Brazilian Dental Science

unesp
UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

SHORT COMMUNICATION DOI: https://doi.org/10.4322/bds.2024.e4416

Surface hardness evaluation of a 3D printable resin designed for final restorations

Avaliação da dureza superficial de uma resina para impressora 3D destinada para restaurações finais

Bruno Trivellato RODRIGUES[1], Selene Paiva PARAGUASSU[2], Dora Isabel de Sousa Martins FREITAS[2], Sérgio Kiyoshi ISHIKIRIAMA[2], Rafael Massunari MAENOSONO[1]

1 - Centro Universitário de Santa Fé do Sul, Departamento de Materiais Odontológicos, Santa Fé do Sul, SP, Brazil
2 - Universidade de São Paulo, Faculdade de Odontologia de Bauru, Departamento de Dentística, Endodontia e Materiais Odontológicos, Bauru, SP, Brazil

How to cite: Rodrigues BT, Paraguassu SP, Freitas DISM, Ishikiriama SK, Maenosono RM. Surface hardness evaluation of a 3D printable resin designed for final restorations. Braz Dent Sci. 2024;27(3):e4416. https://doi.org/10.4322/bds.2024.e4416

ABSTRACT

Objective: Advancements in the digital area have triggered significant interest among researchers in recent years, particularly concerning 3D printers. In dentistry, 3D printers are already employed to create dental models, surgical guides, and provisional restorations. Recently, a new 3D printable resin has been introduced with the aim of being used for final restorations (BioCrown, Makertech Labs). Despite its innovative nature, there is considerable interest in the physical and mechanical properties of this new class of material. This study aimed to evaluate the surface hardness of this new resin, comparing it to well-known materials such as acrylic resin for provisional restorations (Triunfo Dent's, Triunfo), conventional composite resin for final restorations (Z250, 3M ESPE), and 3D printable resin for provisional restorations (BioProv, Makertech Labs). **Methods:** Knoop microhardness testing was conducted ($n = 10$), and data were analyzed using the Kruskall-Wallis test, followed by the Dwass-Steel-Critchlow-Fligner test for individual comparisons ($p < 0.05$). **Results**: Higher hardness values (kgf/mm^2) were observed for BioCrown (17.4 ± 2.5) compared to the conventional acrylic resin group (14.5 ± 1.5), but no differences were found for BioProv (17.8 ± 1.5). The conventional composite resin group obtained the highest hardness values (81.3 ± 5.4). **Conclusion:** It can be concluded that the new 3D printable resins for final restorations exhibit low hardness levels, which may indicate inferior performance as final restorations, especially when compared to conventional composite resins. Further studies are necessary to comprehend and enhance the mechanical properties of 3D printable resins.

KEYWORDS

Bioprinting; Composite resins; Permanent dental restoration; Hardness tests; Three-dimensional printing.

RESUMO

Objetivos: Avanços na área digital têm despertado um interesse significativo entre os pesquisadores nos últimos anos, particularmente quanto às impressoras 3D. Na odontologia, impressoras 3D já são utilizadas para criar modelos dentários, guias cirúrgicos e restaurações provisórias. Recentemente, uma nova resina para impressora 3D foi introduzida com o objetivo de ser utilizada em restaurações finais (BioCrown, Makertech Labs). Apesar da sua natureza inovadora, existe um interesse considerável nas propriedades físicas e mecânicas desta nova classe de materiais. Este estudo teve como objetivo avaliar a dureza superficial desta nova resina, comparando com materiais já conhecidos como resina acrílica para restaurações provisórias (Triunfo Dent's, Triunfo), resina composta convencional para restaurações finais (Z250, 3M ESPE) e resina para impressora 3D para restaurações provisórias (BioProv, Makertech Labs). **Metodos**: Foi realizado teste de microdureza Knoop ($n = 10$) e os dados foram analisados pelo teste Kruskall-Wallis, seguido do teste Dwass-Steel-Critchlow-Fligner para comparações individuais ($p < 0,05$). **Resultados**: Valores de dureza (kgf/mm2) maiores foram observados para BioCrown

(17,4 ± 2,5) em comparação ao grupo de resina acrílica convencional (14,5 ± 1,5), mas não foram encontradas diferenças para BioProv (17,8 ± 1,5). O grupo de resina composta convencional obteve os maiores valores de dureza (81,3 ± 5,4). **Conclusao**: Pode-se concluir que as novas resinas para impressora 3D indicadas para restaurações finais apresentam baixos níveis de dureza, o que pode indicar desempenho inferior como restaurações finais, principalmente quando comparadas às resinas compostas convencionais. Mais estudos são necessários para compreender e aprimorar as propriedades mecânicas das resinas para impressora 3D.

