Tikrit Journal for Dental Sciences 13(1) (2025) 233-250
https://doi.org/10.25130/tjds.13.1.24

Tikrit Journal
for
Dental Sciences
https://tjds.tu.edu.iq
ISSN:2073-1213

Study the Effect of Flexural Strength on Dental Resins By 3D Printed Method: A Systematic Review

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Keywords:
3d printed resin, flexural strength, denture base, stereolithography, digital light processing,

Article Info.:

Article History:
Received: 7/4/2024
Received in revised form : 27/4/2024
Accepted: 29/4/2024
Final Proofreading: 29/4/2024
Available Online: 1/6/2025

Citation: Hameed EE, Yassen IN, Beddai AA. Study the Effect of Flexural Strength on Dental Resins By 3D Printed Method: A Systematic Review. Tikrit Journal for Dental Sciences. 2025; 13(1): 233-250.
https://doi.org/10.25130/tjds.13.1.24

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Abstract

Denture base materials are susceptible to compressive loads during usage, which might result in prosthesis breakage from repetitive masticatory pressures. To explain the various factors that influence the strength of (3D) printed resins. The aim of this research sought to investigate the various factors that affect the bending strength of three-dimensional (3D) resin prostheses. This research clarifies the different factors affecting flexural strength and the correlation between them. The types of resins that are printed in three dimensions (3D) and their mechanical properties were the subject of research regarding database searches of English-language literature from February 2018 to January 2024 using PubMed, Scopus, EBSCOhost, and Google Scholar. Thirty research articles were considered for full-text analysis, and they all met the inclusion criteria, indicating that, they were appropriate for this systematic review. The involved articles were classified, as per the resins being studied: This research investigated bending strength of three dimensional (3D)-printed resins under a variety of conditions, including various types of printers, resins, printing directions, layers thickness, and sample dimensions. These factors are classified as pre-printing, printing, and post-printing. Most factors had a significant effect on the three-point bending strength of (3D)-printed dental resin. To increase bending strength of three dimensional (3d)-printed dental resins, nano-filler, adjusting printing orientation, the layers' thickness, post-polymerization time and temperature degree.

Introduction:

In 1986, Charles Hull developed the first tri-dimensional (3D) printing process, and the industry grew to include several manufacturing technologies used in a wide range of fields. Hull patented stereolithography (SLA) in 1986 and developed 3D printing technology Since then, 3D printing has progressed substantially (1). Additive manufacturing (AM), also known as rapid prototyping (RP) or 3D printing, is a potential approach in dentistry for fabricating dental restorative and appliance components (2).3D printers are now user-friendly, cost-effective, and smaller and lighter than previously(3). Additive 3D printers offer advantages including the ability to create several complex shapes with low material waste, making it cost-effective (4). Stereolithography (SLA) is the preferred additive manufacturing (AM) Because of its superior accuracy, this technique is suitable for dental applications, resolution, fine building features, and fine surface finish. Stereolithography-based 3D printing(SLA, DLP) is known for producing the highest resolution, isotropic mechanical characteristics between printable materials(5). Stereolithography (SLA) uses a laser light track to polymerize resin, while digital light processing (DLP) builds 3D structures with a digital projector screen (6, 7). Vat polymerization, involving stereolithography (SLA) and digital light processing (DLP), is the layer-by-layer manufacturing of an item with a photocurable resin, and light exposure (7). Surgical guides, temporary crowns, occlusal splints, and denture bases are all examples of dental devices made with 3D printing technology. Due to its high resolution and precision, quick curing, and cheap, digital light processing (DLP) is the most widely used additive manufacturing technique (AM). In general, the printed products were subjected to a post-curing operation using an ultraviolet device to increase the cross-linking of the monomer's unreacted chemical groups and improve the mechanical properties of items(8). Flexural strength (FS) is an accurate measure of the mechanical properties of dental materials. It is necessary to evaluate the bending strength of three-dimensional (3D)- printed resins. Three-dimensional (3D)-printed resin's strength is less than milled or traditional resins because of its print and the process known as photopolymerization(9). Enhancing the quality of printed dental restorations requires knowledge of how printing parameters affect printed object properties. Numerous studies have focused on improving the bending strength of printed projects using 3D printer resins for clinical applications to ensure maximum efficacy. However, published papers summarizing and systematically analyzing these agents are few and may not cover all affected factors. Evaluating available data can help identify factors affecting FS of three-dimensional (3D)-printed dental prostheses. This systematic review identifies a sum of variables and factors that affect the three-point bending strength of three-dimensional (3D) printed dental resins.

