Comparative Evaluation of Fracture Strength of Implant Supported Crown Fabricated from CAD/CAM and 3D Printed Resin Matrix Ceramic

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KEYWORDS
Resin Matrix Ceramic. CAD/CAM. 3D Printing. Hybrid Composite. Fracture Resistance

ABSTRACT
Objective: To compare fracture strength of screw-retained implant-supported crown of resin matrix ceramic when fabricated using CAD/CAM and 3D printing Material and method: vericom Mazic® Duro (CAD/CAM Nano Hybrid Ceramic) was used as particle-filled composite CAD/CAM material, saremco Print Crowntec (3D printable resins-based) as 3D printed composite material, and the control group was composed of IPS e.max. ZirCAD ivoclar vivadent (zirconia) was used to fabricate mandibular first molar screw-retained, implant-supported crowns. After the fabrication, the crowns were cemented with the Rely X U200 self-adhesive resin cement (3M ESPE, Germany) on stock abutments tightened to analogs embedded in acrylic resin. Finally, all crowns were subjected to a fracture resistance test. fracture strength was evaluated by using one–way ANOVA with Chi-square used for the association between the modes of fracture. Result: The results showed that there were significant differences between all the groups used, the control group (Group zirconia) was significantly higher, as the mean was equal to 6391 N. Followed by Group vericom (cad/cam) with a mean of 2558 N, then Group seramco (3D printing) with a mean of 817.92 N. Dunnett T3 test showed statistically significant differences in fracture resistance between the three groups. There was no significant difference between the modes of fracture and the methods. Conclusion: Screw-retained implant-supported crowns manufactured by CAD/CAM technique had better fracture resistance value than those of the 3D printed technique. Clinical Relevance: resin matrix ceramic is a possible substitute for zirconia in an implant-supported crown

1. Introduction

The arrival of digital technology, specifically computer-aided design and computer-aided manufacture (CAD/CAM), has completely transformed patient treatment approaches in the prosthodontics sector. Blocks of pre-polymerized resin are milled to the appropriate shape using the CAD/CAM milling (subtractive) manufacturing technique [1-4].

Techniques for three-dimensional (3D) printing (additive) manufacturing have become more popular recently. The creation of the necessary prosthesis involves applying small portions of the material layer by layer [5,6]. The 3D printing methods utilized include Stereolithography (SLA), Digital Light Processing (DLP), Selective Laser Sintering (SLS), and Fused Deposition Modelling (FDM) [7]. These methods can be a more cost-effective choice for creating crowns than CAD/CAM milling as it speeds up production and requires less raw material [8,9].

Selecting the right material for implant-supported crowns is essential to the longevity of prosthesis and implants because the stiffness of the crown determines how much force and stress it can withstand after a collision. Therefore, while applying brittle materials (such as ceramics) to natural teeth may not pose significant issues, using these materials for implants may result in a variety of mechanical in vivo difficulties, such as chipping or fracture [10,11]. The advantages of ceramics in terms of aesthetics, durability, and color stability have been coupled with the benefits of resin composites, such as reduced abrasiveness and high flexural strength, to create new hybrid materials called resin-based materials. The benefits of resin matrix ceramic include high marginal stability, simplicity of intraoral repair, and easy post-processing [12, 13, 14]. The physical characteristics and degree of wear of resin-based ceramics are comparable to those of natural teeth, according to the experimental results [15-17]. Recent research has focused on resin matrix ceramic materials employing various manufacturing techniques [18-20] Only two studies have specifically addressed the fracture resistance of implant-supported crowns, conducted by Donmez and Okutan [14] and Türksayar et al. [21]. Little study has been done, though, on how different manufacturing techniques affect the fractural behavior of restorations and how they compare to other materials. Thus the present study aimed to compare the fracture resistance of implant-supported crowns when fabricated using CAD/CAM and 3D printing.

2. Material And Method

Thirty-six implant-abutment analogs (n=36’ Dentium, titanium grade IV) and stock titanium abutments (length 5.5mm, diameter 6.5mm) have been selected. The abutments will be screwed into the analogs using a driver according to manufacturer’s instruction (30 N) (22,23). Then place into a custom-made mold with cold cure acrylic at dough stage. Approximately 3-mm clearance between analogue and the margin of the abutment. (14,24). The thirty-six implants were distributed into three groups of 12 implants each group: Group A: vericom Mazic® Duro (CAD/CAM Nano Hybrid Ceramic, Korea), Group B: saremco Print Crowntec (3D printable resins-based materials, Switzerland), Group C : zirconia (IPS e.max. ZirCAD ivoclar vivadent Germany). For each sample the abutment will be sprayed with Scan spray (NHT) then a 3-dimensional digital image was taken by utilizing extra-oral digital scanner (Medit T710, korea) and imported into the CAD software (ExoCAD). (24) Dental design software (EXO CAD) in standard tessellation language (STL) format was used to create the mandibular first molar crown with screw access channel.