PALAVRAS-CHAVE

Bioimpressão; Resinas compostas; Restauração dentária permanente; Testes de dureza; Impressão tridimensional.

INTRODUCTION

The advent of additive manufacturing, more commonly known as 3D printing, has opened up new possibilities within dentistry, drawing attention from both the industry and the scientific community. Currently, 3D printers are being efficiently used for the production of dental models [1], surgical guides [2], complete dentures [3], and temporary restorations [4].

Recently, a new 3D printable resin has been introduced to be used as a final restoration material (BioCrown, Makertech Labs, São Paulo, Brazil). According to the manufacturer, the incorporation of zirconia and silanized ceramics has provided greater strength, allowing it to be used as final restorations such as total crowns, inlays, and onlays. It is noteworthy that other materials currently used for the same purpose have significantly higher costs compared to 3D printable resins, becoming an interesting alternative to reduce the cost of aesthetic and functional rehabilitation.

Despite the significant technological innovation, there is considerable interest regarding the physical and mechanical properties of this new group of resins. It is known that resinous materials, in general, exhibit lower wear resistance, greater pigmentation, color changes, and loss of gloss and smoothness more quickly when compared to human enamel or dental ceramics [5-8]. In recent decades, microhybrid, nanohybrid, and nanoparticulate composite resins have shown improvements in their physical and mechanical properties and are currently considered satisfactory for restorations in both anterior and posterior teeth [9].

Since few investigations are available for this new 3D printable resin proposed for the fabrication of final restorations, the objective of this study was to evaluate the surface hardness of this new material using the Knoop microhardness test, comparing the values with other commonly used materials in dentistry.

MATERIAL & METHODS

This in vitro study presents an experimental design with one variable (material), divided into four levels: resin for final restoration fabricated with 3D printer (BioCrown), resin for provisional restoration fabricated with 3D printer (BioProv), conventional resin for final restoration (Z250), and conventional resin for provisional restoration (Acrylic) (Table I). The response variable was the material hardness (kgf/mm^2), determined through the Knoop microhardness test. Forty specimens were fabricated, with 10 specimens per group (n=10).

Fabrication of specimens

➢ Resin for final restoration in 3D printer (BioCrown):

Disks with a diameter of 10 mm and thickness of 2 mm were designed in Meshmixer software (Autodesk Inc.), generating a .STL file, which was prepared for printing using the Photon Workshop V. 2.2 slicing software (Anycubic 3D Printing, Shenzhen, China). Exposure parameters are described in Table II.

Once the sliced file was prepared, it was transferred to the Photon Mono 4k 3D printer (Anycubic 3D Printing, Shenzhen, China), loaded with Prizma 3D BioCrown resin (Makertech Labs, São Paulo, Brazil). Ten specimens were produced in each printing cycle. After completing the cycle, specimens were removed from the platform, and immersed in isopropyl alcohol (Steenifer Soluções Químicas, Itupeva, Brazil) in the Wash and Cure 2.0 device (Anycubic 3D Printing, Shenzhen, China), with a 5-minute cycle. Post-curing was performed on the same device for 60 minutes. Subsequently, specimens were polished using 600, 1200, and 2400 grit water sandpapers (Buehler LTD, Lake Bluff, USA) on a metallographic polisher (PL02E, Teclago, Vargem Grande Paulista, Brazil).

Table I - Groups, materials, and composition

Group	Product	Composition*
BioCrown	BioCrown Prizma (Makertech Labs, São Paulo, Brazil)	Monomers, Oligomers, Photoinitiators, Pigments, Stabilizers.
BioProv	BioProv Prizma (Makertech Labs, São Paulo, Brazil)	Monomers, Oligomers, Photoinitiators, Pigments, Stabilizers.
Z250	Composite Resin Filtek Z250 (3M ESPE, St. Paul, USA)	Treated silanized ceramic, Bisphenol A diglycidyl ether dimethacrylate (BisGMA), Bisphenol A polyethylene glycol diether dimethacrylate (BISEMA-6), Diurethane dimethacrylate (UDMA), Treated silica, Triethylene glycol dimethacrylate (TEGDMA)
Acrylic Resin	Acrylic Resin Triunfo Dent's (Triunfo, Pirassinunga, Brazil)	Powder: Polymethylmethacrylate, Polypropylene and Pigments Liquid: Methylmethacrylate Monomer, DMT and Inhibitor

*information provided by the manufacturer.