Materials and Methods

Information Sources and Searching Methods

The systematic review followed The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and Participant Intervention Control and Outcomes (PICOS) approach (10). P: Participant is 3d printed resins, Intervention was the groups of factors affecting the flexural strength, C is the comparison between the resin’s types, and O is the factors affected. The PICOS question asked whether the flexural strength (FS) of 3D-printed resin denture base materials. This review aimed to respond to the question: What factors influence the flexural strength of various types of 3D-printed dental resin? This study looked at how different factors affected flexural strength in 3D-printed dental resins used to make various dental prostheses. Bibliographic searches were executed in full publications in English were chosen from the databases, (PubMed, Scopus, Google Scholar, and Web of Science) between (February 2019 to January 2024). Different types of 3d resin were used, depending on the resins used and their benefits. The research strategy depended on select studies, evaluation, scientific, and classification.

Selected studies

The selection. It used the topics and abstracts of database searches, which achieved 30 research studies. (EBSCOhost =2, Google Scholar = 13, Scopus = 9, and PubMed =6)

Three-Point Flexural Test

The maximum force applied prior to specimen deformation or breakage was measured in order to determine the specimen readings Mega Pascals (MPa) were used to assess flexural strength (11). A universal testing machine is utilized to perform a three-point bending test (12). The flexural strength test specifies how well materials or composites can resist bending deflection when energy is applied to the structure(13). The samples were fixed between two supports (20 mm span) and loaded at a crosshead speed of 0.5 mm/min until fractured. Three-point bending was calculated using the load at fracture and the specimen dimensions, which were measured with a digital caliper. The fracture load was transformed to flexural strength (σ) using the formula provided below(14):

σ =3fl/2bd2 (14).

In this equation, σ represents flexural strength, f represents fracture load, l represents support span length, b represents specimen width, and d represents specimen thickness(14).

The Factors Influencing 3D Printing Resin

Printed products are affected by several variables such as printer process parameters such as type of printer, layer thickness, the position of samples on the platform and printing orientation, also material composition which includes the addition of fillers, nanoparticles, and reinforcing agent, while postprocessing such as washing with solution, disinfection and immersion in different materials (13).

Process Parameters.

The mechanical properties of 3D-printed dental restoration materials are influenced by the building orientation(15). Printing results are influenced by process parameters that involve build orientation (16-20), Layer thickness (8, 14), and post-curing (8, 16, 21-24).

Composition of Material

Materials are important to the performance of the process of (3d) printing and the items it generates. Several investigators studied the impact of numerous additives on material conversion and characteristics to enhance printed material (1). One research studied that ZrO_2NP nanoparticles were added to 3D printed resin at concentrations from (0 to 5%) wt and the result was in addition, 3 wt.% had maximum fracture toughness and modulus. Filler concentration significantly increased the flexural strength(25). Altarazi,(2023) researched the effect of adding off addition titanium nanoparticles into 3d resin and subjected to a physical aging process, Nanoparticles improved the mechanical characteristics of resins, according to the literature, The color of titanium dioxide is white, and the particles of (TiO2) have been labeled as one of biocompatible material, which is low cost, non-toxic, and resistant to corrosion(26). Altarazi (2023) found that TiO2 addition into 3d printed resin improves the flexural strength(7). Al-Douri investigated the addition of ZnO nanoparticles into 3d printed resin in different concentrations was enhances the flexural strength(27).

