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Efficacy of build direction of 3D printed full coverage provisional restoration on the fracture resistance after aging

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Abstract
Aim: To compare the efficiency of oblique and horizontal build orientations on the fracture resistance of full coverage provisional restoration fabricated by 3d printer.
Materials and Methods: Typedont die of maxillary first molar was prepared for full coverage crowns. After tooth preparation, typodont was duplicated into thirty-two epoxy dies using a silicon base. Then randomly divided into two equal groups. Dies were scanned by an extraoral scanner digitally. Then software was used for the restoration design. Thirty-two crowns, divided into two groups and each group included 16 crowns, were put on a platform in the 3D printer software and rotated according to each build direction, 120° and 180° directions. The post cured is a LED light design for post-curing. Using A cementation loading device to cement all provisional crowns on their corresponding resin dies. Then, both groups were divided into three sub-groups, six samples nonaged, five samples were subjected to thermal cycle (1250 cycles, 5-55 ˚C), and five samples mechanical cycles (37,000 cycles, 50N). A USB digital microscope was used to assess the surface topography for samples in both groups. The samples were loaded to failure in newton (N) using a universal testing machine. To assess the failure mode pattern, fractured samples were examined using a digital microscope with a magnification of 35x.
Result: Oblique group recorded statistically significant ($p=0.044 < 0.05$) higher mean value; (2122.16 N) than horizontal group subgroup; (1820.18 N) for non-aged groups. Regarding the effect of building direction on fracture load (oblique > horizontal),
Regarding the effect of aging, non-aged > thermally aged > thermo-mechanical aged). The difference between groups regarding failure mode analysis was statistically non-significant.
Conclusion: Oblique printed specimens have greater fracture resistance after aging than horizontally printed specimens. For 3D printing, an orientation of 120° is better.

Keywords: 3D printing, build direction, aging, fracture resistance, provisional restoration.

Introduction

Provisional restorations are temporary prostheses used to maintain the surrounding tissue, preserve aesthetics during dental treatment, and replace missing teeth. They're fabricating before the permanent prosthesis. They protect the teeth against damage leakage, additionally, improper manufacturing of interim restorations may result in gingival irritation or change the occlusion due to adjacent tooth movement, possibly creating severe problems with the final restoration's placement. As a result, evaluating the protective effects of interim restorations is essential [1]. Three-dimensional (3D printing) technology was presented by Charles hull in 1986. Then, the industry has developed a wide range of manufacturing techniques that have been used in a variety of industries. Numerous advantages of 3d printing include increased cost-effectiveness due to the absence of material waste, and the ability of additive manufacturing to print several materials at once [2]. Fractures are a frequent reason for provisional restoration failures. While restorations are designed to prevent fractures, fractures can occur. May result in pain and economic loss for the patient. Thus, the mechanical characteristics of temporary materials are critical and should consider when determining the clinical effectiveness of provisional restorations.

During use, restoration fractures cause by improper occlusion, bruxism, under contoured pontics, and trauma. Fractures may occur even while the patient is doing normal masticatory activities and are particularly common in patients with long-span bridges [3]. Fracture resistance is a mechanical characteristic that indicates how well a material resists spreading cracks caused by pressure on the restored tooth area. Fracture resistance is a basic and recommended test for determining the fragility of a restorative material since it reflects the material's maximal strength and pressure ability before it fractures [4].

Materials and Methods

Samples preparation

Special Maxillary first molar Typedont was selected this tooth was then used as a die to prepare a ceramic crown. According to (5). The preparation process includes the following steps: 2 mm reduction in the occlusal depth and a 1 mm round chamfer and Converging line at a 6-degree angle, Teeth preparation was done according to recommended dimension with a parallel meter device figure (1), using tapered stone with rounded end size 13 (tr 13) [1] The fine grit diamond 852f [2] was used to round any sharp line angles that could be a concentration of stress. Dimension was measured with a periodontal probe. The silicon mold for the typodont die was made using duplicate silicon material. A cylindrical container was used to hold the silicon mixture. The manufacturer recommended mixing the replicating components for 5 minutes. After that, the typodont die was placed in the centre of the container and then removed once it was completely set. The epoxy resin material mix was then poured in silicon duplicates, was left for 24 hours to ensure full setting. Then an extra-oral scanner was used to scan each die independently in order to produce a 3D virtual die. It took around a minute to complete the scanning procedure Figure (2).

Fig 1: Parallelometer device

Fig 2: Epoxy die scanning.

Designing for restoration

The Exocad software generated a virtual die from scanned images that was suitable for finish line identification, and an automatic margin finder was utilised for margin detection. The tooth anatomy was selected from dental database sources that matched the anatomy of tooth 16, detecting any undercuts in the abutment, and calculating the depth of the preparation from all angles.

Software was used to set up the cement spacing, which had a 0.030 mm cement gap. The central fossa was used to assess the occlusal thickness, which was then adjusted to 1.5 mm for standardisation across all samples. Exocad software was used to design the printed crown.

3D Printing process:

When the design was complete exported as an STL file with the 3D printer software [3]. In the 3D printer software, thirty-two crowns were placed on a platform and rotated by the build direction. The 120° orientation was determined by putting the crown's lingual surface parallel to the build platform and rotating it 30 degrees on the Y-axis. The support was placed on the buccal surface by rotating the crown 15° or 30° in the Y-axis. Using a Stereolithography (SLA) printer, 16 provisional crowns were created in each of two directions (120° and 180°). Thirty-two crowns were printed in both build directions (figure 3). The STL file was transferred to the stereo lithography printer machine. The next dent C&B resin was used and put into a custom-made container to fit the form lab form2 correctly The resin liquid was carefully mixed with a special brush to minimize the uneven distribution of components and avoid precipitation, which might interfere with the resin's setting and polymerization. The layer thickness was around 50 um.

