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Comparative Analysis of the Fracture Resistance of a Polymeric Material for 3D Printing and a Milled Polymethylmethacrylate Material as Interim Material for Fixed Partial Dentures: New Material Updated

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Abstract: The aim of this study was to evaluate and compare the fracture resistance of a temporary three-unit fixed dental prosthesis (FDP) made of a new polymeric material obtained by an additive technique (3DPP) using a computer-aided design and manufacturing (CAD/CAM) system, comparing the prosthesis to the respective outcomes of temporary polymethylmethacrylate (PMMA) FDPs obtained by a subtractive technique (milling). Methods: Three-unit FDPs were 3D printed using a polymeric material (n = 20) or milled using polymethylmethacrylate (n = 20). After thermocycling at 5000 cycles at extreme temperatures of 5 °C and 55 °C in distilled water, each specimen was subjected to a compression test on a universal testing machine at a rate of 0.5 mm/min until failure occurred, recording the value in newtons (N). Results: There were statistically significant differences (p-value < 0.005) between the PMMA material (2104.7 N; SD = 178.97 N) and 3DPP (1000.8 N; SD = 196.4 N). Conclusions: The fracture resistance of the PDFs manufactured from milled PMMA showed higher values for fracture resistance. However, the resistance of the 3DPP showed acceptable values under mechanical load; this notable advance in the resistance of printed materials consolidates them as an important alternative to use in interim indirect restorations.

Keywords: PMMA; printed materials; CAD/CAM materials; fracture resistance; interim restorations

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Citation: Abad-Coronel, C.; Córdova, J.; Merchán, A.; Larriva, J.; Bravo, A.; Bernal, B.; Paltán, C.A.; Fajardo, J.I. Comparative Analysis of the Fracture Resistance of a Polymeric Material for 3D Printing and a Milled Polymethylmethacrylate Material as Interim Material for Fixed Partial Dentures: New Material Updated. *Designs* **2023**, *7*, 118. https://doi.org/10.3390/designs7050118

Academic Editors: Ali Zolfagharian and Joshua M. Pearce

Received: 2 August 2023
Revised: 6 October 2023
Accepted: 9 October 2023
Published: 13 October 2023

1. Introduction

Interim, temporary or transitional prosthetic restorations fulfill mechanical, biological and esthetic requirements such as the protection of dental tissues, the healing of periodontal and peri-implant tissues, periodontal splinting, post-surgical prosthetics, the testing of certain esthetic and occlusal parameters, the evaluation of hygiene procedures, as a tool for interdisciplinary communication and for contributing to patient comfort and confidence [1,2].

When the treatment plan calls for full oral rehabilitation, extensive occlusal changes or implant-supported prostheses, the use of temporary restorations may be required for a longer period of time [3]. In such cases, the restorations are immediately subjected to functional loading, with force values ranging from 600 N to 750 N in posterior teeth and 120 N to 200 N in anterior teeth [4,5].

The materials used in the manufacture of temporary prosthetic restorations must exhibit adequate mechanical behavior. One of the most important properties is fracture resistance, which is described in the glossary of prosthodontic terms as "the stress required for material failure; represented by a line plotted on a stress vs. strain graph; this deformation may be less than the ultimate force; that is, the maximum stress in a sample before material failure" [6]. Insufficient fracture resistance causes fracturing of the restoration, as occlusal loads and intraoral conditions—in the long term—may cause them to degrade and require replacement or repair, causing patient discomfort and economic loss [7,8].

Temporary restorations can be fabricated by conventional direct and indirect techniques; in such techniques, essentially, the external contour of the temporary restoration is duplicated from a matrix and the internal adaptation of the restoration is formed directly on the prepared teeth, if a direct technique is performed, or in a stone cast if the indirect technique is performed. In these conventional techniques there are disadvantages, such as their limited mechanical properties and the sensitivity of the technique during the mixing, application and polishing processes [9,10]. To overcome the disadvantages of conventional materials, today—thanks to CAD/CAM technology—new materials have been developed and various workflows have been digitized and automated [11]. Among its advantages are the acquisition of accurate and instantaneous images that can be stored digitally, the easy duplication of a fractured or missing restoration, the execution of standardized, simple and repeatable clinical procedures, patient comfort and compliance and the use of homogeneous industrial parts and blocks that show fewer flaws and voids, resulting in greater reliability [10,12].

Among the CAD/CAM procedures available is additive manufacturing, which, starting from a 3D design database, builds the physical object through the sequential application of thin layers of material [11]. In dentistry, additive manufacturing generally employs different technologies such as stereolithography (SLA), digital light processing (DLP), selective laser melting (SLM), selective laser sintering (SLS) and fused deposition modeling (FDM). One of the methods used for dental crowns and bridges manufactured is the DLP method, in which a digital micromirror device (DMD) creates the light source and image. In this process, a vat of liquid photopolymer is exposed to light from a DLP projector that displays the image of the 3D model [13,14]. It has been reported by Park et al., Lim et al., and Alam et al. that 3D-printed provisional restorations have sufficient mechanical properties for intraoral use compared to milled and conventionally fabricated provisional restorations. Therefore, they can be considered as a reliable method for the manufacture of provisional restorations with better mechanical properties [15–17].