Postprocessing

Important post-processing procedures in additive manufacturing that typically take a long time include support removal, powder removal, or resin removal, it is considered a continuation of the polymerization and curing procedure initiated during the printing process. The purposes of it involve enhancing surface quality, mechanical characteristics, thermal stability, weather resistance, UV resistance, and strength, and altering geometry tolerances in addition to aesthetic purposes. The post-process may be done manually, automatically, or semiautomatically (28). Aging is one of the post-processing procedures which is an artificial thermal cycling is testing process that mimics thermal changes in the mouth, simulating prolonged use of biomaterials(9). The oral environment poses unique challenges for dental structures and restorative materials due to chemical, thermal, and humidity variations that can affect material properties. In (8, 14, 16-18, 21, 24, 29-33) studies explained that aging has a significant effect on mechanical properties.

Preprinting Factors

A novel nanoparticle has been extensively utilized in dentistry, to enhance its mechanical characteristics, biocompatibility, and stable structure (13). Adding ZrO_2, TiO_2, and ZnO nanoparticles to denture base resin printed by a 3D printer increased its bending strength (16, 24, 25). However, using zwitterionic as an additive decreased bending strength.

Printing Factors

Multiple factors are said to influence the finished product of 3D printing, including layer thickness, light source and intensity, and printing direction. To produce optimal results, printer parameters must be properly set(4) Printing orientation layer thickness, and filling density affected 3D-printed resin's flexural strength. (16, 17, 34) Show that there is a statistical difference in flexural strength, but (19) observed that flexural strength (FS) was higher at “0°” degrees and the (FS) is dependent on the printing process orientation and provide adequate flexural strength for use in dental restoration. The primary factor influencing flexural strength is the filling percentage (1). The printing layer was demonstrated to be having an effecting the mechanical characteristics of three-dimensional (3D) printed dental resin, resulting in increased flexural strength(14).

Post Printing Factors

Flexural strength and post-printing factors Nineteen studies evaluated three-dimensional (3D) printed resin, five of which investigated the effect of the aging process in conjunction with other factors on flexural strength (FS)(16, 17, 30, 33, 35), and the other researched the thermal cycling treatment(9). Thermal cycling was found to degrade the FS in a study of 3D-printed resin. Reduced mechanical properties of resin materials may be caused by increased temperature-dependent water absorption, water absorption disfeatures polymer chains by cleaving ester bonds, resulting in poor mechanical properties. Two studies(29, 36) on post-rinsing time, water storage, and disinfectants, using different immersion solutions including distilled water, effervescent tablets, and sodium hypochlorite (NaOCl), examined the impact on flexural strength. The results showed that longer rinsing times deteriorated the condition (8, 14, 32).

Results and Discussion

Data gathering

The authors gathered data separately from 30 included articles, as illustrated in Table 1. The search terms included 3D printing strength, denture base, flexural strength, 3D-printed resin, 3D printed provisional restoration, printing direction, and post-curing period. The included studies looked into a variety of agents that affect the strength of different types of three-dimensional, (3D)-printed resin. Kind of printer, manufacturer, layer thickness of three dimensional, (3D)- printed dental resin, specimens’ dimensions, and post-curing approach.

Following a thorough review of the texts, 30 research papers were identified, involving five kinds of (3D)-printed dental resin for denture base, provisional crown and bridge and denture teeth, orthodontic and occlusal split material. 7 research studied about denture base, fourteen articles studied Provisional crown and bridge, and denture teeth, four studies investigate Orthodontic. Three articles studied occlusal split material, and one study about hybrid resin, one study about dental model. Table1 displays the factors from each study included in the systematic review. The guidelines were created based on sixteen studies that examined post-printing factors (8, 9, 20-23, 27, 29-33, 36-

39) and eleven studies examined printing factors (3, 4, 16, 17, 19, 24, 34, 35, 37, 40, 41) There is also three research about preprinting factor(25, 39, 42). According to these studies, all of the aspects of 3D printed resin require further investigation. These factors are used to demonstrate how they affect flexural strength, either lowering or enhancing.

