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ORIGINAL ARTICLE

Comparative study of hardness of three biocompatible printable resins for temporary dental use

Estudio comparativo de dureza de tres resinas imprimibles biocompatibles de uso odontológico provisional

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ABSTRACT

Introduction: Temporary restorations in dentistry can be fabricated from various materials, such as polymethyl methacrylate (PMMA) and bis-acrylic resin. Recently, three-dimensional (3D) printing has emerged as a novel manufacturing approach. Among the required properties, hardness is considered a key mechanical parameter due to its relevance for material stability and clinical performance.

Objective: To evaluate the microhardness of three printable resin-based provisional restorative materials, fabricated by computer-aided design and manufacturing, following the ISO 10477 standard.

Material and Methods: Three specimens of dimensions 50 mm × 30 mm × 5 mm were fabricated for each group using Harz Labs Dental Sand Printable Resin (Group H), Materials Raydent C&B 3D Printable Resin (Group R), and Nextdent C&B MFH Printable Resin (Group N). An Anycubic Photon LCD printer was used for the printing, and the post-processing was made according to the particular protocol of each manufacturer. The surface hardness was measured using the Vickers hardness test to later evaluate and compare the values obtained according to the ISO 10477:2020 standard protocol.

Results: In terms of Vickers hardness, the results showed that Group N had the highest values (16.26 HV), followed by Group R (8.17 HV) and Group H (7.37 HV). There were statistically significant differences in Vickers hardness between the groups, with Group N being significantly superior to the other two groups

Conclusions: Group N (Nextdent C&B MFH) proved to have the highest Vickers hardness among the materials evaluated. However, all materials met the standards ISO 10477, which certifies them as compatible for use in intraoral applications.

Keywords:
CAD CAM; Dental Restoration, Temporary; Hardness Tests.

RESUMEN

Introducción: En odontología existen diversos materiales para restauraciones provisorias, desde el polimetilmetacrilato hasta resinas bis-acrílicas. Actualmente, la impresión 3D se ha posicionado como una alternativa innovadora para su confección. Estos materiales deben cumplir ciertos requisitos, siendo la dureza uno de los parámetros mecánicos más relevantes por su relación con la estabilidad y el desempeño clínico.

Objetivo: Evaluar la microdureza de tres materiales restauradores provisionales a base de resina imprimible, manufacturados mediante diseño y fabricación asistidos por computadora, de acuerdo con la norma ISO 10477.

Material y Métodos: Se utilizaron 3 especímenes de dimensiones de 50 mm × 30 mm × 5 mm para cada grupo, utilizando Resina imprimible Harz Labs Dental Sand (Grupo H), Resina imprimible 3D Materials Raydent C&B (Grupo R), y Resina imprimible Nextdent C&B MFH (Grupo N). Para la impresión se utilizó Impresora LCD Anycubic Photon y postprocesamiento según protocolo particular de cada fabricante. Se midió la dureza superficial mediante prueba de dureza Vickers para posteriormente evaluar y comparar los valores obtenidos según protocolo norma ISO 10477:2020.

Resultados: Se evidenció que el Grupo N, tenía los valores más altos (16,26 HV), seguido por el Grupo R (8,17 HV) y el Grupo H (7,37 HV). Hubo diferencias estadísticas en la dureza Vickers entre los grupos, con el Grupo N siendo significativamente superior a los otros.

Conclusiones: La resina Nextdent C&B MFH presentó la mayor dureza Vickers entre los materiales evaluados, lo que indica un mejor desempeño en esta propiedad. No obstante, todos los materiales cumplieron con los estándares establecidos por la norma ISO 10477.

Palabras Claves:
CAD CAM; restauraciones provisionales; dureza.

INTRODUCTION

Digital scanning and design have changed the way dentistry is practiced. The design and manufacture of restorations and/or prosthetic elements can be integrated into a workflow within Computer-Aided Design/ Computer-Aided Manufacturing systems, known by their acronym CAD/CAM.(1)

One of the methodologies for printing through digital workflow (CAM) is liquid photopolymerization (VAT polymerization), where a type of photosensitive resin is cured by a light source to produce solid layers and eventually an entire structure. VAT polymerization has different printing methods, such as the Liquid Crystal Display (LCD) method, where a resin placed on a surface is photo-activated by UV light from an array of LEDs shining through an LCD screen, revealing only the pixels necessary for the polymerization of the exposed layer.(2)

Currently, there are printable resins that can be used to fabricate temporary dental structures. This study focuses on the three most commonly used resins.