In group A, comprising milled VM (Vericom Mazic® Duro, CAD/CAM), the STL A file was imported into the milling machine software program (Hyperdent CAM Software). This process defined the milling strategy, along with the positions and supports of the specimens on the dental material block. 12 crown of vericom Mazic® Duro (CAD/CAM Nano Hybrid Ceramic) was manufactured by using a 5-axis CAD/CAM machine (ARUM 5X_500, Australia). Subsequently, the specimens were trimmed from their supports and glazed using Mazicglaze (Korea). For the control group, (ARUM 5X_300 pro, Australia) dry milling machine was utilized, followed by the sintering process to achieve the original size, strength, and color. In group B, consisting of CT (Saremco Print Crowntec 3D printing), the STL C file was imported into the printer software (ASIGA) to slice the virtual drawings and establish the printing settings. The printing settings were changed in accordance with the manufacturer's instructions in order to standardize the production process, and this design was repeated. A digital light processing-based 3-dimensional (3D) printer (MAX UV; ASIGA, Australia) was used to fabricate the crowns with a 50-µm layer thickness and a 45-degree print orientation was determinedas shown in figure (1-1).

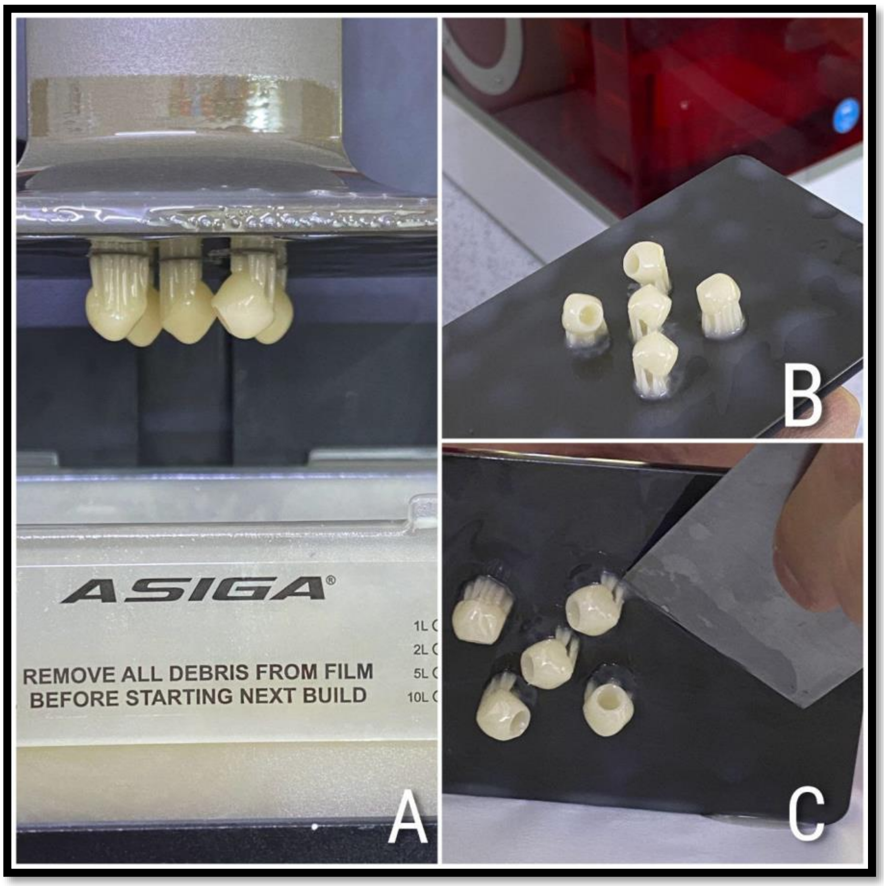

Figure (1-1): A: 3D printing process, B: remove the building platform from the machine, C: Remove the crowns from the platform by putty knife.

The inside surface of the CT crowns was cleaned using a an 96% alcohol solution, and any remaining resin was removed using Cleani Washer (Ackuretta, Taipie,Taiwan). Using an air syringe, all crowns were dried after washing. Following that, CT crowns were put into a polymerization apparatus (Ackuretta, Taipie,Taiwan). Crowns were then pretreated with sandblasting per manufacturers' recommendations for adhesive cementation (Table 1).