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[1] SkYSEA – Beijing, China

[2] Henry Schein INC.- Meisinger, USA – 852F-016-FG

[3] Preform formlab, USA

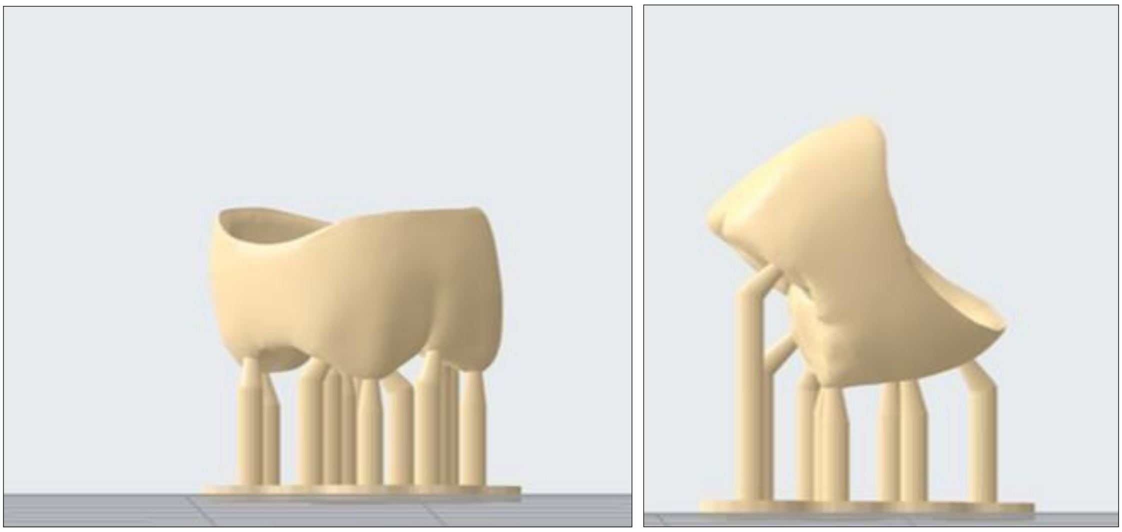

Fig 3: Designed virtual specimen and supports with various build directions

Finishing and polishing:
After the fabricated of the temporary crowns using 3d printing technology, jota Arkansas stone 649 [4] was used to finish and polish the 3d printed crown after the projected sprues at all supporting structures were eliminated. Figure (24). The finished interim crown was then placed in ethanol to eliminate any remaining uncured resin before being removed from the bath.

Post-curing
The LC-3DPrint Box is an Ultraviolet light box designed for post-curing 3D printing resin materials to ensure complete polymerization and better mechanical properties.

Cementation procedure
Zinc oxide non-eugenol temporary cement was used to cement the crowns to the corresponding epoxy resin dies. Each crown was cemented using a specifically designed loading apparatus that could support a load of 3 kg.

Thermocycling
Five cemented crowns from each group were subjected to thermocycling. The specimens were stored in water at 37 °C for 24 hours and then subjected to thermocycling (1250 cycles 5–55°C) [5]. In the computerized thermocycling unit, the dwell duration was 25 seconds, and the lag time was 10 seconds, corresponding to three months of service inside the oral cavity. Lang *et al*. (2003) [6], at the end of the test, it was dried and checked to see any cracks, chips, or fractures.

Mechanical aging
Mechanical aging via cyclic loading was performed using a programmable logic-controlled equipment with robota chewing simulator [6], and its parameters are presented. ROBOTA chewing simulator has four chambers simultaneously simulating the vertical and horizontal movements in the dynamic condition. Each chamber is made up of an upper jackobs chuck that serves as a hardened steel stylus antagonist holder and can be tightened with a screw, and a bottom Teflon housing that serves as a sample holder, Five samples from each group were subjected to mechanical ageing for a total of 37,500 cycles, which corresponded to a clinical simulation of three months [6]. An applied weight of 5 kg, or 50 N of chewing power, was used.

Measurement
To determine the surface topography of temporary crowns after thermocycling and thermomechanical loading in each group, one specimen of each subgroup was tested using a USB digital microscope at a magnification of 25x. The images were captured (Figure 36-38) and transferred to a personal computer equipped with the Image-tool software.

Fracture resistance
Each sample was placed separately on a computer-controlled universal testing apparatus. The software was used to record data using a 5 kN load cell. A metallic rod with a spherical tip (5.6 mm in diameter) and a cross-head speed of 1 millimeter per minute was used for the fracture test in order to ensure uniform stress distribution and prevent contact damage with the steel indenter. The load at failure manifested by an audible crack and confirmed by a sharp drop at load-deflection curve recorded using software.

Fractographic analysis
After the fracture resistance test, all fractured specimens were viewed with a USB digital microscope equipped with a 25x magnification power. Images were captured and transmitted to an IBM computer to detect the failure mode pattern, equipped with Figure (41) Image-tool program.

Results
Oblique vs Horizontal

- Non-aged groups, it was found that Oblique group recorded statistically significant (p=0.044 < 0.05) higher mean value; (2122.16 N) than horizontal group subgroup; (1820.18 N) as indicated by paired T-Test. Table (1) and figure (4).
- Thermally aged groups, it was found that Oblique group recorded statistically non-significant (p=0.109 > 0.05) high her mean value; (1831.65 N) than horizontal group subgroup; (1546.1 N) as indicated by paired t-test. Table (1) and figure (4).

[4] Jota Arkansas white corundum mounted stone 649, Switzerland
[5] Robota automated thermal cycle; BILGE, Turkey
[6] Model (ACH -09075DC -T, AD - Tech Technology CO, LTD, Germany)

- Thermo-mechanical aged groups, it was found that horizontal group subgroup recorded statistically non-significant (*p*=0.911 > 0.05) higher mean value; (1407.54 N) than Oblique group subgroup; (1397.76 N) as indicated by paired T-Test. Table (1) and figure (4).