Discussion

This study classified the variables that influence the three-point bending strength of (3D)- printed dental resins into three groups. Factors to consider before printing, during printing, and after printing. Printing material, fillers/nanoparticles, and printers were all used as preprinting variables. Printing variables were direction, layer thickness, and light intensity. Thermal cycling, different post-curing times, temperatures, rinsing, and water storage were among the post-printing factors. Several factors can affect the strength of the produced object during the printing operation. This systematic review discovered that certain influences affect the flexural strength (FS) of printed resin and should be evaluated preprinting.

Conclusions

The additive manufacturing technique is considered a revolution in dentistry due to its advantages in manufacturing dental prostheses such as denture bases, surgical guide interim crowns, and bridges. 3Dprinted resin and stereolithography are the most common techniques utilized. Most studies in this research found that three-dimensional (3d) printed resin had a weaker bending strength than milled and PMMA resins. All of the variables investigated affected the bending strength of additive manufacturing (3D) printed dental resin. Some studies discovered using nanoparticles or fillers increased (FS). Increasing the post-curing duration improves strength. Strength will increase with the thickness of the layers. Thermal cycling and immersion in water and solutions will decrease the strength of 3D-printed dental resin.

Table 1. The included studies looked at the factors that influence (FS) of various 3D-printed resins

Printer type, and printing technology	Wavelength \light intensity	Type of resin and manufacturing	Factors	Layer thickness \ PCT	Samples' dimensions	Results	year of publication
STEREOLITHOGRAPHY (SLA)	the extreme laser speed was 5000 mm sec−1	hybrid composite resin material.	build direction vertically and horizontally printed groups.	the layer thickness was 0.05 mm. PCT /30 mins	25mm x 2 mm x 2mm	There was no statistically significant difference in flexural strength (FS) among the test groups, but fractographic analysis revealed a unique fracture mode.	2019 (18)
(DLP) (D-150), SLA (FORM2, FDM	405 um (Diameter of laser spot) 150 W,	EXT DENT Co, C&B Poly Polymethyl	Flexural strength was compared between 3d printed	25–100 um 120 mins, 25–100	150mm x 84mm x3mm x100m	This study discovered that temporary crowns made	2020 (3)

	140 um (Diameter of laser spot) 65 W, 400 um (Diameter of nozzle) 350W	acrylate, Standard (GPGR04) FORM LABS Co Poly Polymethyl acrylate, COLOR FABB Co Polylactic acid, PLA	three-unit fixed dental prosthesis to traditional restoration and milled prosthesis.	um 60 mins, 100–500 um	m, 145 mm × 175 mm × 175 mm, 227 mm × 148 mm × 150 mm 100	employing (DLP) and (SLA) technologies have sufficient bending strength to be used in dentistry.	
VELTZ, D2 3D PRINTE R ZENITH, D 3D PRINTE R	A 405-nm UV, “LED” light in intensity of 1.4 mW/cm3	NEXT DENT C&B, NEXT DENT C&B MFH, ZMD-1000B temporary and DIO Navi C&B	different 3D printed C&B resin materials and assessed changes in their features based on post-curing time.	100 µm PCT/15, 30, 60, 90, and 120 mins	(25 mm x 2mm x 2 mm), DIN EN ISO 4049	Results showed that post-curing the 3D printed resin for 60-90 minutes increased its flexural strength (FS	2020 (22)
FORM 2; (FORML ABS)		NEXT DENT BASE;VE RTEX DENTAL	printing orientation (0,45,90 degree)	100 µm	80mmx 10 mmx 4mm According to (ISO 178)	Statistically significant increases in FS were observed for samples printed at direction of 90,45, and 0.	2020 (34)
3D PRINTE R (ASIGA, MAX) DLP	365–405 nm	(IMPRIMO LC Splint, (BISPHEN OL-A-ethoxylate diacrylate (BisEMA)	The effects of post-curing process, thickness of layers, with socking in water on FS, hardness, and conversion degree of a light-curable methacrylate based resin.	Fifty percent of samples were 100 µm in thickness And another fifty percent 50 µm PCT/ 30 mins at 60 ◦C	(3.2mm x 10mm x 65 mm).	Mechanical characteristics of 3D-printed of occlusal splints. The post-curing process, storage in water, as well as the printing layer thickness all have an influence on the final outcome. Application	2021 (8)