Another CAD/CAM process is subtractive fabrication, which begins with the design of a virtual restoration, whose data is sent in a file to a milling machine that fabricates the restoration in the block or disc of the selected material by means of automated subtractive cutting [18]. The milling machine gives the volumetric shape to the material and can operate in wet or dry conditions and move along defined paths known as milling axes, which can be in a number of three, four or five axes [19]. Subtractive production has the disadvantage of the production of material waste and the poor reproducibility of more complex geometries due to limiting factors such as the cutter size, tolerance and range of motion [20–23]. Al-Wahadni et al. concluded that milled CAD/CAM crowns showed greater resistance to fractures than crowns printed with DLP technology. Meanwhile, in the study by Taşın S, et al., it was suggested that these temporary restorations—both printed and milled—have better mechanical properties than those manufactured by conventional techniques. This study further recommends milled materials for long-term treatment, due to their high potential to dissipate destructive fracture energy [24,25].

Among the temporary restoration materials most frequently used with the subtractive CAD/CAM method are polymeric materials based on PMMA. These polymers show greater homogeneity due to the lower infiltration of contaminants and bubbles, as well as their higher flexural strength (100 MPa), higher modulus of elasticity (3200 MPa) and better color stability [26–28]. In addition, the CAD/CAM process prevents the formation of an inhibited oxygen surface layer and prevents polymerization shrinkage [29,30]. CAD/CAMprocessed PMMA is also characterized by reduced monomer release, improved optical properties and easy machinability [30].

Telio® CAD (Ivoclar Vivadent, Schaan, Liechtenstein) is a material in the form of crosslinked PMMA blocks and discs for the fabrication of long-lasting temporaries. This is a highly homogeneous material composed of crosslinked PMMA (99.5%) and pigment (0.5%). Due to their industrial production as CAD/CAM blocks, they do not show polymerization shrinkage [31].

For the additive method, the most-used materials are polymeric materials, which are mainly composed of bisphenol A-glycidyl methacrylate (Bis-GMA), urethane dimethacrylate (UDMA) and other components such as triethylene glycol dimethacrylate (TEG- DMA) for handling its high molecular weight, viscosity and conversion rate [32]. However, for the improvement of physical and biological properties, micro and nano fillers are added, which in turn can cause adverse effects such as pore generation, limited depth of curing and decreased polymerization conversion [33,34].

An important factor the for obtaining of adequate mechanical properties with this material is its degree of conversion [35]; in 3D printing the resin is not completely polymerized inside the tank, so to eliminate any residual photo initiator, post-processing is required with intense ultraviolet exposure [36].

The evolution of CAD/CAM materials at this time is inexorable. Recently, a new polymeric material for 3D printing has been launched on the market, its manufacturer describing it as "the first-class II hybrid nanoceramic restorative resin that features an optimal combination of translucency and opacity to mimic natural dentition. It is radiopaque, with mechanical properties such as flexural strength of 147 MPa y flexural modulus of 7986 MPa. It is indicated for the fabrication of artificial teeth for dental prostheses, which are used for: provisional full-arch restoration on dental implants, as well as teeth for removable full dentures" [37].

Despite the fact that there are numerous studies that demonstrate the superiority of provisional restorations fabricated using the subtractive technique, there are still concerns concerning its limitations—such as the high cost of this type of fabrication, which limits its use. The additive method is an alternative way of digitally fabricating restorations, and has advantages over milled restorations such as mass production with little material waste, reduced manufacturing time, easy access to materials for 3D printing and the availability of low-cost 3D printers. The mechanical properties of this type of fabrication have been reported; however, they have shown mixed results [15–17,24,25].

In addition, the evolution of materials for 3D printing is unavoidable, and innovative materials such as hybrid nanoceramic restorative resin need to be studied in depth to help professionals select the best materials and techniques for manufacturing temporary crowns and FDPs. For this reason, the aim of this study was to evaluate the fracture resistance of a temporary three-unit fixed dental prosthesis (FDP) made of a new polymeric material obtained by an additive technique (3DPP), using a computer-aided design and manufacturing (CAD/CAM) system, and compare it to the respective outcomes of temporary polymethylmethacrylate (PMMA) FDPs obtained by a subtractive technique (milling).