Table 1: Comparison of fracture resistance test results (mean± SD) between building direction groups as function of ageing.

Variable		Experimental group								Paired T-Test
		Oblique				Horizontal				
		Mean	SD	95% CI		Mean	SD	95% CI		
				Low	High			Low	High	P Value
Ageing	Non-aged	2122.16^{A}	168.2	1987.6	2256.8	1820.18^{A}	273.5	1601.4	2038.9	0.0440*
	Thermal	1831.65^{A}	298.4	1570.1	2093.2	1546.1^{AB}	192.6	1377.3	1714.9	0.1099ns
	Thermo-mechanical	1397.76^{B}	64.4	1341.3	1454.2	1407.54^{B}	178.2	1251.3	1563.7	0.911ns
Anova	P Value	0.0002*				0.0259*				

Different superscript capital letter in the same column indicating statistically significant difference between groups (*p*<0.05) CI; confidence intervals *; significant (*p* < 0.05) ns; non-significant (p>0.05).

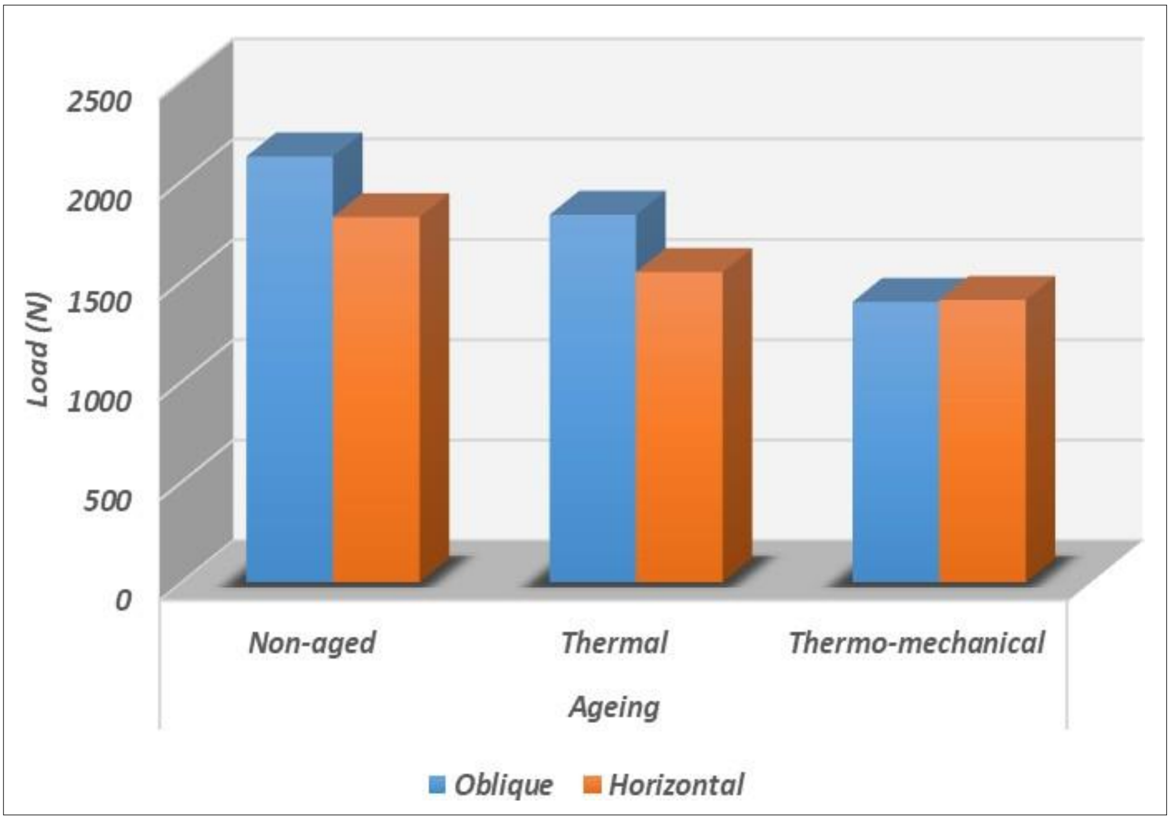

Fig 4: Column chart showing fracture resistance mean values for both building groups as a function of ageing

With Oblique group, it was shown that the highest mean values were registered for non-aged subgroup; (2122.16 N) followed by thermally aged subgroup mean values; (1831.65 N), whereas the lowest mean values were recorded for thermo-mechanical subgroup; (1397.76 N). The difference among subgroups was statistically significant as revealed by ANOVA test (*p*=0.0002 < 0.05). Tukey's post-hoc test showed non-significant (*p*>0.05) difference between (non-aged and thermodynamic aging) subgroups.

With horizontal group, it was shown that the highest mean values were registered for non-aged subgroup; (1820.18 N) followed by thermally aged subgroup mean values; (1546.1 N), whereas the lowest mean values were recorded for thermo-mechanical subgroup; (1407.54 N). The difference among subgroups was statistically significant as proven by ANOVA test (*p*=<0.0001 < 0.05). Tukey's post-hoc test showed non-significant (*p*>0.05) difference between (non-aged and thermally aged) and (thermally and thermo-mechanical aged) subgroups

Effect of building direction on fracture resistance

Totally, regardless of aging the difference between both groups was statistically significant (*p*=0.0096 < 0.05) as indicated by two-way ANOVA where (Oblique higher than horizontal).as shown in Table 2, Figure 5.