						of heat and light in PCT unit improves. Mechanical characteristics and conversion of three-dimensional resin occlusal splints. The FS grew as the thickness of the printing layer decreased.	
3D PRINTER (DLP)		NextDent ortho rigid 3D printer (NextDent 5100, 3D Systems, NextDent B.V.)	adding “zwitterionic materials”	PCT/10 mins	64mm x 10mm x 3.3mm3 ISO 20795	The addition of “Zwitterion” resulted in decreased (FS)	2021 (42)
STERIOLITHOGRAPHY (SLA)		Form 3B: FORMLABS, Somerville, MA, USA.	The influence of post-rinse duration. Wash by isopropanol for 5 mins, 12 mins, 20 mins, 30 mins, 1 hour, and 12 hours.	100 µm /PCT 20mins/80 ºC without inert gas	(30 mm x 5 mm x 5 mm3)	The growing post-rinsing period reduced the bending strength of three-dimensional (3D)-printed resin samples.	2021 (29)
DIGITAL LIGHT PROCESSING (DLP)	200 W, 20 mins	NEXT DENT, 3(Trimethoxysilyl)propyl methacrylate	ZrO_2 nanoparticles were used to enhance strength and as reinforcement to 3D-printed dental resin in varying concentrations ranging from 0 to 5% by weight.	Layer thickness 50 µm, PCT/20 mins	25 x 2 x 2 mm3 (ISO) 10477,	The addition of ZrO_2 NPs (3%, 4%, and 5%) improves the FS significantly over the unmodified printed resin. After three months of storage in artificial saliva, groups with higher filler content experienced a	2021 (25)

						greater reduction in strength than those with lower filler content.	
D20II, 3D PRINTER (DLP)		NEXT DENT, C&B, 3Delta TEMP, FREE PRINT TEMP	The impact of printing direction and aging process on three-point bending	FREE PRINT, NEXT DENT c&b 50 µm , 3Delta 100 µm Post cure time, PCT. The FREE PRINT and 3Delta temperatures were post-cured for 2 x 2000 flashes in a nitrogen atmosphere. The Next Dent temperature was 30 minutes.	2mm × 2mm ×25 mm3 ISO 4049	The orientation of printing has a significant impact on the mechanical features of the samples. To attain the best results, align the layers vertical to the load direction. Other factors such as the material, aging, and the direction of print all had a significant impact on FS.	2021 (17)
LOW FORCE STERIO LITHOGRAPHY (LFS)	05 nm ultra violet light, with a laser power of 250 m W.	FORM LABS OFFER DENTURE TEETH RESIN in A2 and Form 3.	Post-curing temperatures are (40, 60, and 80◦C) for different durations (15, 30, 60, 90, and 120 minutes).	50µm	25 mm x 2 mmx 2 mm, ISO 10477	Raising post-curing temperature significantly enhanced three-point bending strength.	2021 (21)
STEREO LITHOGRAPHY (SLA)		DENTAX FREE PRINT Temp. and NEXT DENT,	The Printing angle and the load direction “0º”, “45°”, “90º”	50-µm PCT/ Manufacture Instruction,	25mm x 2mm x 2 mm,	The statistical analysis revealed that the bending strength of	2021 (19)