The first printable resin is NextDent C&B Micro Filled Hybrid from the Netherlands.(3) This biocompatible polymer-based material is used for bridges and crowns. Its polymerization is initiated by the presence of a light- or UV-sensitive initiator. The technical specifications indicate compliance with ISO 10993-1 and 10477 standards, as it is non-cytotoxic and non-mutagenic. It is characterized by a Shore D hardness of 80-90.

Secondly, the 3D Materials Raydent C&B printable resin from South Korea(4) is a biocompatible material for printing temporary dental crowns and bridges. The manufacturer's technical specifications indicate compliance with ISO 10477. It is characterized by a Shore D hardness > 90.

Finally, the Russian brand HARZ Labs Dental Sand(5) describes a biocompatible, low-shrinkage polymerization material that complies with ISO 10993. It is characterized by a Shore D hardness of 90-92.

The manufacturers do not provide the specific chemical composition of their resins; the only information provided is the use of monomer-based acrylic esters with a CE Class IIa certification, which allows the use of this material in the body for up to 30 days.(6,7) Hardness is the ability of the surface layer of a material to resist penetration by an indenter, thus representing its resistance to localized plastic deformation on its surface.(8) Shore D hardness is the measurement scale used for the study of soft materials,(9) and is the scale on which the hardness values provided by the manufacturers of printable resins are found. However, these measurements can be replicated by other hardness tests that are sensitive to both hard and soft materials, such as the Vickers scale, which allows testing of materials with irregular surfaces and smaller thicknesses.(10)

The International Organization for Standardization (ISO) develops international technical standards for product manufacturing. ISO 10477:2022 is the most up-to-date version of the technical norm that standardizes the fabrication of polymer-based crowns and veneers. Type 2 is defined as "polymer-based crown and veneer materials whose setting is effected by the application of energy from an external source such as heat and/or radiation (visible or UV range). "Within this type, Class 2 is highlighted as "polymer-based crown and veneer materials containing a photoactivated polymerization initiator".(11) Furthermore, ISO 6507-1:2018 is the technical standard (norm) that standardizes the performance of the Vickers hardness test.(12)

From a clinical and functional perspective, both conventional and newly developed materials must meet specific properties to ensure adequate performance in the mouth. Temporary restorations must withstand functional and parafunctional forces, maintaining their integrity throughout the clinical use period. Among the most relevant characteristics to be evaluated are surface hardness, flexural strength, brittleness, marginal adaptation, fluorescence, final polish, and color stability.(13) In the initial evaluation stages of new materials, especially under in vitro conditions, mechanical properties play a central role. Among these, surface hardness stands out as a critical parameter, as it is related to wear resistance and the longevity of the temporary restoration.

The **objective** of this study is to determine and compare the surface microhardness of three printable provisional resins for intraoral use, as well as to evaluate whether the Vickers hardness values obtained meet the requirements established by the ISO 10477 standard according to our experimental conditions.

MATERIALS AND METHODS

This was an in vitro experimental study. The methodology was based on verifying compliance with ISO 10477:2020 and ISO 6507-1:2018 standards for three printable resins. Sample testing was performed in the Materials Laboratory of the Department of Mechanical and Metallurgical Engineering at the Pontifical Catholic University of Chile, in the period between 2022 and 2023.

Sample Preparation

Hardness: The sample size was determined according to the guidelines of ISO 10477:2020. Three specimens were prepared for each printable resin, resulting in a total of nine specimens. Three indentations were made on the top and three on the bottom of each specimen, for a total of six indentations per specimen and 54 indentations.