Table 2: Comparison of total fracture resistance test results (mean± SD) between building direction groups

		Mean	SD	95% CI		Statistics
				Low	High	
Building	Oblique	1783.86	177.01	1632.9	1934.7	P Value
	Horizontal	1591.27	214.8	1409.9	1772.6	0.0096*

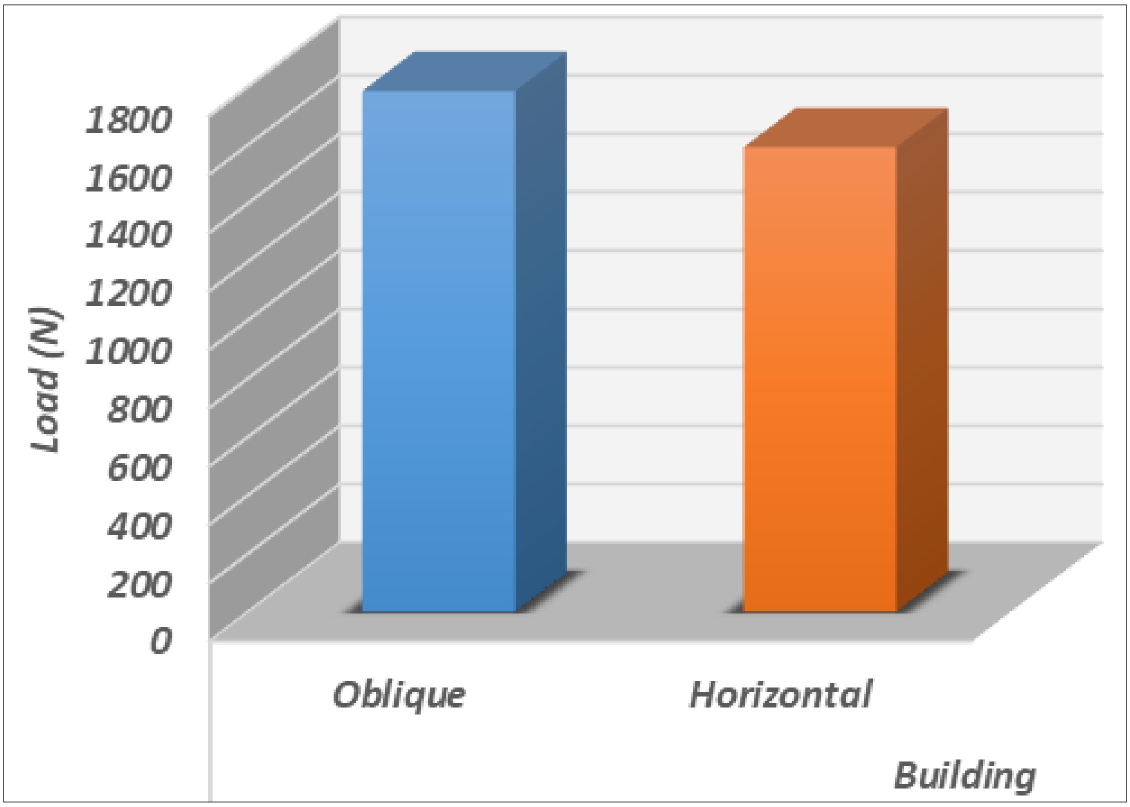

Fig 5: Column chart showing fracture resistance mean values for both building groups

Effect of ageing on fracture resistance

Totally, irrespective of building direction group, the difference between aged and non-aged subgroups was statistically significant ($p=0.0003 < 0.05$) as indicated by two-way ANOVA where (non-aged > thermally aged > thermo-mechanical aged). Table (3), Figure (6).

Comparison of total fracture resistance test results (mean ± SD) as function of ageing.

Table 3: Comparison of total fracture resistance test results (Mean± SD) as function of ageing.

Variable		Mean	SD	95% CI Low	95% CI High
Ageing	Non-aged	1971.17^{A}	220.85	1794.46	2147.88
	Thermal	1688.87^{B}	245.5	1473.69	1904.06
	Thermo-mechanical	1402.65^{C}	121.3	1296.33	1508.97
Anova	P Value	< 0.0001*			

Different superscript capital letter in the same column indicating statistically significant difference between groups ($p<0.05$) CI; confidence intervals *; significant ($p<0.05$) ns; non-significant ($p>0.05$).

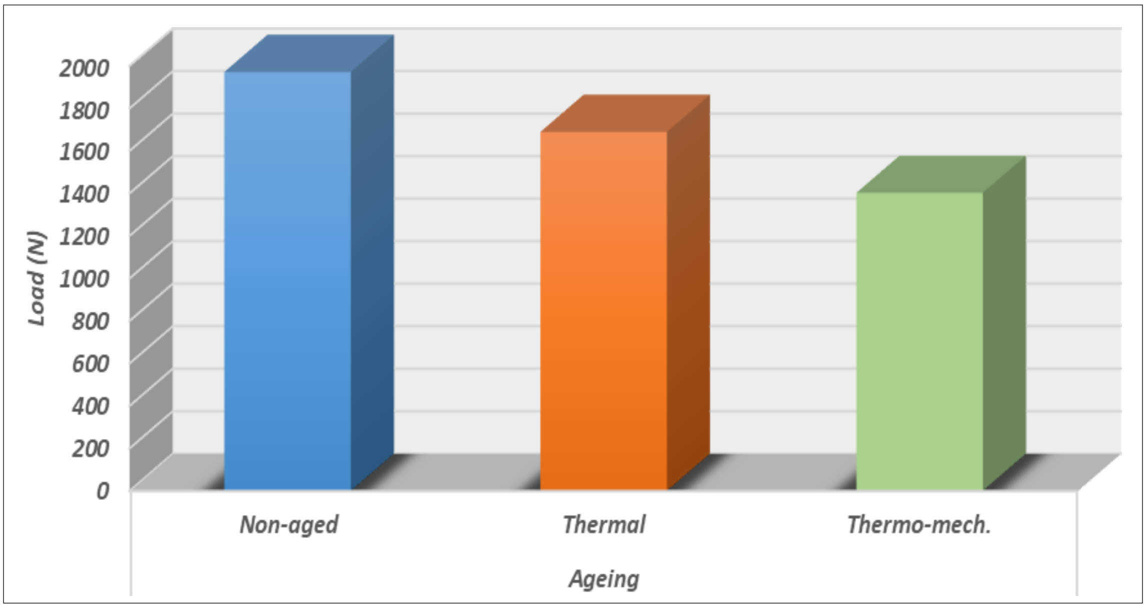

Fig 6: Column chart showing total fracture resistance mean values as function of ageing