		MFH		post-curing under nitrogen gas.		both investigated materials is significantly dependent on degrees of orientation. Three point bending strength was superior at “0°”, so, it depends on printing direction.	
NEXT DENT;3 D SYSTE MS VERTE X DENTA L,		heat-polymerize d acrylic resin SPA, NEXT DENT Denture 3D+, 3D systems, VERTEX DENTAL, B.V.,	Thermal cycling treatment	50 µm 10M, Ten thousand repetition s at 5-55°C, with 5 seconds of moveme nt and 30 seconds of rest. 10,000 cycles equal one year of intra-oral use.	64 x10 x 3.3 ±0.2 mm ISO 20795-1: 2013	3D-printed specimens show more irregularities, including minor acute lamellae with numerous empty spaces, deep holes, and layers. The use of thermal cycling significantly decreased flexural strength (FS), and 3D-printed dental resin performed worse than heat-polymerized resin in all checked properties.	2021 (43)
DLP 3D PRINTE R(NEXT DENT ND5100, SLA 3D PRINTE R (FORM 3,	405 nm ultra-violate, “LED” used as the light source. with a 250 µW	The NextDent C&B FORMLA BS DENTURE TEETH A2	The researchers explored the effects of different washing solutions such as (isopropyl alcohol and	50 µm PCT /60 mins	A bar measur ing (25 mm x, 2 mm x 2 mm) Follow ed ISO 10477	There was also a distinct connection between the cleaning solution and the resin utilized. Also, a one-way ANOVA	2021 (31)

FORMLABS			Tri-propylene glycol monomethyl ether) and numerous times (3, 5, 10, 15, 30, 60, and 90 minutes) on 3D printed resin samples.			was used to analyze the difference in FS between cleaning duration for each 3D-printed resin cleaning solution, and no significant differences were found in either group.	
STEREOLITHOGRAPHY (SLA)		Dental LT Clear V1 (Formlabs) polymer,	1 day,3 days, 5 days, and 7 days. To reduce environmental impact, all samples were kept in a darkened environment with a humidity of 55-58% along with a temperature of 24°C.	followed by ultraviolet post-curing to raise conversion of photopolymer, according to the demands of (FORMLABS) Company	according (ISO 178:2019). 80mmx 10mmx 4mm	On day 7, three-point bending tests produced the specimens with the highest flexural strength and failure stress.	2021 (33)
EVERES ZERO, (DLP)		Dental resin (A2 EVERES TEMPORARY, SISMA, Italy)	Samples in varying printing thickness of layers (25, 50, and 100 µm). After printing, samples were subjected to seven different treatment conditions, including water socking for 24 hours, 30 days, light or heat curing for five or	layer thickness printed (25micrometer, 50microm ter or 100µm). PCT/ 20mins	(25mm x 2mm x 2mm) according to ISO 4049	100µm thickness, showed the highest FS compared to other thickness. Post-printing and printing thickness have a combined effect.	2022 (14)

			fifteen mins, and control.				
ASIGA DIGITAL LIGHT PROCESSING (DLP), FORM 2 STERIOLITHOGRAPHY (SLA), NEXT DENT 5100 (DLP)	405 nm/13.14Mw/cm^2 , 395 nm/ 1.176 mW/cm^2 ,405 nm/ 1.4 mW/cm^2	ASIGA Denta BASE, (ASIGA, FORMLABS DENTURE BASERESIN, LP, NEXTDENT Denture 3D+, The NETHERLAND)	Bending characteristics of 3D-printed dental resins and accuracy were compared to those produced through traditional heat-polymerization	50 µm 10M\60° C,	65 x10 x 3.3 mm^3 (±0.2 mm^3) ISO/FDIS 1567)	3d printed samples had inferior FS and modulus of elasticity than traditional heat-polymerized samples. Heat-polymerized samples exhibited the highest FS (93.4MPa) while NEXT DENT specimens had the minimum (FS). No significant differences between FORMLABS and ASIGA specimens.	2022 (4)
FORMLABS FORM, 2 PRINTER (SLA)	405nm laser wavelength	NEXT DENT, denture 3D+	Investigate how printing direction and curing time influence physical and mechanical characteristics.	The layers thickness 50 µm / PCT 20,30 and 50 mins / 60 ºC	(65mm x10mm x3.3 mm3)	Changing the orientation of printing from 0° to 90° led to a significant increase in bending strength. FS did not differ significantly when post-curing durations were raised from 20 to 50 minutes.	2022 (16)
NEXT DENT 5100 3D SLA, ASIGA ,MAX, UV (DLP)	405 nm ultra-violet LED, UV LED (385–405 nm)	Telio CAD; Next Dent c&b MFH, ASIGA DENTA TOOTH, ASIGA,	The effect of (CAD/CAM milling and 3D-printing) manufacturing processes on the	The post-curing stage was carried out in accordance with the	The distance between both retainers was set to	(FS) varied significantly among traditional IFDPs and all materials except digital light	2022 (35)