2. Materials and Methods

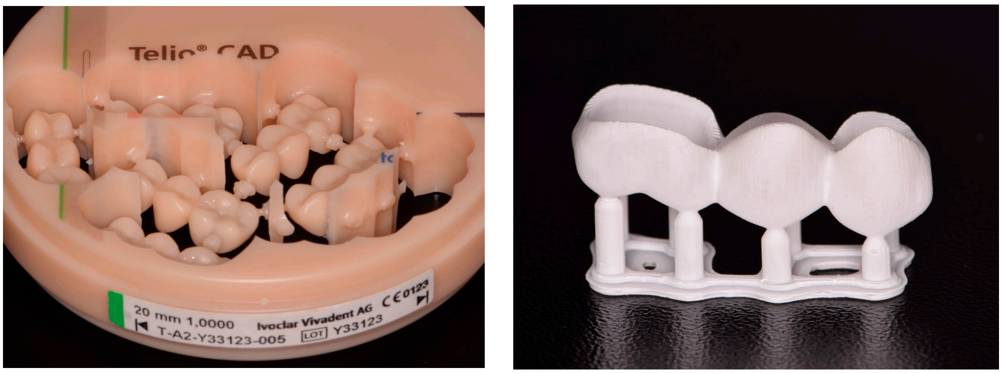
2.1. Sample Preparation

Preparations for a three-unit fixed dental prosthesis (FDP) were made in a model that mimics the structure and characteristics of the human mouth (typodont). The prepared abutments were the maxillary right first premolar and maxillary right first molar, and the replaced tooth (pontic) was the maxillary right second premolar. The following protocol was followed for the preparation: chamfer termination line, occlusal reduction of 2 mm, axial reduction of 1.5 mm with parallelism between axial walls of 6 degrees and rounded angles.

Subsequently, 40 FDPs were generated using the following materials and procedures (Table 1). A digital impression of the prepared typodont was obtained using an intraoral scanner (PrimeScan 2.0, Dentsply-Sirona, New York, NY, USA). The model was digitized and a three-unit restoration was designed using the biogeneric mode (InLAB 20.0, Dentsply-Sirona, New York, NY, USA). The design was transferred via CAM software (InLab CAM, 20, Dentsply-Sirona, New York, NY, USA) to the integrated milling unit (MCX5, Dentsply-Sirona, New York, NY, USA) to obtain the PMMA samples (n = 20; Figures 1 and 2). For the 3D-printed samples, the same design was transferred using CAM software (RayWare, SprintRay, Los Angeles, CA, USA) to the 3D printer (SprintRay Pro DLP 3D, Los Angeles, CA, USA); this printer has an XY resolution of 55 or 95 microns and a light energy of 28.8 mW/cm^2. The provisional restoration design was placed with the teeth facing the impression platform and the occlusal plane parallel to the impression platform. The software algorithm automatically oriented and added supports and the "OnX" resin setting and 100 µm layer thickness were selected on the printer. Samples (n = 20) were printed, removed from the printing platform, and all supports were eliminated.

Table 1. Materials used in the study.

CAD/CAM Material	Material	Ref/Lote
ONX NanoCeramic Hybrid	Printed polymer 3D (3DPP)	S21K23XBL
Telio CAD	Polymethyl methacrylate (PMMA)	T-A2-Y33123-005



(**a**) (**b**)

Figure 1. (**a**) PMMA milled samples immediately after removal from the milling unit, (**b**) 3D-printed polymer samples immediately after removing from the 3D printer.

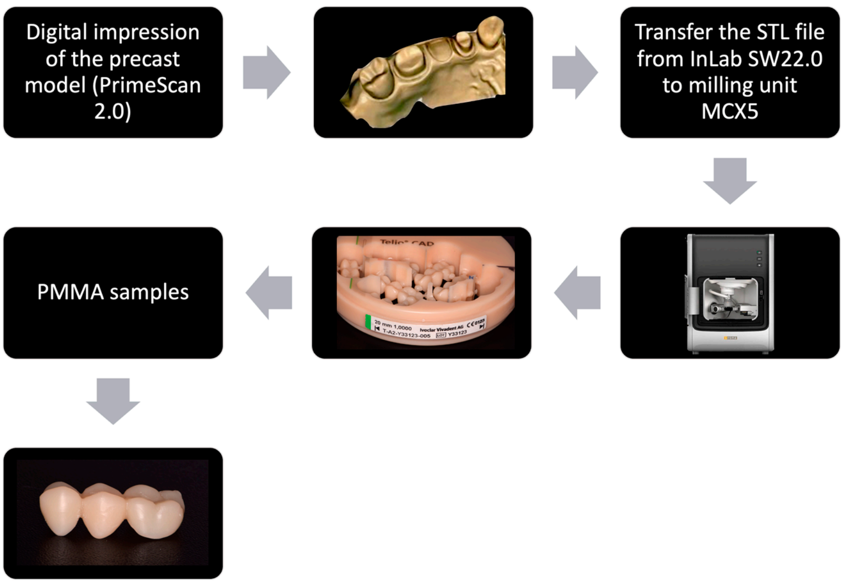


Figure 2. Manufacturing scheme of PMMA milled samples.

The printed samples then went through a post-production process using an automated multi-stage washing system (Pro Wash/Dry, Sprintray, Los Angeles, CA, USA) with 91% isopropyl alcohol (IPA), and a photopolymerization system (ProCure 2, Sprintray, Los Angeles, CA, USA) applying the pre-programmed "Onx" profile (Figures 1 and 3).