➢ Resin for provisional restoration in 3D printer (BioProv):

The fabrication of specimens in this group was carried out using the same parameters as the BioCrown group, employing Prizma BioProv resin (Makertech Labs, São Paulo, Brazil).

➢ Conventional resin for final restoration (Z250):

An additional disk from the 3D resin group was used to create a mold with addition silicone (Ivoclar Vivadent, Schaan, Liechtenstein). The disk was placed on a glass plate, and heavy silicone was used to replicate the 10 mm diameter and 2 mm thickness disk. After the mold polymerized, it was removed, and its interior was filled with Filtek Z250 resin (3M ESPE, St. Paul, USA) using a spatula. The resin was compressed by a glass plate against the mold, and photoactivation was performed using a light-curing unit (Kavo, Biberach, Germany) for 40 s. After 7 days the specimen underwent the same finishing and polishing sequence described for the other groups.

➢ Conventional resin for provisional restoration (Acrylic):

The same silicone mold was used for the fabrication of specimens in this group. Acrylic resin was handled following the manufacturer's instructions, in a 3:1 ratio. After obtaining a homogeneous material, it was placed on the mold and then compressed with a glass plate. After 10 minutes the specimens were removed and subsequently polished as described for the other groups.

Table II - Exposure parameters used in the Photon Workshop V. 2.2 slicing software (Anycubic 3D Printing)

Parameter	Prizma BioCrown	Prizma BioProv
Layer thickness	0.05 s	0.05 s
Normal exposure time	3.5 s	3.5 s
Off time	1.0 s	1.0 s
Bottom exposure time	60 s	60 s
Bottom layers	8	8

Knoop microhardness test

After polishing, the Knoop microhardness test was performed on Buehler Omnimet (Dusseldorf, Germany). Prepared specimens were positioned under the diamond tip, which made three indentations spaced 100 μm apart, at a force of 0.49 N for 15 s. The Knoop hardness calculation was based on the formula: KNH = 14228 x c / d2, where "c" is the load in gram-force, and "d" is the length of the longest diagonal.

Statistical analysis

The obtained values were assessed using the Shapiro-Wilks normality test. As one of the groups did not show a normal distribution, the non-parametric Kruskall-Wallis test was chosen, followed by the Dwass-Steel-Critchlow-Fligner test for individual comparisons ($p \leq 0.05$).

RESULTS

The mean hardness values± standard deviation and differences between groups are described in Table III. The acrylic resin group exhibited the lowest hardness values. The 3D printer resins, BioProv and BioCrown, showed similar surface hardness, with both groups having values higher than the acrylic resin group. Conventional composite resins demonstrated surface hardness values superior to all other tested groups.

Table III - Mean values ± standard deviation of Knoop hardness observed in each group

	BioCrown	BioProv	Z250	Acrylic
(kgf/mm²)ᵀ	17.4 ± 2.5 B	17.8 ± 1.5 B	81.3 ± 5.4 C	14.0 ± 1.5 A

*Different capital letters represent differences between groups ($p<0.05$).

Discussion

Understanding the physical and mechanical properties of restorative materials allows for predicting their clinical behavior, using faster and more cost-effective tests compared to randomized controlled clinical trials. While the latter provides a higher level of scientific evidence, they require more time and cost and should be conducted after preliminary laboratory trials [10].

In the context of resin-based restorative materials, one crucial aspect to study is clinical wear, especially because past composite resins exhibited low wear resistance and were contraindicated in areas of significant masticatory stress [11]. The incorporation of hybrid, microhybrid, and nanoparticulate fillers has significantly increased the wear resistance of composite resins. Despite still having wear resistance lower than dental enamel and dental ceramics, current composite resins demonstrate satisfactory clinical performance, being suitable for both anterior and posterior teeth [12,13].