Preparation of the test specimens: Using Dassault's 3DEXPERIENCE software, a 50 mm × 30 mm × 5 mm specimen was digitally designed. The STL file was exported to Chitubox (Slicer) software to prepare for 3D printing in printable resin. The specimens were manufactured using the Anycubic Photon® 3D printer, which utilizes LCD technology, with the following resins: Nexdent® C&B Micro Filled Hybrid (MFH), 3D Materials® Raydent C&B, and Harz Labs® Dental Sand.

The samples were printed with a layer thickness of 100 µm and an orientation of 90 degrees to the printing platform, resulting in two free faces for testing. Printing and post-processing parameters were defined according to each manufacturer's recommendations. Fifteen minutes after polymerization, the support bars were removed, and excess material was removed with 320-grit sandpaper. Each bar was then stored in a grade 2 aqueous solution (purified water according to ISO 3696, 1987[14] at room temperature for 24 ± 2 h until mechanical testing.

Sample testing: A WILSON® VH1150 Vickers hardness tester was used with a penetration load of 500 gF and a testing time of 10 s. For each material, six low-force Vickers hardness (VH) test measurements were performed, three on one free face surface (A), and three on the opposite face (B), maintaining a separation of 1.5 mm between each indentation.

Statistical Analysis

Measures of central tendency and dispersion were calculated using Stata 14 S/E software, licensed by the University of Chile, and descriptive statistics were performed for each group. The Shapiro-Wilk test was used to determine the normality of the data distribution for each material.

The coefficient was calculated between the three indentations made on the free face "A" versus the three on the counterpart "B," aiming to obtain a similarity percentage of at least 70% in each of the A/B pairs.

The data used for this research are openly available on Zenodo through the identifier: https://doi.org/10.5281/zenodo.17379256[15]

Ethical component

This study corresponds to an in vitro investigation, based exclusively on the laboratory analysis of 3D-printed dental materials. No human participants, biological samples, or clinical data were involved at any stage of the research. Therefore, the study poses no risk to human subjects and does not require review or approval by an Ethical Scientific Committee, in accordance with current institutional regulations for research that does not include direct human participation.

RESULTS

Surface Hardness

Table 1 shows a non-parametric distribution of surface hardness for 3D Materials® Raydent C&B and HARZ Labs® Dental Sand. The Kruskal-Wallis test was used for comparative statistical analysis with a significance level of 0.05, yielding a p-value < 0.000, which indicates significant differences between at least two of the materials. The Dunn post hoc test was used to determine which groups showed differences.

Table 1: Surface hardness values in the Vickers hardness test

Material	Surface Hardness			
	No.	Mean (In VH)	SD	p value
NextDent ® C&B Micro Filled Hybrid	18	16.26	± 1.10	0.25736*
3D Materials ®Raydent C&B	18	8.18	± 0.98	0.02501
HARZ Labs® Dental Sand	18	7.37	± 0.98	0.00038

The values in Table 2 show that the surface hardness of the NextDent® group “n” was significantly higher and statistically significant compared to the other materials studied, with a p-value < 0.001. The Vickers hardness values of the 3D Materials® resin and the HARZ Labs® resin group (p = 0.053) did not reach a statistically significant difference (p < 0.05).

Table 2: Comparative analysis of the studied groups using Dunn's post hoc test

Material (A)	**Material (B)**	**p value**
		Dunn's post hoc test
NextDent ® C&B Micro Filled Hybrid	3D Materials ®Raydent C&B	0.000*
NextDent ® C&B Micro Filled Hybrid	HARZ Labs® Dental Sand	0.000*
3D Materials ®Raydent C&B	NextDent ® C&B Micro Filled Hybrid	0.000*
3D Materials ®Raydent C&B	HARZ Labs® Dental Sand	0.053
HARZ Labs® Dental Sand	NextDent ® C&B Micro Filled Hybrid	0.000*
HARZ Labs® Dental Sand	HARZ Labs® Dental Sand	0.053

p < 0.05 indicates significant differences

Figure shows that the “N” group (NextDent®) exhibited significant differences in Vickers hardness compared to the other two groups studied. Furthermore, there were no significant differences between “H” (HARZ Labs®) and “R” (3D Materials®). The “N” group had the highest surface hardness value of the materials studied (19.3 HV), while the “H” group had the lowest Vickers hardness value (6.7 HV).