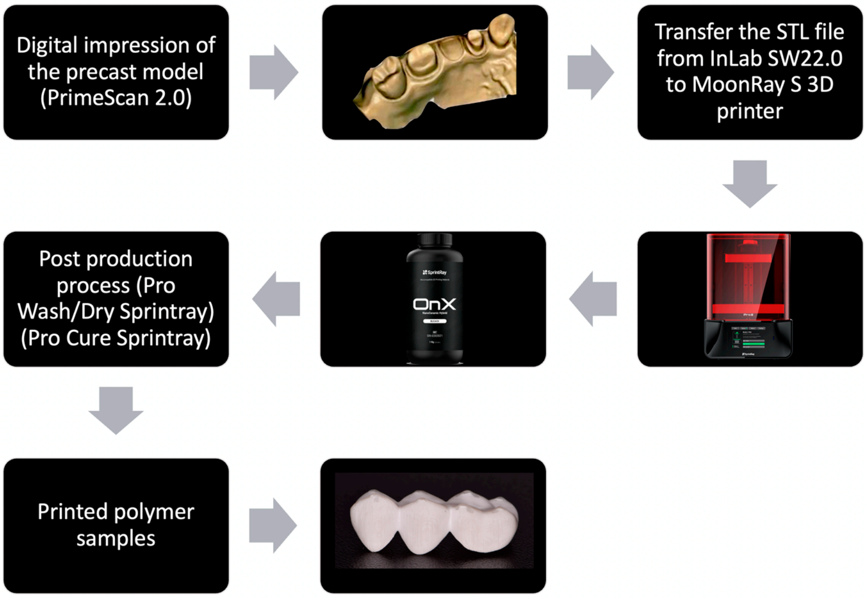


Figure 3. Manufacturing scheme of 3DPP samples.

Subsequently, all samples were subjected to a thermocycling process, at 5000 cycles with extreme temperatures of 5 °C and 55 °C in distilled water. The process was performed in a computerized thermocycling unit (Thermocycler™, SD Mechatronik, Feldkir-chen-Westerham, Germany).

2.2. Fracture Resistance Test

For fracture resistance testing, using the initial scan of the prepared typodont, a master cast typodont was fabricated from a beryllium-free nickel–chromium alloy (Wirona, Bego, Goldschlägerei, Bremen, Germany; Figure 4). The typodont was fixed on the platform of the universal testing machine (Shimadzu AGS-X series Universal Testing Machine; Shimadzu, Tokyo, Japan) and the previously inspected specimens, without cementing agent, were placed on it.

Figure 4. Master cast typodont fabricated from a beryllium-free nickel–chromium alloy.

The specimen was subjected to a quasi-static load test at a speed of 0.5 mm/min at a direction parallel to the major axis of the tooth, with an initial preload of 10 N, using a universal testing machine (Shimadzu AGS-X series Universal Testing Machine, Tokyo, Japan) equipped with a 5 kN load cell (Figures 5 and 6).

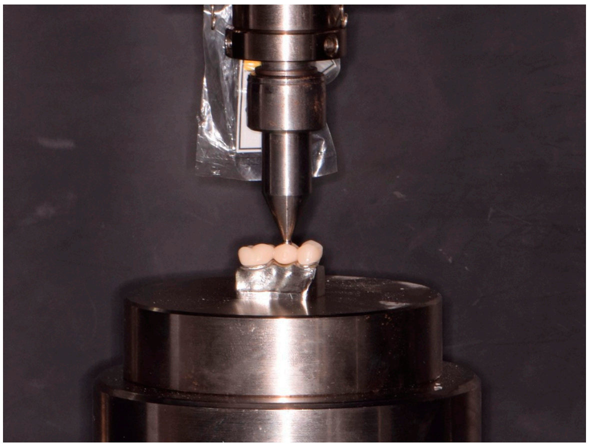


Figure 5. Sample on the typodont, fixed on the platform of the universal testing machine before the fracture test.