Table (1) surface treatment of the material

Material	Surface treatment
vericom Mazic® Duro (CAD /CAM)(VM)	Sandblast with 25-30μm alumina(0.2MPa), Clean with oil free air syringe and with ethanol
Saremco Print Crowntec (3D printing)(CT)	ndblast (aluminium oxideAl2O3, particle size110 µm).
IPS e.max. ZirCAD ivoclar vivadent(Zir)	ndblasting with Al2O3, 25–70 µm, 1 bar Thoroughly clean the IPS e.max ZirCAD restoration with water and blow dry

The screw openings for all abutments were sealed with Teflon tape, and the screw access holes were sealed using light-cure composite (DIAFIL, Korea) according to the method outlined by Zacher et al.[25] Then the exterior surfaces of all 36 abutments were air-borne particle abraded (50 µm Al2O3, approximately 10 mm distance, 1 bar pressure, for approximately 60-second airborne-particle abrasion time per abutment). [22] Successively, each specimen was cemented to the corresponding implant abutment with the Rely X U200 self-adhesive resin cement (3M ESPE, Germany) was used to cement each crown on its respective abutment. Initially, finger pressure was used to seat each crown on its corresponding implant, and any excess cement was carefully removed. Next, a 5 kg vertical static load was applied using a specially designed loading mechanism (or around 50 N) for 6 minutes to each crown's occlusal surface [26]. As directed by the manufacturer, light curing was then applied to each surface for 20 seconds. Following this, the samples were kept for seven days at room temperature (25 °C) in deionized distilled water (25 °C) [27,28]. Samples were subjected to thermal cycling for 500 cycles between 5 and 55 °C with a dwell time of 30 s [22]. A fracture strength test was performed on every crown-abutment combination. A LARYEE Universal testing machine was used to mimic masticatory forces as show in figure (1-2).

Figure (1-2): crown-abutment combination in LARYEE Universal testing machine)

The force was transmitted through a metal sphere that has a 5-mm diameter and was put on the occlusal surface of the crown. The occluding rod and the crown were separated by one millimeter of rubber, which served as a tension relief. [29]. The testing apparatus was set up so that the indenter moves at a speed of one millimeter per minute until spontaneous fracture [22].

Statistical Analysis

The statistical analysis was performed by SSPS 26.0 (SPSS Inc., Chicago,IL ,USA). To verify that the distribution was normal, the Shapiro-Wilk test was employed. To analyze the data, Dunnett's T3 test were used, the mode of fracture analysis was performed by The chi-square test. ($p \leq 0.05$) was chosen as the significance threshold.

3. Results and Discussion

There were notable differences in the maximum fracture loading forces across the tested groups. The results of analyzing the data by one-way ANOVA showed that there were highly significant differences (p-value= 0.001) between all the methods used, results for survival following Fracture Loading are shown in (Table 2).

Table (2): Summary findings for the loading force in Newton (N) For Studies Groups (Descriptive Statistics and Inferential statistics).

Trait / Groups	**Mean ± S.D.**	**Confidence Interval 95%**		**Minimum Value**	**Maximum Value**
		Lower	**Upper**		
Group I (A)	6391.00 ± 1935.86 c	5161.02	7620.98	3460	9170
Group II (B)	2558.00 ± 296.36 b	2369.70	2746.30	2142	3168
Group III (C)	817.92 ± 143.47 a	726.76	909.07	625	1055
P. Value	0.001				
Degree of Freedom	2				

Dunnett's T3 test was employed for a more detailed comparison among different groups, specifically highlighting where significant differences occur. The control group (Group zirconia) was significantly high, with a mean equal to 6391, followed by Group Vericom (cad/cam) with a mean of 2558, then Group Seramco (3D printing) with a mean of 817.92. The mode of fracture analysis showed different fracture and failure patterns. The chi-square test results showed no significant difference between the mode of fracture and methods (p-value =0.109). Two resin matrix ceramic materials were employed in different manufacturing techniques to examine the impact of CAD/CAM and 3D printing processes on the fracture resistance of screw-retained implant-supported crowns and zirconia (CAD/ CAM) material which was chosen as the control group. The null hypothesis was rejected as the fabricated method affected the fracture resistance of implant- supported crown. Based on the results of this study, the mean value was 2558.00N for vericom (CAD/CAM milling), 817.92N for seramco (3D printing) and 6391.00N for zirconia. The results indicated that the impact of manufacturing techniques on fracture resistance values was significant.