Fractographic analysis of fractured samples

Mode of failure

Table (4) Failure mode classification (%) of failure mode analysis for both experimental groups as function of ageing was classified into three modes as observed by digital microscope are Table (5) and illustrated (7) in Figure (8-9).

Table 3: Show Repairable and Catastrophic

Repairable		Catastrophic
Type I	Type II	Type III
Restoration only	Restoration + die above cervical line	Restoration + die below cervical line

The difference between groups regarding failure mode analysis was statistically non-significant, as proved by Chi-square test (p=1<0.05).

Table 4: Frequent distribution (%) of failure mode analysis for both experimental groups as function of ageing

Variable	Material	Group	Failure mode		
			Repairable		Catastrophic
			Type I	Type II	Type III
Ageing	Non-aged	Oblique	6 (100%)	0 (0%)	0 (0%)
		Horizontal	6 (100%)	0 (0%)	0 (0%)
	Thermal	Oblique	5 (100%)	0 (0%)	0 (0%)
		Horizontal	5 (100%)	0 (0%)	0 (0%)
	Thermo-mechanical	Oblique	5 (100%)	0 (0%)	0 (0%)
		Horizontal	5 (100%)	0 (0%)	0 (0%)
Chi Square Test		P Value	1 NS		

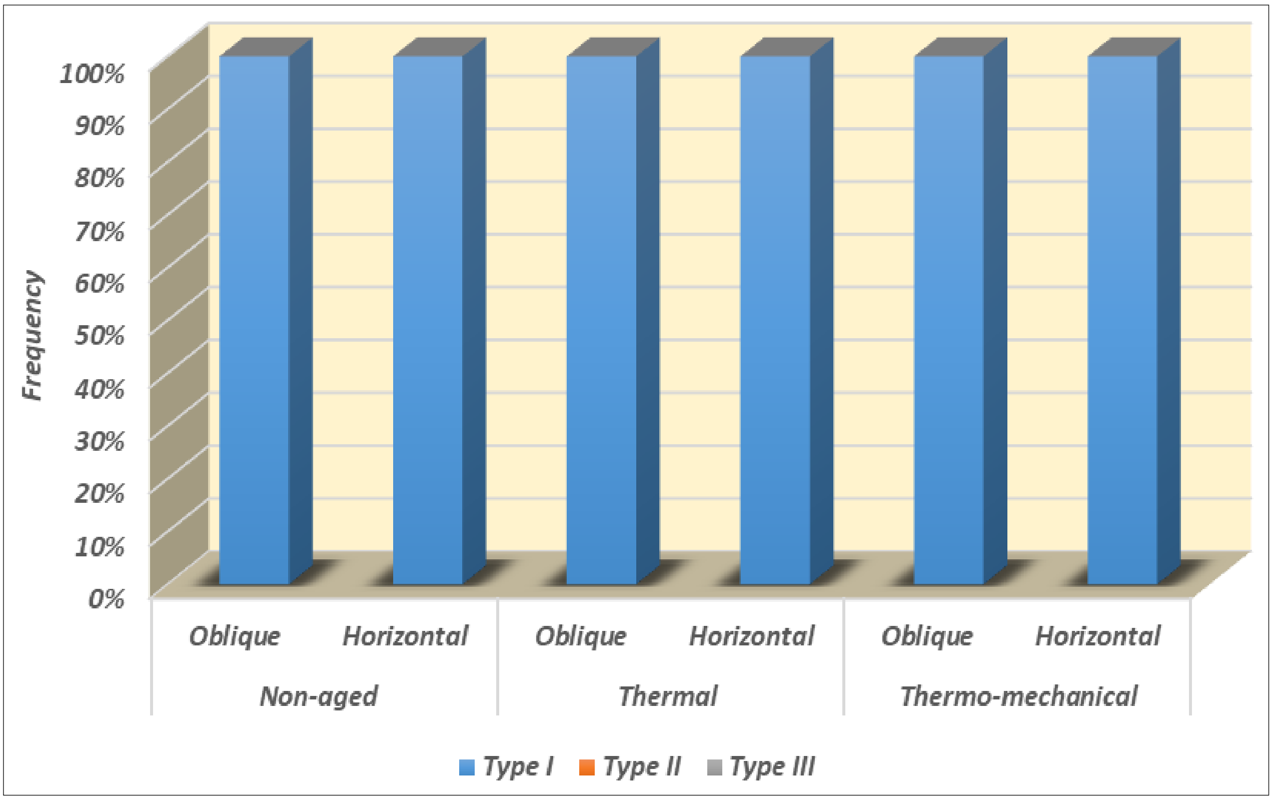

Fig 7: Column chart showing frequent failure mode (%) for both building groups as function of ageing

Fig 8: Digital microscope photograph (x25), mode of fracture of Oblique group (120˚) (A) nonaged. (B) Thermocycling, (C) Thermo mechanical