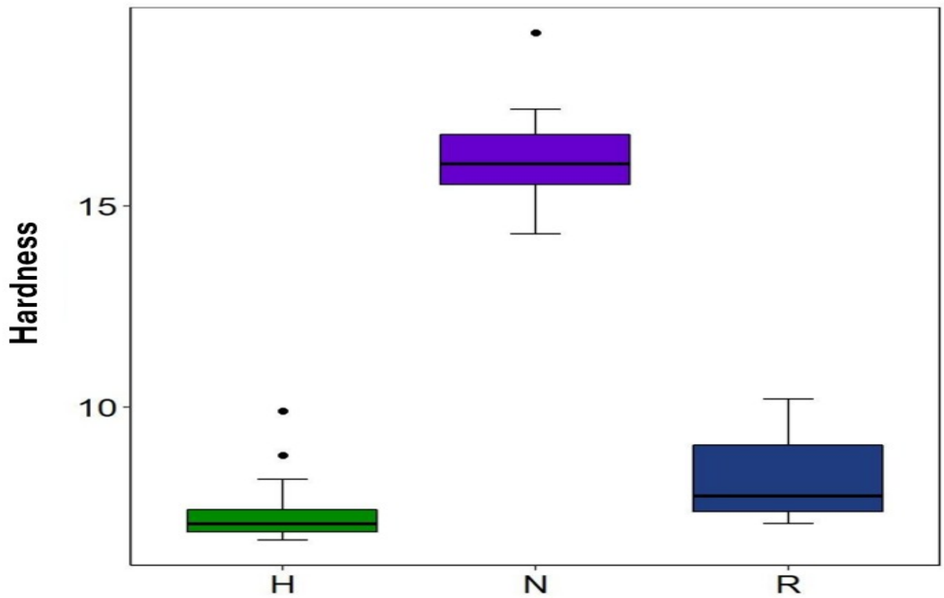

Figure: Box Plot of Vickers hardness values for different groups of printable resins. Harz Labs®: green, Nexdent®: purple, Raydent: blue.

DISCUSSION

Statistically significant differences were demonstrated between the various materials studied. It is noteworthy that the three resins studied meet the requirement of at least 70% similarity between opposing surfaces, established by ISO 10477:2020, making them suitable for intraoral use.

In the study by Aati *et al*.,[16] the surface hardness of the NextDent® printable resin was evaluated using the Vickers test, yielding results consistent with the findings of our research. The experiment included groups of nanocomposite samples with different proportions of zirconium oxide nanoparticles, to which multiple indentations were applied under a controlled load, after different storage periods in artificial saliva.

The hardness values showed a progressive increase as the nanoparticle concentration increased, reaching the highest levels in the resin with the highest reinforcement content and the lowest in the unmodified resin. Consequently, the results described by Aati and colleagues are consistent with those observed in our study.

Atria *et al*.[7] evaluated three commercial resins for provisional restorations (Crowntec, Temporary C&B, and C&B MFH) and one experimental resin (Permanent

Bridge) using mechanical tests (biaxial bending, finite element analysis, and Weibull)and biological tests (cell proliferation, immunohistochemistry, and cytotoxicity). In this study, the resin manufacturers Nextdent, Harz Labs, and 3D Materials were contacted, and information regarding the composition of the latter was obtained.

According to the technical information obtained from the manufacturers, both printable resins differ in the type and proportion of their monomeric components. NextDent® C&B Micro Filled Hybrid consists of more than 60% polymethyl methacrylate (PMMA), combined with 15–25% triethylene glycol dimethacrylate (TEGDMA) as a co-monomer. The material also includes less than 2.5% phosphine oxide as a photoactivated polymerization initiator. In contrast, 3D Materials® Raydent C&B contains a smaller proportion of polymethyl methacrylate, reported between 20–35%, and a similar content of TEGDMA ranging from 20–25%. This resin also incorporates 20–28% urethane dimethacrylate (UDMA) as an additional base monomer, and 1–10% phosphine oxide as the photoactivator. Additionally, Raydent® includes 0.1–5% titanium dioxide as an inorganic filler.