		ERFURT,	mechanical characteristic of a 3-unit provisional fixed dental restoration after thermomechanical aging.	manufacturer's instructions for each method.	20 mm. The connectors among the abutment teeth were designed to be 4 × 4 mm with a pontic height of 9mm.	processing (DLP) (ASIGA)	
(LCD) (DLP)	405 nm 385 nm	(Key Splint Hard)	mechanical characteristic of a 3D-printed hard type occlusal splint material can be affected by stroboscopic post-curing in a nitrogen gas (N_2) atmosphere as opposed to an air atmosphere, as well as the type of printer.	100µm Post-curing in a N_2 atmosphere or in air atmosphere (n = 20 per subgroup). For each subgroup, 10 samples were aged in boiling deionized distilled water for 16 h before testing, and the other half had been kept in the air atmosphere without any aging.	3mmx10mmx60mm3	A three-way ANOVA revealed that post-curing period , type of printer , and aging all had a significant impact on FS. Aging in boiling water resulted in reduced FS.	2022 (20)

(NEXT DENT 5100)		(Next Dent C &B MFH N1;3D Systems)	The effect of postpolymerization methods (dry, water, and glycerin-submerged) and duration (25, 30, 35, 40, and 45 minutes)	PCT/ 25,30,35, 40,45 mins (300-550 nm) ultra violet-light exposure for 30 mins	25mmx 2mmx2 mm According to (ISO) 10477-2018	The fracture strength analysis explained that significant main effect for all three factors. Dry post conditioning at 25 mins and non-aged procedure resulted significantly higher fracture resistance and FS values.	2022 (24)
DIGITAL LIGHT PROCESSING (DLP) AND STERIOLITHOGRAPHY (SLA)		(NEXT DENT,) (FORMLABS)	The impact of disinfectant chemicals on the FS of 3D-printed resins used as denture bases. (The soaking solutions are distilled water (DW), effervescent tablets, and sodium hypochlorite (NaOCl).	50 µm layer thickness , PCT/30 min Temperature 60 °C)	64mm x10mm x3.3mm ± 0.2 mm, ISO 20795-1:2013	After soaking in the solution, all materials' flexural strength decreased significantly. (FS) was significantly reduced by both the effervescent tablet and the (NaOCl) immersion, with the latter producing the lowest values.	2023 (32)
3D PRINTER		NEXT DENT, Ortho rigid, Dental LT Clear, DENTONA Flexisplint, Cosmos Bite Splint, and ProArt Print Splint), one milled	This study compares the bending strength and surface hardness of 3D-printed occlusal splint resin to milled and conventional cold-polymerized		64mm x 10mm x 3.3mm ±0.2 mm According to (ISO 20795-1:2013)	Pro Art CAD Splint had the greatest FS values, which were significant. Unlike the other groups.	2023 (44)