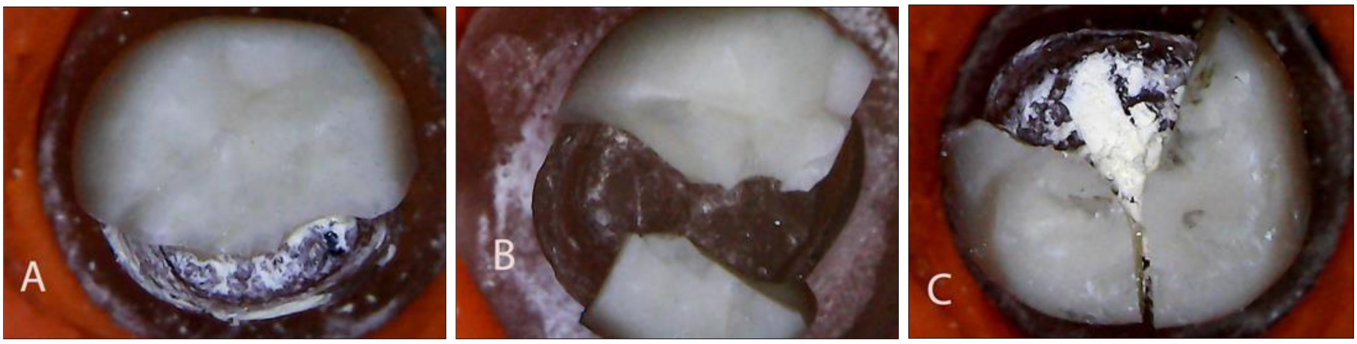

Fig 9: Digital microscope photograph (25x), mode of fracture of horizontal group (180˚) (A) nonaged. (B) Thermocycling, (C) Thermo mechanical

Discussion

There is limited information on the fracture strength of temporary constructions created via 3D printing. Numerous studies have been conducted to assess the fit of temporary restorations on the inside. This is why the current study aimed to evaluate the effects of build direction, horizontal or oblique, on the fracture resistance of 3D printed full coverage provisional restoration.

Provisional restorations are critical in fixed prosthodontic rehabilitation, especially when prolonged treatment is required before the final prosthesis placement. Temporary materials should meet biological, mechanical, and aesthetic requirements. Additionally, they are critical for diagnosing and evaluating treatment plans; they must fulfil various criteria, including biocompatibility, marginal adaptability, strength, and durability. They should have the same shape and function as the finished restoration. Successful final restoration requires a high-quality provisional restoration [8].

Recently, 3D printing technology has been widely utilised to construct complex freeform objects. Can simply modify the geometric shape of a 3d printed object. It has several advantages over subtractive milling, including the ability to print anything from little objects to large structures, as opposed to subtractive milling, which is constrained by the size of the blocks. Rapid prototyping is a manufacturing technology that enables more rapid product production. The material was applied layer by layer throughout the three-dimensional printing processes to create the final three-dimensional structure, which reduced material waste, reduced costs, increased its mechanical properties (no fractures), and produced a more economical temporary restoration [9].

This study was conducted in which typodont prepared according to the method described by [5]. Preparation criteria were followed for ceramic crowns, as this is the most often used material for constructing full coverage crowns. The die was prepared to utilize depth grooves with a 2mm reduction in the occlusal depth to ensure accurate repeatability of crown sample placement over the die, with a 6° convergence angle because crown retention is strongly affected by this angle. The tooth preparation was more conservative with a 1 mm round chamfer finish line to increase aesthetics and fracture resistance. Theoretically, the more parallel the walls of the tooth preparation, the higher the retention. All sharp line angles were rounded to avoid stress concentrations [10].

Although natural molars' mineralization, size, age, and mechanical properties made standardisation difficult, this is why the current study used an artificial upper 1st molar to achieve standardization [11].

The duplicated material was done using REPLISIL 22N due to its low viscosity to record fine details, superior mechanical properties with a high ultimate tensile strength, and extremely high accuracy in dimension and design of duplicating form [12].

The epoxy material was selected because it has a similar degree of flexibility to dentin (12.9gpa). Epoxy resin was also used in this investigation due to its excellent dimension accuracy, surface reproduction, strength, and abrasion resistance [11].

A digital calliper was used to check the reproduction's accuracy and ensure that all epoxy die duplicates were equal in size. Measurements were taken occlusso-gingivally, facio-lingually, and mesio-distally.

To eliminate variable factors and ensure homogeneity of results in the current investigation, "typodont teeth" were prepared by the same operator using a parallelometer device and then duplicated. As a result, utilizing the technique given in Section "Materials and methods," standardized and almost identical epoxy models could be manufactured.

Smoothing and finishing the preparations without any abnormalities, including rounding all line and point angles, facilitated and validated that all details were recorded during scanning. Scanning accuracy is reduced when rough and irregular dies are scanned, according to (13).

Our study scanned dies using an extraoral scanner (medit T300). That's because it was designed to scan a wide range of dental models and impressions to provide accurate data quickly [14]. Each epoxy resin die was scanned to ensure that the restorations were fully seated. The temporary restoration was designed using the Exocad software, and the processes were performed using the STL file.

For the purposes of standardisation in the current experiment, the cement spacing was measured and adjusted for all specimens during the design processes using 3d form software, and it was around 0.030mm. The same procedure was used to standardise the occlusal thickness of all crowns, which was 1.5mm from the central fossa [15].

In the present study, the crowns were placed on a platform within the 3D printer software and rotated in accordance with the build direction. Provisional crowns were built in two orientations (120°, 180°) using a stereolithography (SLA) printer. The build orientation is frequently one of the most powerful aspects determining the mechanical properties of fabricated components and one of the few that is present in practically all additive manufacturing (AM) procedures [16].