The emergence of new resin-based restorative materials, such as 3D-printed resins, triggers great interest in understanding their properties before clinical use. Various laboratory test models can be employed to evaluate wear resistance, such as wear analysis through profilometry after simulated brushing [14], wear analysis through two- or three-body wear [15], and microhardness analysis [16].

In this study, the microhardness test was chosen as it is a simpler and more cost-effective test compared to others, as it does not require cycling materials for wear assessment. Although not directly assessing wear, the microhardness test shows a significant correlation with wear ($r = -0.91$), as observed by Say *et al.*, 2003 [16].

Regarding the obtained results, acrylic resins exhibited the lowest hardness values among the tested materials. Simoneti *et al.*, 2022 [17] observed very similar surface hardness values for this material group, aligning with its clinical indication for use in provisional restorations.

The BioProv and BioCrown groups did not differ from each other. Both showed surface hardness values higher than those of the acrylic resin group. Castro *et al.*, 2022 [18] evaluated BioProv resin and obtained surface hardness values similar to those found in this study. In a scanning electron microscopy (SEM) analysis, the authors observed only small filler particles (likely composed of silica), which could explain the higher hardness values compared to acrylic resin. It is essential to note that BioProv resin is recommended by the manufacturer for provisional restorations.

Until now, no other studies have evaluated BioCrown resin. However, initial analysis suggests that its wear resistance might be compromised, given its hardness values similar to BioProv resin and significantly lower than conventional composite resins (Z250). Conventional composite resins (Z250) demonstrated hardness values four to five times higher than the 3D printer resin groups. Sahadi *et al.*, 2021 [19] observed similar data, supporting the observation that composite resins remain an excellent choice for the restoration of both anterior and posterior teeth.

This study has limitations. As a single laboratory test was performed, further studies are potentially necessary to better understand the properties of this new material group. Additional laboratory tests evaluating wear and SEM analysis for a better understanding of the type of filler particles incorporated are suggested.

CONCLUSION

Based on the data obtained in this study, it can be concluded that BioCrown resin, proposed for final restorations, shows surface hardness values higher than acrylic resin, similar to 3D printable resins recommended for provisional restorations, and four to five times lower than conventional composite resins.

Author's Contributions

BTR: Methodology, Formal Analysis, Validation. SPP: Methodology, Formal Analysis. DISMF: Methodology, Formal Analysis. SKI: Resources, Funding Acquisition. RMM:

Conceptualization, Writing – Review & Editing, Visualization, Supervision, Project Administration and Funding Acquisition.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

Funding

This study was partially supported by *Programa Pesquisador Docente (PPD)* provided by the University Center of Santa Fé do Sul (UNIFUNEC).

Regulatory Statement

Not applicable.