		(ProArt CAD Splint), and one cold-polymerized (ProBase Cold)	splint resin.				
3D PRINTER		Tera, HARS, TC-85RESIN	The influence of different post-curing environments (nitrogen versus air) and rinsing protocols (centrifuge, ethanol, isopropanol, and isopropanol + water) were studied.	100 µm	10mmx 40mmx 1mm according to ISO 178:2019	The degree of conversion did not differ significantly between groups. However, the polymerization environment accounted for 24.0% of the variance.	2023 (36)
3D PRINTER PHOTON MONO (SHENZHEN, CHINA)	Wave length of 405 nm		Exploration the effect of Zinc oxide ZnO nanoparticles were added at concentrations of 2%, 3%, and 4% to 3D-printed resin.	Z axis 50µm 45 mins	64mmx 10mmx 3.3mm ±0.2 According to ISO (20795-1:2013)	Nanoparticles significantly increased (FS) at all concentrations, with the highest observed at 3%.	2023 (27)
DIGITAL LIGHT PROCESSING (DLP) NEXT DENT 5100; ASIGA DENTA TOOTH, NOVA 3D MASTER NOVA3D,		Crown & Bridge Next dent, Denta Tooth; Asiga, NSW, Jamg He temporary resin;	Half of samples in each group underwent accelerated aging, which included simulated brushing and thermal cycling.	Layer thickness 50 µm.	2 mm × 2 mm × 25 mm ISO10477	The A2 group had highest FS before aging than the other groups, and only groups A1 and A2 experienced a decrease in strength after aging. Three-point bending, hardness, and roughness of the surface of	2023 (30)

						three dimensional (3D)- printed temporary dental resins after aging differed dependent on the material, system, and printing direction.	
STERIO LITHOG RAPHY (SLA)	405 nm laser wavelength	NextDent denture 3D+, Netherland)	Influence of adding TiO_2 nanoparticles and subjecting it to a physical ageing process.	50 µm layer thickness , The samples were cured using an “ultraviolet” light curing chamber with a 405 nm LED wavelength and 39W energy at 60°C.	64mm ×10mm ×3.3mm	Adding TiO2 nanoparticles to 3D-printed dental resin improved its flexural modulus, Vickers hardness, and impact strength, and. It also increased Martens' hardness over the unmodified resin.	2023 (39)
ASIGA, MAX, DLP PRINTER	wavelength = 385, pixel resolution = 62	NEXT DENT Denture 3D+, GC Temp Print and Sprint Ray EU Denture Base.	A variety of technologies were used to compare the FS of various resins. (traditional, CAD/CAM, subtractive manufacturing (milled) and additive manufacturing (3d-printed) and polymerization process.	Post curing duration PCT/20, 40 mins	According to ISO-20795-1:2013 Dimensional samples was (64 mm x 10 mm x 3.3 mm3)	CAD-CAM subtractive manufacturing milled samples had the maximum flexural strength, followed by 3D-printed dental composite resins. There were no statistically significant differences, between 3d-printed and conventional resin groups after 40 mins	2023 (40)

						of polymerization and curing.	
W3D PRINTER (WILCOS),		3D printing resin (Resilab Temp),	The effect of different post curing times (no curing,16 mins,32 mins and 1 h)	16 mins, 32 mins and 60 mins	64mm x 10mm x 3.3mm 3 ISO 20795 (25mm x 10mm x 3mm) according to ISO 4049 (25 x 10 x 3 mm)	Flexural strength improved with groups that were polymerized for 32 minutes or one hour	2024 (23)
ZORTREX (FDM), FORM LABS (SLA), NEXT DENT (DLP)		acrylonitrile butadiene styrene (ABS) polymer, PMMA-based liquid photopolymer resin is used in both (DLP) and (SLA) printers.	Evaluating the flexure strength of 3D-printed models using FDM, DLP, and SLA technology	No post-cure with FDM and isopropyl alcohol (IPA) wash and ultraviolet (UV)cure with (SLA) and (DLP)	20mm x 5mm x 2 mm	The FDM group had the highest flexure strength at 69.36 ± 6.03 MPa, while the DLP group had the lowest at 67.47 ± 20.58 MPa.	2024 (37)

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