18.47) A
Mean	80.15	108.71

Mean followed by different letter in the rows are statistically diferent ($p < 0.05$).

DISCUSSION

It was possible to observe that the direct composites showed superior behavior than the indirect composites. These results are according to the findings of other previous studies [5,8]. Probably the quantity and the kind of the particles present in the direct composite resin (Charisma) had some influence on the flexural strength results [3,4]. This may be due to the fact that it is classified as a hybrid composite resin, which has better mechanical results when compared to micro-particles composite resins, which is the classification of the indirect composite resin used in this study (Solidex) [3,4].

The mechanical properties of the composite resins are closely related to their composition, and factors like the size of the particles, filling content, resinous matrix, and arrangement between the filling content and the matrix are among the responsible factors of the physical and mechanical behavior of said materials [1,9-13]. This way, the combination of hybrid composites with microparticles of load may have improved the flexural strength over a microparticle composite resin [14-17].

On the other hand, there was no improvement on the flexural strength with the use of fiber reinforcement. These results are according to the findings of other studies [3,4] and do not confirm the proposition that the use of fiber reinforcement on composites may improve their mechanic resistance. The presence of fibers may only set a different fracture pattern [3,4].

Another factor with a statistically significant difference was related to the kind of curing deployed on the composites. It is known that the curing is closely connected to the level of conversion of the composites, which may influence in higher or lower scale the mechanic (and consequentially flexural) strength [7,16-21]. In this experiment, the use of stroboscopic light determined higher values of flexural strength when compared to those obtained with LED light, showing statistically significant differences. These results are within expectations, considering that stroboscopic light curing has higher rates of conversion of monomers into polymers, and consequentially, better mechanical resistance of the composites (direct or indirect) [3,14,22]. A stroboscopic light curing device emits light flashes of high intensity (around 1200 mW/cm^2) during only 20 milliseconds, followed by 80 milliseconds without any light emission [3,22]. This kind of exposure improves the efficiency of the polymerization because it allows partial relaxation of the composite molecules, allowing greater depths to be reached [3]. Consequently, perhaps a bigger amount of non-reactive double chain carbon groups will be available for reaction. Continuous curing devices (without any interruption of light emission) may stabilize the polymeric chains located below the initially cured surface of the composite, reducing the polymerization potential [3,22].

The direct composite used in this study have Bis-GMA/TEGDMA monomers in its composition, which are normally cured with lower intensity curing sources [21]. When submitted to higher intensity curing lights, it showed better flexural strength, probably because it obtained a higher rate of monomer conversion [3,4]. Furthermore, Charisma is a micro-hybrid composite resin with 64% of filling in its content, while Solidex only has 53% [3]. The increase on the filling content of the matrix of the composite resin enhances its mechanical properties, such as diametral tensile strength, compression, abrasion resistance, thermal expansion coefficient and modulus [23,24].

Considering the results of this study, it is possible to consider the hypothesis that the use of fibers does not increase the flexural strength of these materials. However, the use of curing systems with better monomer conversion capacities should be considered for better mechanic resistance of the composites.

CONCLUSION

The use of polyethylene fiber reinforce did not improve the direct or indirect composite resins flexural strength employed in this experiment; the direct resin showed better flexural strength than the indirect resin, and the use of stroboscopic light determined higher values of flexural strength.