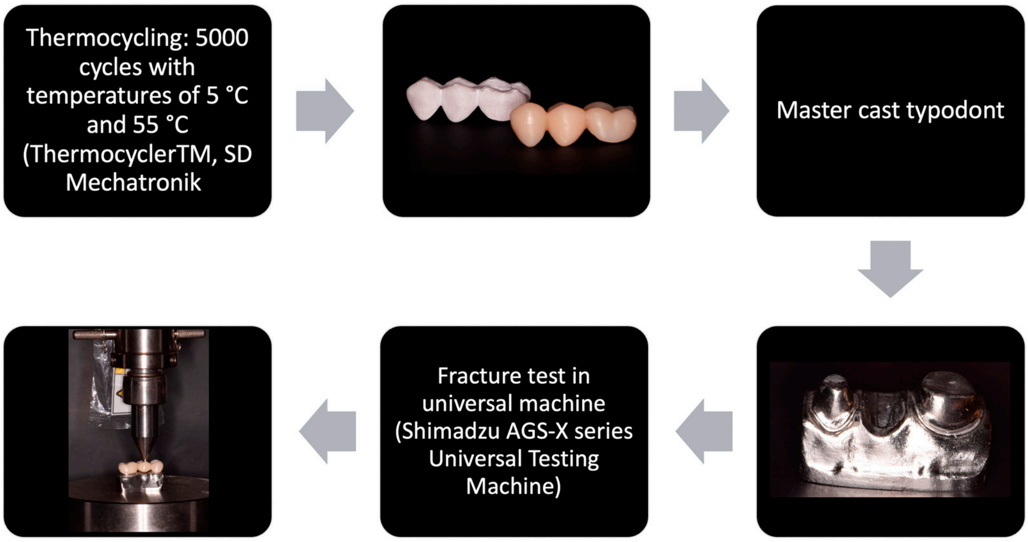


Figure 6. Diagram of the thermocycling process and fracture test.

The load was applied through a hardened steel pilot punch with a radius of 3 mm applied in the central pit of the crown. The force/displacement of the specimens were determined using the software incorporated in the instrument (Trapezium X Testing Software, Shimadzu, Tokyo, Japan). All specimens were loaded to fracture and the fracture force was recorded in Newtons (N).

2.3. Statistical Analysis

Statistical analysis of the fracture resistance of the materials studied was carried out using statistical software (SPSS; IBM Co., New York, NY, USA). The normality of the data distribution was checked with the Shapiro–Wilk Test; this result allowed the use of the Mann–Whitney U nonparametric test of independent samples. The significance level was set at $p < 0.05$.

3. Results

Descriptive statistics showed that the highest values of average fracture resistance were recorded with the PMMA material, with a mean of 2104.7 N (SD = 178.97), 95% CI (1882.5:2326.9); the measurements showed low dispersion (CV = 8.5%), the lowest value was 1829.5 N and the highest was 2257.6 N. While the sample with the lowest fracture resistance was with 3DPP, with an average of 1000.8 N (SD = 196.4 N), 95% CI (757.0 N:1244.8 N) and a higher dispersion (CV = 19.6%), the minimum and maximum value of fracture resistance reached was 842.8 N and 1343.8 N, respectively (Table 2; Figure 7). These results would indicate that there is a superiority of milled PMMA in terms of fracture resistance compared to the ONX material used in 3D printing. In addition, the results of the dispersion of the 3DPP indicate that the measurements are relatively further from the mean, while the results of the milled PMMA have less variability.

Table 2. Descriptive results of fracture resistance for materials.

Descriptive	PMMA	3DPP
Mean	2104.7	1000.8
SD	178.97	196.4
CI 95%	(1882.5:2326.9)	(757.0:1244.8)
CV	8.50%	19.60%
Minimum value	1829.5	842.8
Maximum value	2253.6	1343.8

SD: standard deviation; CV: Coefficient of variation, 95% CI: 95% confidence interval for the mean, unit of measurement newton (N).

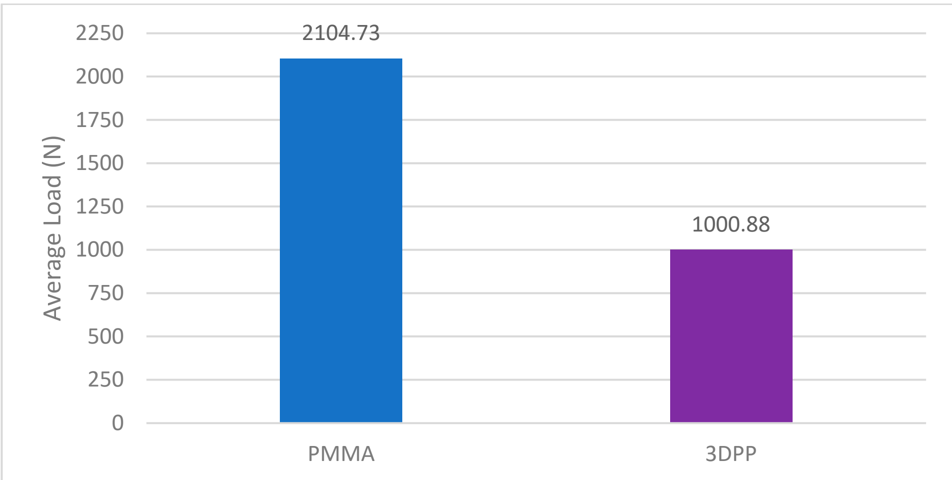


Figure 7. Average fracture resistance of the printed polymer material and milled PMMA.

Figure 8 shows the quartiles of the measurements of both materials. The PMMA shows that in Quartile 1, 25% of the values were below 1924.59 N; Quartile 2 (median) reflects that 50% of the measurements were below 2192.79 N and in Quartile 3 75% of the observations were lower than 2240.83 N. With the ONX material, Quartile 1 indicated that 25% of the values were lower than 884.2 N, Quartile 2 (median) showed 50% of the measurements as being below 940.6 N and Quartile 3 showed 75% of the observations as being below 1147.7 N.