Taken together, these differences suggest that NextDent® is formulated predominantly as a PMMA-based micro-hybrid resin matrix, whereas Raydent® presents a more heterogeneous formulation with a lower PMMA ratio and the incorporation of UDMA and titanium dioxide, which may influence both its polymer network density and final surface hardness under Vickers testing.

NextDent®, with a PMMA concentration exceeding 60%, surpasses the levels found in 3D Materials®. Its hardness is comparatively intermediate between that of a heat-cured PMMA (17.7–19.4 HV) and a self-cured PMMA (14.2–15.3 HV).[17,18]

Digholkar *et al*.[19] compared the microhardness of the printed microhybrid composite E-Dent 100—with a particle size equivalent to that of NextDent® resin—from Envision TEC (additive manufacturing group, FA), with a polymethyl methacrylate (PMMA) Ceramill TEMP manufactured using CAD-CAM technology and with a third group of conventionally produced PMMA, without following a specific guideline or standard for the measurements. Significant differences were observed between the Knoop microhardness values of the analyzed groups, with the additively manufactured material exhibiting the highest values, followed by the conventional material, and lastly, the milled material. It was concluded that the provisional material from the additively manufactured group (E-Dent 100) exhibits superior microhardness compared to conventional provisional dental materials.

Digholkar *et al*.[19] attribute these results to the fact that photoactivated printable resins, such as the one evaluated in group FA, incorporate multifunctional crosslinked monomers—capable of forming a three-dimensional network by joining different homogeneous polymer chains—along with inorganic fillers that increase abrasion resistance and reduce polymerization shrinkage. Consequently, the greater density of their structure confers superior surface hardness than polymethyl methacrylate, a monofunctional material with low molecular weight and linear chains that exhibits lower strength and hardness.

Simoneti *et al*.[20] confirm Vickers hardness values of the conventional acrylic and the bisacrylic resin, Protemp 4 for temporary use.[21] It is observed that the hardness of Protemp 4 surpasses that of 3D Materials® and HARZ Labs® resins,[21] but is lower than that of the self-curing acrylic and Nextdent® resin.

According to the comparison, NextDent® C&B MFH exhibited the highest Vickers hardness value (16.2 HV) among all materials evaluated. It was followed by self-curing acrylic, which showed 14.2 HV, and Protemp® 4 by 3M, with a value of 10.7 HV. Among the remaining printable resins, Raydent® C&B reached a hardness of 8.1 HV, while HARZ Labs® Dental Sand showed the lowest value, at 7.3 HV. These findings indicate that NextDent® demonstrates the greatest surface hardness within the group of materials compared, outperforming both the other printable resins and the conventional provisional materials included in the reference.

The method differed for each resin, following the manufacturer's recommendations. According to Kim *et al*.,[22] it has a significant effect on the mechanical properties of printable resins and could partially explain the differences in values between them. Only the HARZ Labs® resin underwent a more thorough post-processing with heat, UV light, and ultrasonic cleaning; even so, its Vickers hardness values were not the best. It is worth noting that the manufacturer omitted certain elements, such as the speed at which the test was performed, how the print support structures were removed (considering the human factor), layer thickness, and print orientation.

The clinical applicability of polishing is related, in part, to the base particle size of the printable resin. NextDent® resin is classified as a microhybrid filled resin, Raydent® as a hybrid filled resin, and Harz Labs® as a micro filled resin. Based on this, the poor performance of Harz Labs® and Raydent® resins in Vickers hardness tests would be justified. However, they could hypothetically outperform NextDent® resin in some surface roughness or polishing tests. Nevertheless, surface hardness alone is not an indicator of stiffness and strength, and cannot predict the clinical behavior of long-span prostheses,[23] so its comparison should be used from a referential point of view and as a complement to other properties.

A recent study by Yay Kuscu *et al*.[24] investigated the influence of restoration thickness and post-curing duration on the surface hardness (HV) of 3D-printed provisional resin. The authors reported that thinner specimens (1 mm) exhibited significantly higher Vickers hardness values compared with thicker samples (2 mm and 3 mm), while the differences associated with post-curing time (20 vs. 25 min) were not statistically significant. These findings indicate that the microhardness of printed provisional restorations depends more on geometric design (thickness) than on minor variations in post-curing parameters. Therefore, optimizing the restoration thickness at the digital planning stage is essential to maximize surface hardness, and consequently improve wear resistance and clinical durability.