REFERENCES

1. Suryajaya W, Purbiati M, Ismah N. Accuracy of digital dental models and three-dimensional printed dental models in linear measurements and Bolton analysis. F1000 Res. 2021;10:180. http://doi.org/10.12688/f1000research.31865.1. PMid:33968366.
2. Oh KC, Park JM, Shim JS, Kim JH, Kim JE, Kim JH. Assessment of metal sleeve-free 3D-printed implant surgical guides. Dent Mater. 2019;35(3):468-76. http://doi.org/10.1016/j.dental.2019.01.001. PMid:30685109.
3. Aboheikal MM, Nabi NA, Elkerdawy MW. A study comparing patient satisfaction and retention of CAD/CAM milled complete dentures and 3D printed CAD/CAM complete dentures versus conventional complete dentures: a randomized clinical trial. Braz Dent Sci. 2022;25(1):e2785. http://doi.org/10.4322/bds.2022.e2785.
4. Jain S, Sayed ME, Shetty M, Alqahtani SM, Al Wadei MHD, Gupta SG, et al. Physical and mechanical properties of 3D-Printed provisional crowns and fixed dental prosthesis resins compared to CAD/CAM milled and conventional provisional resins: a systematic review and meta-analysis. Polymers (Basel). 2022;14(13):2691. http://doi.org/10.3390/polym14132691. PMid:35808735.
5. Gresnigt MMM, Cune MS, Jansen K, van der Made SAM, Özcan M. Randomized clinical trial on indirect resin composite and ceramic laminate veneers: up to 10-year findings. J Dent. 2019;86:102-9. http://doi.org/10.1016/j.jdent.2019.06.001. PMid:31181242.
6. Schlichting LH, Resende TH, Reis KR, Raybolt Dos Santos A, Correa IC, Magne P. Ultrathin CAD-CAM glass-ceramic and composite resin occlusal veneers for the treatment of severe dental erosion: an up to 3-year randomized clinical trial. J Prosthet Dent. 2022;128(2):158.e1-12. http://doi.org/10.1016/j.prosdent.2022.02.009. PMid:35750501.
7. Arruda BM, Bassi JC, Vitti RP, Scatolin RS. Color stability of bulk fill composite resins submitted to coffee staining. Braz Dent Sci. 2021;24(1). http://doi.org/10.14295/bds.2021.v24i1.2304.
8. Ramos NC, Augusto MG, Alves LMM, Kleverlaan CJ, Dal Piva AMO. Wear of dental ceramics. Braz Dent Sci. 2023;26(1):e3638. http://doi.org/10.4322/bds.2023.e3638.
9. Borgia E, Baron R, Borgia JL. Quality and Survival of Direct Light-Activated Composite Resin Restorations in Posterior Teeth: A 5- to 20-Year Retrospective Longitudinal Study. J Prosthodont. 2019;28(1):e195-203. http://doi.org/10.1111/jopr.12630. PMid:28513897.
10. Betts JA. Laboratory controlled trials are different from clinical trials. BMJ. 2012;345(aug14 1):e5425, author reply e5431. http://doi.org/10.1136/bmj.e5425. PMid:22893644.
11. Ferracane JL. Resin composite--state of the art. Dent Mater. 2011;27(1):29-38. http://doi.org/10.1016/j.dental.2010.10.020. PMid:21093034.
12. Demarco FF, Collares K, Coelho-de-Souza FH, Correa MB, Cenci MS, Moraes RR, et al. Anterior composite restorations: A systematic review on long-term survival and reasons for failure. Dent Mater. 2015;31(10):1214-24. http://doi.org/10.1016/j.dental.2015.07.005. PMid:26303655.
13. Demarco FF, Cenci MS, Montagner AF, de Lima VP, Correa MB, Moraes RR, et al. Longevity of composite restorations is definitely not only about materials. Dent Mater. 2023;39(1):1-12. http://doi.org/10.1016/j.dental.2022.11.009. PMid:36494241.
14. Ishikiriama SK, De Oliveira GU, Maenosono RM, Wang L, Duarte MA, Mondelli RF. Wear and surface roughness of silorane composites after pH cycling and toothbrushing abrasion. Am J Dent. 2014;27(4):195-8. PMid:25831602.
15. Koottathape N, Takahashi H, Iwasaki N, Kanehira M, Finger WJ. Two- and three-body wear of composite resins. Dent Mater. 2012;28(12):1261-70. http://doi.org/10.1016/j.dental.2012.09.008. PMid:23083806.
16. Say EC, Civelek A, Nobecourt A, Ersoy M, Guleryuz C. Wear and microhardness of different resin composite materials. Oper Dent. 2003;28(5):628-34. PMid:14531611.
17. Simoneti DM, Pereira-Cenci T, Dos Santos MBF. Comparison of material properties and biofilm formation in interim single crowns obtained by 3D printing and conventional methods. J Prosthet Dent. 2022;127(1):168-72. http://doi.org/10.1016/j.prosdent.2020.06.026. PMid:33168174.
18. Castro EF, Nima G, Rueggeberg FA, Giannini M. Effect of build orientation in accuracy, flexural modulus, flexural strength, and microhardness of 3D-Printed resins for provisional restorations. J Mech Behav Biomed Mater. 2022;136:105479. http://doi.org/10.1016/j.jmbbm.2022.105479. PMid:36279743.
19. Sahadi BO, Nima G, Andre CB, Sebold M, Palma-Dibb RG, Faraoni JJ, et al. Microhardness homogeneity of RBCs light-cured with a multiple-peak LED and surface characterization after wear. Braz Dent J. 2021;32(3):92-104. http://doi.org/10.1590/0103-6440202104044. PMid:34755794.

Rafael Massunari Maenosono
(Corresponding address)
Centro Universitário de Santa Fé do Sul, Departamento de Materiais Odontológicos, Santa Fé do Sul, SP, Brazil.
Email: rafamaenosono@hotmail.com

Date submitted: 2024 June 21
Accept submission: 2024 July 22