Stereolithography (SLA), rapid fabrication, high-resolution process, and dimensional accuracy for additive manufacturing (AM) [17]. Other 3D printing processes could not produce fine details, and complicated geometries and SLA could. SLA has a resolution of 5 nm in the X/Y direction and 10 nm in the Z direction. This technique was used to print provisional dental resin restorations. The liquid resin used in this study was NextDent C&B (a biocompatible class II material), allowing it to be used intraorally for a long time [18].

[19]. reported that the nature of incremental layers in additive manufacturing technology might result in crack propagation and structural failure of the printed material. The bonding between the layers is weaker than the bonding inside the layer itself. This is due to residual stresses and porosities during UV polymerization and material shrinkage.

In the current investigation, ZONE cement was employed rather than ZNO cement. As with ZOE cement, residual eugenol alters the polymerization of some resins and causes sensitivity in certain patients. Using ZNONE cement eliminates this issue and results in more retention than ZOE. [20].

The current study applied a particular cementation loading instead of using figure pressure to cement and seat the temporary crown on epoxy resin dies. Continuous pressure must be used during the setting process to ensure uniform cement thickness throughout all specimens. [21].

This study selected five samples of each group thermo cycled 1250 cycles, 5°C-55°C, 20-second intervals to simulate three months of intra-oral conditions [22]. Thermal cycling hydrate the surface of specimens and accelerates the ageing process. It has been discovered that the interim resin absorbs water, resulting in the degradation of polymeric chains due to monomer hydrolysis, reducing the restoration's mechanical properties [23].

An occlusal force between 10 and 120 N has been thought to be a suitable measurement for the occlusal load when chewing. In order to simulate the masticatory forces that the posterior teeth receive intra-orally during function, five samples from each group were mechanically loaded in the simulator and subjected to 37,500 mechanical cycles of 50 N. [24].

In the present study, the surface topography of the samples from both groups was evaluated using a USB digital microscope equipped with a built-in camera. The photos were captured at maximum resolution (2272- 1704 pixels) and viewed with a fixed magnification of X25 on an IBM-compatible personal computer. Each image is 1280 × 1024 pixels in size [25]. In the present study, the fracture resistance test showed that the oblique group recorded statistically significant higher mean values than the horizontal group with non-significant differences between (non-aged and thermally aged) subgroups.

This result coincides with the finding of [19]. Who demonstrated the effect of build orientation on the mechanical properties of an AM device? Also, it was mentioned that the mechanical properties of dental restorative materials are affected by the build direction (layer orientation) in 3D printing. This is related to the nature of additive manufacturing technology's incremental layers, which can cause crack propagation and structural failure of the printed material Layer orientation was discovered to alter the compressive strength of 3D-printed composite material in an *in vitro* investigation. The compressive strength of a material printed vertically with the load perpendicular to the layer orientation is higher than that of a material printed horizontally. It's also critical to remember that the bond between the layers is weaker than the bond within the layers. This is illustrated by the quantity of residual strains and porosities that build during UV polymerization and material shrinkage.

The increased fracture resistance of the printed group in the current investigation might be attributed to the thin printed layer thickness employed in the current study throughout the fabrication process, which was around 50 m. These findings were consistent with [19]. In addition, found that the 3D group showed the highest values for fracture resistance compared with the milled group within the three tested thicknesses. The 3D-printed composite crowns had strong fracture loading forces, with the greatest range of 2383.5 N for the 1.5-mm thickness preparation. The measured fracture loading forces for milled composite crowns were lower, with the greatest range of 1284.7 N recorded for the 1.5-mm thickness preparation.

It was found that vertically printed specimens with the layers oriented perpendicular to the load direction have shown improved mechanical properties compared with those of horizontally printed specimens with the layers oriented parallel to the load direction [26].

Also found that the printed layer direction being perpendicular to the load direction was better than being parallel in terms of the material's compressive strength employed SLA technology to produce crowns with various constructive angles and found that a 120° angle gave improved dimensional accuracy and less support surfaces for crowns [19].

Increased dimensional accuracy and fewer crown support surfaces. The impact of ageing on fracture load was examined in the current investigation. The findings showed that the vertical group recorded a statistically higher mean value (2122.16 N) for the non-aged group than the horizontal group subgroup (1820.18 N), while the vertical group had a non-significantly higher mean value for the thermally aged group. The horizontal group subgroup recorded a statistically non-significant higher mean value than the vertical group subgroup with reference to the thermo-mechanical age groups. In line with these findings [27], revealed that water absorption, which is generated from storage in water or artificial saliva and thermocycling, seriously influences the strength of provisional restorations.

Regarding the repair ability, the present study revealed that both oblique and horizontal 3D printing directions had 100% repair ability in Type I.

Conclusion

Within the limitation of the present *in vitro* study, the following conclusions could be drawn:

1. Provisional crowns with an oblique orientation showed higher fracture resistance than horizontal ones.
2. Thermocycling and thermo mechanical aging revealed an effect on fracture resistance of the provisional restoration constructed by both orientation angles (120˚, 180˚).