REFERENCES

1. Kikuti WY, Chaves FO, Di Hipólito V, Rodrigues FP, D'Alpino PH. Fracture resistance of teeth restored with different resin-based restorative systems. Braz Oral Res. 2012 May-Jun;26(3):275-81.
2. Kamble VD, Parkhedkar RD, Mowade TK. The effect of different fiber reinforcements on flexural strength of provisional restorative resins: an in-vitro study. J Adv Prosthodont. 2012 Feb;4(1):1-6.
3. Casselli DS, Worschech CC, Paulillo LA, Dias CT. Diametral tensile strength of composite resins submitted to different activation techniques. Braz Oral Res 2006 Jul-Sep;20(3):214-8.
4. Pereira CL, Demarco FF, Cenci MS, Osinaga PW, Piovesan EM. Flexural strength of composites: influences of polyethylene fiber reinforcement and type of composite. Clin Oral Investig. 2003 Jun;7(2):116-9.
5. Cesar PF, Miranda WG Jr, Braga RR. Influence of shade and storage time on the flexural strength, flexural modulus, and hardness of composites used for indirect restorations. J Prosthet Dent. 2001;86(3):289-96.
6. Coelho-de-Souza FH, Rocha Ada C, Rubini A, Klein-Júnior CA, Demarco FF. Influence of adhesive system and bevel preparation on fracture strength of teeth restored with composite resin. Braz Dent J. 2010;21(4):327-31.
7. Catelan A, Santo MR, Menegazzo LM, Moraes JC, dos Santos PH. Effect of light curing modes on mechanical properties of direct and indirect composites. Acta Odontol Scand. 2013 May-Jul;71(3-4):697-702.
8. Bae JM, Kim KN, Hattori M, Hasegawa K, Yoshinari M, Kawada E, et al. Fatigue strengths of particulate filler composites reinforced with fibers. Dent Mater. 2004 Jun;23(2):166-74.
9. Han B, Dong Y, Gao X, Wang X, Tian F. Effect of filler content on the microtensile bond strength of composite resin and dentin in Class I cavities. Quintessence Int. 2012 Feb;43(2):16-22.
10. Tanoue N, Sawase T, Matsumura H, McCabe JF. Properties of indirect composites reinforced with monomer-impregnated glass fiber. Odontology. 2012;100(2):192-8.
11. Meiers JC, Kazemi RB, Donadio M. The influence of fiber reinforcement of composites on shear bond strengths to enamel. J Prosthet Dent. 2003 Jul;89(2):388-93.
12. Rodrigues Junior SA, Zanchi CH, Carvalho RV, Demarco FF. Flexural strength and modulus of elasticity of different types of resin-based composites. Braz Oral Res. 2007 Jan-Mar;21(1):16-21.
13. Soares CJ, Pizi EC, Fonceca RB, Martins LR. Mechanical properties of light-cured composites polymerized with several additional post-curing methods. Oper Dent. 2005 May-Jun;30(3):389-94.
14. Antonopoulou A, Papadopoulos T, Hatzikyriakos A. In vitro evaluation of shear bond strength and mode of failure of the interface between an indirect composite bonded to fiber-reinforced composite substructures. J Prosthodont. 2012 Aug;21(6):451-9.
15. Garoushi S, Lassila LV, Vallittu PK. The effect of span length of flexural testing on properties of short fiber reinforced composite. J Mater Sci Mater Med. 2012 Feb;23(2):325-8.
16. Keulemans F, Palav P, Aboushelib MM, van Dalen A, Kleverlaan CJ, Feilzer AJ. Fracture strength and fatigue resistance of dental resin-based composites. Dent Mater. 2009 Nov;25(11):1433-41.
17. Van Heumen CC, Kreulen CM, Bronkhorst EM, Lesaffre E, Creugers NH. Fiber-reinforced dental composites in beam testing. Dent Mater. 2008 Nov;24(11):1435-43.
18. Kim MJ, Jung WC, Oh S, Hattori M, Yoshinari M, Kawada E, et al. Flexural properties of three kinds of experimental fiber-reinforced composite posts. Dent Mater J. 2011;30(1):38-44.
19. Costa AK, da Silva LH, Saavedra GS, Paes TJ Jr, Borges AL. Flexural strength of four adhesive fixed dental prostheses of composite resin reinforced with glass fiber. J Adhes Dent. 2012 Feb;14(1):47-50.
20. Sun W, Cai Q, Li P, Deng X, Wei Y, Xu M, Yang X. Post-draw PAN-PMMA nanofiber reinforced and toughened Bis-GMA dental restorative composite. Dent Mater. 2010 Sep;26(9):873-80.
21. Eronat N, Candan U, Türkün M. Effects of glass fiber layering on the flexural strength of microfill and hybrid composites. J. Esthet Restor Dent. 2009;21(3):171-81.
22. Portero PP, Bandéca MC, Ditterich RG, Grullón PG, Virgens Filho JS, Gomes OMM. Effect of light-curing units and glass fiber reinforcement on flexural strength of direct and laboratory-processed composites. RPG Rev Pós-Grad. 2010 Jan-Mar;17(1):25-30.
23. Meiers JC, Freilich MA. Design and use of a prefabricated fiber-reinforced composite substructure for the chair side replacement of missing premolars. Quintessence Int. 2006 Jun;37(6):449-54.
24. Uctasli S, Tezvergil A, Lassila LV, Vallittu PK. The degree of conversion of fiber-reinforced composites polymerized using different ligth curing sources. Dent Mater. 2005 May;21(5):469-75.

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