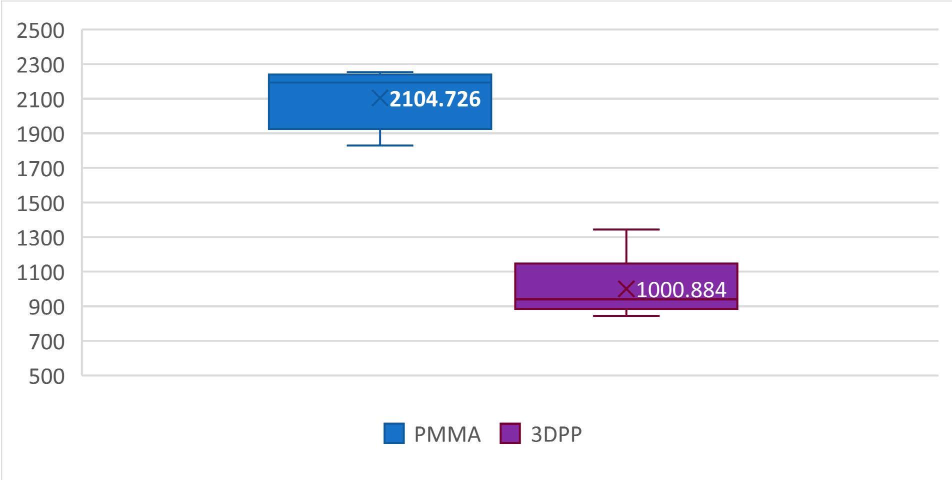


Figure 8. Box plot of the average fracture resistance of the printed polymer material and milled PMMA.

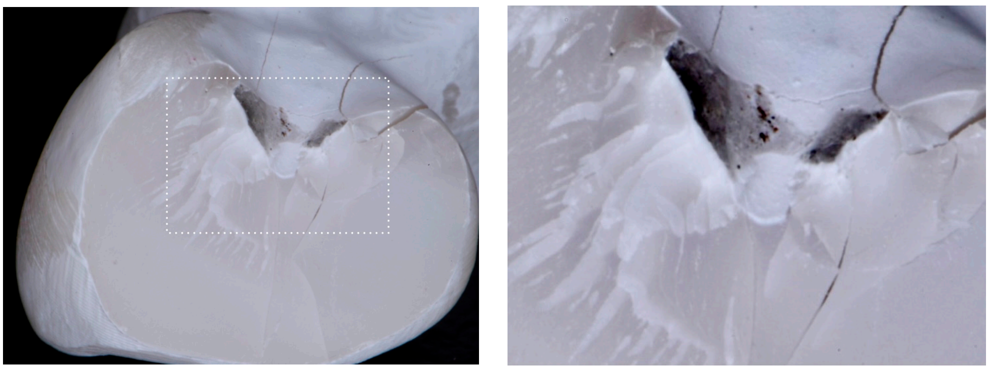
According to the results shown in Table 3, the null hypothesis was rejected (W = 40.0; p-value < 0.05). Consequently, with a significance level of 5%, it was concluded that there was a significant difference between the average fracture resistance of the materials studied.

Table 3. Mann–Whitney U test for independent simples.

PMMA	3DPP	Statistical	p-Value
2192.79 N	940.56 N	40	0.012

Significance level 5%.

The fractographic analysis was carried out on the fracture surface of each sample. The fracture surface of the samples after loading was observed and analyzed using a high-resolution stereomicroscope (Olympus; SZX7, NewYork, NY, USA). We can see that in the case of the 3DPP PDFs, the fracture was located at the level of the pontic (second premolar); the fracture showed a large number of vertical and horizontal cracks (Figure 9a), while in PMMA PDFs, fracturing occurred in the crown of the mesial abutment, where a clean and defined fracture is observed (Figure 9b).



(**a**) (**b**)

Figure 9. *Cont.*

(**c**) (**d**)

Figure 9. Images of the fracture surface models of the analyzed materials. (**a**) 3DPP fracture; (**b**) 3DPP details of the fracture mode; (**c**) PMMA fracture; (**d**) PMMA details of the fracture mode.

4. Discussion

Temporary PDFs are essential in oral rehabilitation treatments; these components must satisfy biological, aesthetic and mechanical requirements. Regarding the mechanical properties, resistance to functional loads and tensile forces are of radical importance. Therefore, the selection of the appropriate material for the fabrication of temporary fixed restorations is considered fundamental in fixed prosthetic treatments [38]. Extended wearing times of more than 6 months with prostheses made of some materials may be referred to as long-term temporization. As stated by the German Society for Dental, Oral and Cra-niomandibular Sciences (DGZMK), long-term temporaries are indicated for treatments involving changes in vertical dimension, esthetics or phonetics, for palliative prosthodontic treatments in cancer patients and in order to shorten healing times or to explore potential abutment teeth with uncertain prognoses for definitive restorative treatment. All these objectives may require temporary prostheses for about 1 year or even longer [39].