As indicated by the current data, the fracture strengths of the majority of studied crown materials were found to be sufficiently high to withstand the force peaks applied in the posterior area, known to reach up to 900N [(30)] Only CT material may be used with limitations. With respect to recorded results fracture strength, 3D printing manufactured materials (CT) showing lower fracture resistance values compared to CAD/CAM milling materials (VM) ($\leq$ 0.01)and the result agree with these studies (Türksayar etal.,2023, Suksuphan P et al.,2023) [(21,31)] and disagree with study of Donmez and Okutan [(14)] stated that 3D printing and CAD/CAM milling material had similar fracture resistance which may be due to the absence of aging or related to the design of restoration which did not include a screw access channel , However, Corbani et al., 2020 conducted in vitro studies [(19)] reported significantly higher fracture resistance values for an additively manufactured nanocomposite resin when compared with subtractive manufactured material, this difference may be caused by using different milling machine and mechanical cyclic load. These results may be related to the composition of resin matrix ceramic material because it is composed of ceramic-based filler particles that incorporated into a composite resin polymer matrix to generate resin matrix ceramic and each specific substance has a varied filler proportion and composition [(32)]. 3D printing material total content of inorganic fillers (particle size 0.7 µm) is 30 - 50 % by mass, in compare to CAD/CAM milling block 80% of Nano-particle ceramic fillers. Additionally, the fillers can stop the propagation of cracks through bridging effects and crack deflection, according to Zimmerman et al. [(20)]. While some printer characteristics like printing speed, cure depth, and cured line width, print orientation, build platform location, and supporting structure configuration may affect the strength of 3D printing crowns. Previous research [34,35] has shown the effect of build orientation on additive manufacturing device's mechanical characteristics. According to Grzebieluch et al. [33], samples that were printed vertically onto the platform had the best mechanical qualities because the printed items were positioned so that the tensile force produced during mastication was applied along the layer rather than across it. Every specimen used in this investigation was produced with a 45-degree construction orientation as per the manufacturer's recommendations. The type of process that used in 3D printing technique may effect mechanical characteristics because in digital light processing(DLP), the laser beam's reflection toward a mirror polymerizes the whole printed layer and this may experience worse mechanical characteristics (Tahayeri etal., 2018). So, the lowest loading force of 3D printing crowns in this study could be explained by the low flexural modulus of 3D Printing crown, which is the result of variations in its manufacturing process and structural compositions (low filler contents) [36,33]. In this study, zirconia restorations would be superior in terms of fracture resistance compared to resin matrix ceramic restorations and this agrees with Takano et al. [37]. Patients with implants-supported restorations may have increased masticatory forces because of the loss of proprioception, which is normally supplied by the tooth's periodontal ligament that is limited to damping effects of the crown materials in implant–supported restorations [38], and because zirconia had high E-modulus so the occlusal loads are therefore directly transferred to the peri-implant bone. Resin matrix ceramic materials have a higher capacity to absorb shock and approximate E-modulus to dentin [11,39]. The strength of restorations may be affected by the presence of a screw channel. Previous research predicted that the screw channel will weaken screw-retained restorations [40,41]. However, different research [42] discovered no discernible impact of the screw channel on the failure load of ceramic crowns made of monolithic zirconia, lithium disilicate, and veneered zirconia. Another study show, the kind of crown material used has a direct bearing on how weak a screw channel becomes, particularly when composites or other materials with a lower strength are used [43].The main limitation of this study is that the Clinical conditions could have been better reflected if artificial saliva had been used during thermocycling aging, Future studies on screw- retained, implant-supported crowns should investigate how different printing parameters affect the mechanical properties of pros theses, along with how screw stability is affected when cyclic loading is applied, to corroborate the results of the present study.

4. Conclusion

Within the limitations of this study, it can be concluded that CAD/CAM manufacturing technique had better fracture resistance value than those of 3D printed technique. Even though 3D printing is less expensive and produces less waste during the manufacturing process, the mechanical qualities of the material used in 3D printing still require development to be on level with other hybrid materials.

Declretions Section

A. Author Contribution:

1- Design of the work: dr.diana ,dr.hayder

2- Data collection: dr.diana

3- Data analysis and interpretation: dr.diana, dr.hayder

4- Drafting the article: dr.diana

5- Critical revision of the article: dr.hayder

6- Final approval of the version to be published: dr.diana, dr.hayder

B. Ethical Approval

No ethical approval was need because this study is labrotary research

C. Funding

No funding was obtained for this study

D. Conflict of Interest

There is no conflict of interest.

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