Conflict of Interest
Not available

Financial Support
Not available

References

1. Moon W, Kim S, Lim BS, Park YS, Kim RJ, Chung SH. Dimensional accuracy evaluation of temporary dental restorations with different 3D printing systems. Materials. 2021 Mar 18;14(6):1487.
2. Alharbi N, Osman R, Wismeijer D. Factors Influencing the Dimensional Accuracy of 3D-Printed Full-Coverage Dental restorations using Stereo lithography Technology. Int J Prosthodont. 2016;29(5):503-10.
3. Karaokutan I, Sayin G, Kara O. *In vitro* study of fracture strength of provisional crown materials. J Adv Prosthodont. 2015;7(1):27-31.
4. Kurniawati CS, Rachmawati D, Mas'Adah D. The Fracture Resistance of Fiber Reinforced Composite Restorative Material has Higher Yield than Nanohybrid Resin Composite. J Phys Conf Ser. 2018;1073:5.
5. Shillingburg HT. Esthetic Considerations. Fundamentals of fixed prosthodontics. Quintessence Publising Co; c2012. p. 413-424.
6. Lang R, Rosentritt M, Behr M, Handel G. Fracture resistance of PMMA and resin matrix composite-based interim FPD materials. Int J Prosthodont [Internet]. 2003;16(4):381-4. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12956492
7. Rosentritt M, Behr M, van der Zel JM, Feilzer AJ. Approach for evaluating the influence of laboratory simulation. Dent Mater [Internet]. 2009 Mar;25(3):348-52. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0109564108002157
8. Heboyan A. Provisional Restorations in Restorative Dentistry. World Sci. 2019;(July):10-7.
9. Katreva I, Dikova T, Abadzhiev M, Tonchev T, Dzhendov D, Simov M, *et al.* 3D-printing in contemporary prosthodontic treatment. Sci. Med Dent. 2016;2(1):7.
10. Christensen GJ. Observations: Frequently encountered errors in tooth preparations for crowns. J Am Dent Assoc [Internet]. 2007;138(10):1373-5. Available from: http://dx.doi.org/10.14219/jada.archive.2007.0055
11. Sagsoz NP, Yanikoğlu N, Sagsoz O. Effect of Die Materials on the Fracture Resistance of CAD / CAM Monolithic Crown Restorations. Ohdm [Internet]. 2016;15(3):165-8. Available from: https://www.longdom.org/open-access/effect-of-die-materials-on-the-fracture-resistance-of-cadcam-monolithiccrown-restorations-2247-2452-1000900.pdf
12. Abu M, Eneen E, Gihan El-Naggar D, Taymour M. Marginal accuracy of zirconium reinforced lithium silicate (Vita Suprinity) crowns with two marginal designs before and after cementation under thermo mechanical cycling *in vitro* study. ~ 382 ~ Int J Appl Dent Sci [Internet]. 2019;5(4):382-90. Available from: www.oraljournal.com
13. González de Villaumbrosia P, Martínez-Rus F, García-Orejas A, Salido MP, Pradíes G. *In vitro* comparison of the accuracy (trueness and precision) of six extraoral dental scanners with different scanning technologies. J Prosthet Dent [Internet]. 2016;116(4):543-550.e1. Available from: http://dx.doi.org/10.1016/j.prosdent.2016.01.025
14. Asaad R, Aboushahba M. Influence of Different Sintering Protocols on Translucency and Fracture Resistance of Monolithic Zirconia Crowns. Egypt Dent J. 2020;66(4):2649-60.
15. Kale E, Seker E, Yilmaz B, Özcelik TB. Effect of cement space on the marginal fit of CAD-CAM-fabricated monolithic zirconia crowns. Journal of Prosthetic Dentistry. 2016;116:890-5.
16. Qin Y, Qi Q, Scott PJ, Jiang X. Determination of optimal build orientation for additive manufacturing using Muirhead mean and prioritised average operators. J Intell Manuf [Internet]. 2019;30(8):3015-34. Available from: https://doi.org/10.1007/s10845-019-01497-6
17. Zhang J, Yang Y, Zhu B, Li X, Jin J, Chen Z, *et al.* Multifocal point beam forming by a single ultrasonic transducer with 3D printed holograms. Appl Phys Lett. 2018;113:24.
18. Li X, Xie B, Jin J, Chai Y, Chen Y. 3D Printing Temporary Crown and Bridge by Temperature Controlled Mask Image Projection Stereolithography. Procedia Manuf [Internet]. 2018;26:1023-33. Available from: https://doi.org/10.1016/j.promfg.2018.07.134
19. Alharbi N, Osman R, Wismeijer D. Effects of build direction on the mechanical properties of 3D-printed complete coverage interim dental restorations. J Prosthet Dent. 2016 Jun 1;115(6):760-7.
20. Hill EE, Lott J. A clinically focused discussion of luting materials. Aust Dent J. 2011;56(Suppl. 1):67-76.
21. Naser BK, Ibrahim AF. Evaluation of Fracture Strength of Cemented Monolithic Zirconium Crown Using Different Types of Luting Agents: *In vitro* Comparative Study. Int J Med Res Heal Sci. 2018;7(5):52-7.
22. De Oliveiraa JC, Aielloa G, Mendesa B, Urbanb VM, Campanhab NH, Jorgeb JH. Effect of storage in water and thermocycling on hardness and roughness of resin materials for temporary restorations. Mater Res. 2010;13(3):355-9.
23. Astudillo-Rubio D, Delgado-Gaete A, Bellot-Arcís C, Montiel-Company JM, Pascual-Moscardó A, Almerich-Silla JM. Mechanical properties of provisional dental materials: A systematic review and meta-analysis. PLoS One. 2018;13(2):1-19.
24. Bankoğlu Güngör M, Karakoca Nemli S. Fracture resistance of CAD-CAM monolithic ceramic and veneered zirconia molar crowns after aging in a

mastication simulator. J Prosthet Dent. 2018;119(3):473-80.

25. Haggag K, Abbas M, EL Sharkawy Z. Effect of Human Enamel on Wear of Three Types of Interim Restorative Materials (an *in-vitro* Study). Egypt Dent J. 2017;63(4):3933–45.
26. Martín-Ortega N, Sallorenzo A, Casajús J, Cervera A, Revilla-León M, Gómez-Polo M. Fracture resistance of additive manufactured and milled implant-supported interim crowns. J Prosthet Dent [Internet]. 2022;127(2):267-74. Available from: https://doi.org/10.1016/j.prosdent.2020.11.017
27. Reeponmaha T, Angwaravong O, Angwarawong T. Comparison of fracture strength after thermomechanical aging between provisional crowns made with CAD/CAM and conventional method. J Adv Prosthodont. 2020;12(4):218-24.

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