In recent years, with advances in CAD/CAM technology, the indirect fabrication of temporary restorations has become easier, and so their clinical use has become more and more widespread. However, until now, there has not been enough scientific evidence comparing the mechanical properties of the materials used in this study (Table 4); for this reason, this research was justified by the objective of evaluating the fracture resistance of temporary restorations fabricated using CAD/CAM technology, both in PMMA and 3DPP. This study stated as a null hypothesis that there would be no significant difference between the fracture resistance of temporary restorations fabricated in PMMA using the milling method and resin restorations fabricated using the 3D printing method. This hypothesis was rejected, as it evidenced a significant difference between the fracture resistance of the two materials. It was shown that PMMA restorations had a higher average fracture resistance, with a mean of 2104.7 N, and 3DPP restorations showed a low value of 1000.8 N. In a study by Suralik et al., the mechanical properties of 3D-printed prostheses were compared with those of self-cured and CAD-CAM restorations. The mean fracture strength fracture of FDP of the 3D-printed resin (408.49 N) differed significantly from that of milled PMMA (294.64 N), which is in contrast to the data obtained in this study, as both the printed polymer and the PMMA had considerably higher values—1000.8 N and 2104.7 N, respectively. Although the restoration design was the same, in the study by Suralik et al., the use of analogs (dental implant replicas inserted into a model to duplicate the location of an implant placed in the mouth) embedded in metal master typodont as pillars for the restoration could have made a difference [40], as the behavioral and mechanical properties of dental tissues are very different from those of titanium—the material with which implant analogues are manufactured.

Table 4. Summary of articles related to the study topic.

Author	Resistance to Fracture/Milled Restorations	Resistance to Fracture/Printed Restorations
Present study *	2104.7 N	1000.8 N
Suralik, et al. (2020) ** [40]	294.64 N	408.49 N
Reeponmaha et al. (2020) *** [41]	953.60 N	1004.19 N
Henderson, et al. (2022) * [42]	729 N	520 N
Abad, et al. (2021) * [43]	1663.57 N	1437.74 N

* 3 unit Fixed Dental Prostheses. ** Implant-Supported Fixed Dental Prostheses. *** Single temporary crowns.

Reeponmaha evaluated the fracture strength of single-unit temporary crowns fabricated with different materials and techniques after receiving stress from a simulated oral condition, obtaining a maximum fracture strength of 953.60 N for Brylic Solid (milled PMMA) and 1004.19 N for Freeprint Temp (printed resin); although the value of the printed polymer was close to the value of the present study, the mean of the milled PMMA differed—probably due to the FDP design, marginal fit and the thickness of the material [41].

In the study by Henderson et al. it was reported the results of average failure loads at a storage time of 24 h, with a loading rate of 1 mm/min at 520 N for 3D-printed bis-acrylic and for PMMA at 729 N. After 30 days of storage at 100% humidity, the failure load of milled PMMA and 3D-printed bis-acrylic temporary prostheses decreased significantly; the authors expected this decrease in the mechanical properties of the materials, as it has been reported elsewhere that the reduction is explained by water absorption and consequent dissolution and hydrolysis, leading to the gradual decomposition of the polymer network [42]. These facts, after including the samples in a thermocycling process, could also support the low fracture resistance of the 3D-printed FDPs in this study. This would imply that this material could present optimal mechanical characteristics in the short term and with lower stresses—for example, in partial coronary restorations or single unit fixed restorations. Previously, a study by Abad et al. compared the fracture resistance of provisional restorations obtained by additive techniques (3D impressions) and subtractive techniques (milling) for a three-unit fixed dental prosthesis (FDP) using the same methodology as in the present study, so that the values are perfectly comparable. The results of the provisional restorations of the milling group showed a higher fracture resistance (1663.57 N) than the provisional restorations obtained from the light-curing micro hybrid resin group (1437.74 N)—findings that are close to the mean resistance values of both materials [43]. It is important to highlight, then, that the type of printed material is relevant—even when using the same study, processing and post-processing techniques. Therefore, it is necessary to emphasize the importance of performing independent studies on each material intended to be used for restorative and prosthetic purposes. Additionally, the strength of the material can be affected by the underlying material used as a matrix, which may have a much higher elastic modulus and could be intentionally used to evaluate the unique strength of the two materials in the same scenario.

Rayyan et al., in their study, showed superior fracture resistance values for CAD/CAM materials (Cercon 1289 N) as opposed to conventional polymers, whose resistance decreased notably, presenting much lower values (899 N). The machinable polymers showed good clinical survival and cost-effectiveness as temporary materials; however, it should be noted that in our study, the values could be higher due to the difference in the thermocycling carried out in the study described above, which consisted of 50,000 cycles at extreme temperatures of 5 to 60 °C in distilled water [44].