In line with our findings, the 2025 study on provisional restorations for pediatric use showed that 3D-printed resins provided adequate mechanical performance, including surface hardness values comparable to milled resins even after thermomechanical aging, suggesting that modern printable resins can maintain hardness over time under functional loading. This supports the potential clinical viability of 3D-printed provisional materials beyond in vitro testing, adding evidence that, with appropriate post-processing and material selection, they can withstand long-term occlusal forces.[25]

A 2025 systematic review showed that while 3D-printed resins offer the advantages of additive manufacturing, their microhardness tends to be lower than that of conventional resins — which suggests that, despite advances, 3D-printed provisional materials may still underperform in terms of surface hardness and long-term wear resistance compared to traditional options. This underlines the critical need to optimize printing parameters and post-processing protocols when using these materials clinically.[26]

Finally, and in line with the points mentioned above, despite being on the market for over six years, the performance of these materials still lacks robust evidence studies, with a dearth of case reports and even fewer randomized clinical trials. This research takes into account just one aspect of a more comprehensive analysis of dental materials and can be considered a starting point for further experimental studies encompassing other available brands, important physical properties, and three-dimensional digital impression parameters. Once all the properties of these materials have been validated, the next step would be to study their intraoral behavior through controlled clinical trials.

Limitations of the study

This study presented methodological **limitations** that should be considered when interpreting the results. First, limited access to the testing laboratory restricted the availability of time and equipment, which prevented the inclusion of a control group. Initially, it was planned to compare the performance of printable resins with specimens of commonly used materials for provisional restorations, such as self-curing acrylic, heat-cured acrylic, and bis-acrylic resins, under identical experimental conditions. The absence of this control group reduced the possibility of directly contrasting the obtained values with standard parameters under the same testing conditions.

Additionally, the manual removal of printing supports and the subsequent polishing process may have introduced minor variations in the calculation of absolute density. Although these variations are considered minimal due to the reduced surface area involved, their influence cannot be completely ruled out. For future research, the use of a digital densitometer is recommended to validate the results obtained through conventional calculations and improve the accuracy of density measurements.

Overall, these limitations suggest that the findings should be interpreted with caution and highlight the need for further experimental studies including control groups and more precise instrumental techniques to strengthen the evidence on the physical behavior of printable resins..

CONCLUSIONS

Nextdent C&B MFH resin exhibited the highest Vickers hardness values among the materials evaluated, indicating superior performance for intraoral use. However, all materials met the standards established by ISO 10477.

RECOMENDATIONS

Based on the results obtained and the methodological limitations identified in this study, the following recommendations are proposed for future research on printable resins for provisional restorations:

1. Analysis of anisotropy according to printing orientation

It is recommended to systematically evaluate the influence of printing orientation on surface hardness and density, considering the X, Y, and Z axes, in order to characterize the anisotropic behavior of printable materials.

2. Expansion of the mechanical properties evaluated

Vickers hardness testing should be complemented with other relevant physical–mechanical properties for clinical use, such as flexural modulus, fracture resistance, wear resistance, dimensional stability, water absorption, and behavior after artificial aging.

3. Studies on intraoral behavior and clinical evidence

Once their physical properties have been validated in the laboratory, it is recommended to move forward toward controlled clinical studies and randomized trials to assess the intraoral performance of these materials, including marginal adaptation, wear, color stability, and biofilm formation.

4. Comparison among brands and traceability of chemical composition

It is suggested to expand the analysis to other printable resins available on the market and perform a deeper assessment of the chemical composition declared by manufacturers, considering its impact on polymer network density and final mechanical performance.

Taken together, these recommendations aim to strengthen the scientific evidence available on printable resins, consolidate reproducible methodological protocols, and contribute to the development of materials that may improve clinical performance in provisional restorations.

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Conflict of interests

The authors declare no conflict of interest.

Authors´ contributions

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All the authors participated in the discussion of the results and have read, reviewed and approved the final text of the article.