The results of the fractographic analysis of the 3DPP FDP are similar to those obtained in the study by Grzebieluch et al., where they describe that both samples made from machinable and printable composites show cracks and clear delamination in their material structure [45]. The results of the fractographic analysis of the PMMA samples in the present study do not agree with those of Peñate et al. and Cekic–Nagasy et al., who specified that the connector was always the weakest point in the milled PMMA group [46,47].

Fractography of the 3DPP FDPs in the present study showed fractures at the level of the pontic (second premolar); this fracture behavior was not observed in a study by Alkhateeb in NextDent resin FDPs printed at 0° and 45° [48], nor in the study of Henderson, where in the PDFs of three materials, fracturing was observed in the connector next to the distal abutment [42].

It is important to highlight that in this study, the coefficient of variation in PMMA was low—8.5%—which indicates that when replicating the fracture resistance values of this material, it was observed that they were much more similar to each other and were less dispersed in relation to the mean. Meanwhile, the 3DPP showed an average coefficient of variation of 19.6%—that is, greater dispersion in relation to the average, a factor that must be taken into account for its interpretation and decision making.

The use of PMMA as a material for temporary FDPs is supported by sufficient scientific evidence as well as fracture resistance values that are comparable to those obtained in the present study [49], taking into account that the fracture values exceeded the maximum masticatory forces in the posterior region of approximately 900 N. Unlike the subtractive method, the results obtained in this study by the additive method are values of resistance to fracture that, although they are lower, could still be considered as a clinical option as they resist the force required during mastication [50]. However, the 3D printing industry is in continuous development, so it is recommended to study Sprintray's successor material, OnX Tough—a "hybrid ceramic resin" that offers to be five-times stronger than first-generation resins due to its NanoFusion™ technology, which allows for a smaller and more evenly distributed nano-sized filler [51].

Additives are currently being incorporated to modify the mechanical properties of the resins used for 3D printing with medical purposes. Manapat et al. demonstrated an approach that takes advantage of the metastable, temperature-dependent structure of graphene oxide (GO) to improve the mechanical properties of conventional 3D-printed resins produced by stereolithography (SLA) [52]. Lu Y et al. showed a significant improvement in fracture toughness for carbon fiber-reinforced samples produced by three-dimensional stereolithographic printing [53]. Gerdroodbar et al. investigated the effects of the inclusion of Glass Beads (GB) in acrylate-based photopolymer resin and its 3D printing, and concluded that these prepared resins had the necessary rheological conditions to be used in 3D printers and that the compression and flexion modulus increased as a result of the effect of the Coates Glass Beads (CGB) [54]. Undoubtedly, as confirmed by contrasts with other studies, the additive manufacturing (AM) of prosthetic devices has a consistent effect on the creation of prostheses developed in various fields besides dentistry, with improved mechanical properties [55].

The limitations of this study include the fact that the experimental part was in vitro and that no fixation cement was used, which could have been important for studying its effects; this could have created lower bending forces and a lower damping effect between the tested surfaces [56]. Another limitation to consider is the type of load, since in the present study static loads were used, while during the masticatory function, dynamic loads are also experienced. Future studies will need to include factors that simulate the oral environment such as saliva, diet and habits, among others.

In vitro studies of other properties such as wear resistance, fatigue, hardness, micro and nanohardness, chromatic properties and color stability are suggested.

In addition, long-term clinical studies are required to better understand the behavior of different temporary materials in order to make better clinical decisions.

5. Conclusions

The fracture resistance of the PDFs made of milled PMMA showed a highest fracture resistance compared to the 3DPPs made of the newly printed polymeric material. According to the observed results, there has been a notable advance in the resistance of printed materials, showing acceptable values under mechanical load, which makes the additive technique and consolidates them as an important alternative to use in interim indirect restorations and a promising option for long-term provisionalization in prosthetic dentistry.

Author Contributions: Conceptualization, C.A.-C.; methodology, C.A.-C., C.A.P., J.C., A.M., A.B., B.B. and J.I.F.; software, C.A.P. and J.I.F.; validation, C.A.-C. and J.I.F.; formal analysis, C.A.-C., C.A.P., J.C., A.M., A.B., B.B. and J.I.F.; investigation, C.A.-C., C.A.P., J.C., A.M., A.B., B.B. and J.I.F.; resources, C.A.-C., C.A.P., J.C., A.M., A.B., B.B. and J.I.F.; data curation, C.A.-C., C.A.P., J.C., A.M., A.B., B.B. and J.I.F.; writing—original draft preparation, C.A.-C., C.A.P., J.L., J.C., A.M., A.B., B.B. and J.I.F.; writing—review and editing, C.A.-C., C.A.P., J.L., J.C., A.M., A.B., B.B. and J.I.F.; visualization, C.A.-C., C.A.P., J.L., J.C., A.M., A.B., B.B., J.I.F. and C.A.P.; supervision, C.A.-C., C.A.P. and J.I.F.; project administration, C.A.-C. All authors have read and agreed to the published version of the manuscript.

Funding: This research did not receive external funding.

Data Availability Statement: All the photographies, statistics and graphics have been incorprated in this manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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