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Retention Evaluation of Implant Supported Fixed Partial Denture Frameworks Fabricated by Different Techniques

[1]Anas M. Khalaf, B.D.S. and [2]Ahmed Asem Saeed, B.D.S. ,M.Sc. ,Ph.D.
[1]B.D.S. ,M.Sc. student, Directorate of Health/Nineveh, Nineveh, Iraq
[2]Department of Prosthodontics, College of Dentistry, University of Mosul, Nineveh, Iraq
** Corresponding author at Department of Prosthodontics, College of Dentistry, University of Mosul, Mosul, Iraq.*

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ABSTRACT Objectives: The aim of the current study to compare the retention of implant supported fixed partial denture frameworks fabricated by different techniques.
Materials and Methods: A master implant model was scanned by a 3D-Scanner to create the master design from which 24 Cobalt-Chrome implant supported fixed partial denture frameworks produced by 3 different techniques. Eight frameworks were fabricated by conventional casting of milled wax, eight by hard metal milling, and the last eight by direct metal laser sintering. Frameworks of each group were used to evaluate the differences in retention by pull-off test inside universal testing machine running at a crosshead speed of 5 mm/min. Differences in retention were statistically analyzed by using one-way ANOVA tests at the significant P-value of ($p \leq 0.05$).
Results: There were statistically significant differences among the three study groups of retention test. There was significant increase in retention of frameworks fabricated by DMLS technique, followed by frameworks by conventional casting, whereas frameworks fabricated by milling of metal showed the least retention values compared to the other techniques.
Conclusion: There was an effect of production method on the retention. As seen by the increase in retention of frameworks fabricated by DMLS technique compared to the hard metal milling and conventional casting techniques. The new techniques of fabrication for implant supported metal frameworks have an effect on their retention to the underlying abutments.
Keywords: Retention, Implant supported frameworks, DMLS technique.

I. INTRODUCTION

Implant-supported fixed dental prosthesis in different forms can be used predictably to rehabilitate patients with edentulous or partially dentate jaws [1]. Metal ceramic restorations, whether tooth supported or implant supported, are still considered the gold standard due to their exceptional biocompatibility, constant esthetics, superior strength, and marginal adaption, despite the current focus on all-ceramic restorations [2].

Manufacturing processes have improved over time from manual ways, to automated computer-aided procedures with a high level of technological sophistication and cutting-edge technologies. Two main families of computer-aided processes must be highlighted for this latter set of state-of-the-art processes: computer-aided design and milling subtractive systems (CAD/CAM) and computer-aided design and fabrication additive manufacturing methods (AM) [3].

The traditional technique for fabricating the different metal prosthesis is the lost- wax technique using metal alloys for casting [4]. This technique has a lot of steps which means its time consuming and the increased number of variables that can cause inconsistencies in the final prosthesis [5].

The CAD/CAM technologies have revolutionized the Co-Cr restorations production either by subtractive or additive manufacturing techniques [6] [5].

CAD/CAM hard milling is one of the subtractive processes for producing Co-Cr restorations [7][8][9].

However, many of the flaws and porosities produced by traditional casting are reduced by utilizing standardized Co-Cr blanks fabricated in industrial conditions. Also, tools and machinery wear increased substantially, because of the rigid Co-Cr blanks used and increased servicing costs [2], in addition to that, production of small dental objects from large blocks cause a lot of waste are the main disadvantages of this technique [10].

Direct Metal Laser Sintering technique which is one of the additive manufacturing techniques that utilize CAD/CAM technology for

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the silicone was poured in the container in which the block and its abutments were placed, and epoxy resin material (Sikadur, Sika, Switzerland) was mixed according to manufacturer's instructions and poured into the impression to produce an epoxy resin replica of the master model. The epoxy resin material was left for 24 hours to set. Another impression of the abutment was taken with the same procedure mentioned above, also using the silicone, but this time the impression was poured with type IV dental stone (Elite Stone, Zhermack, Italy).

Framework Design: A 3D scanner (S600 ARTI, Zirconzahn, Italy) was used to scan the produced stone model and convert it into a digital version, to avoid direct scanning of the metallic abutments as this procedure would have required the use of powder spray which was avoided for better standardization. The produced 3D model was transferred to a CAD software to design a standardized framework that is going to be used for constructing all the frameworks that is going to be used in this study.

Fabrication of the Frameworks: The STL file of the final 3D design was sent to the laboratory to produce the frameworks, 8 frameworks by lost wax casting technique, 8 frameworks by hard metal milling and 8 frameworks by direct metal laser sintering technique making a total of 24 frameworks.

All of the frameworks were subjected to sand blasting by fine Aluminum Oxide particles (50 µm in size) on the external surface only, the frameworks were exposed to sand blast for 30 seconds at 3 bars pressure. The inner surfaces of them were left untouched to avoid any possible discrepancy.

Twenty-four impressions of the master model were taken with a 3D printed box that was used as a customized container to make the duplications and in which the impressions were poured to obtain the 24 duplications of the master model. Duplication silicone was used for the duplications, these impressions were poured with epoxy resin (Sikadur, Switzerland) and were used with their 24 corresponding frameworks in the retention test [14].

Retention Testing: The frameworks were seated and looted on their abutments, and the abutment-framework pair was fastened with tightening screws into the bottom fixed compartment of the universal testing machine, and the retention of the frameworks was assessed using a pull-out test. For this test two orthodontic wires of (0.9- mm) used which engaged in the distal and the mesial connectors and held in place by the upper movable compartment of the machine [15] as shown the purpose of fabricating Co-Cr restorations directly from a 3D CAD model by using a laser beam that melts and fuses fine layers of metal powder layer upon layer until the final product is produced [11]. Complicated prostheses can be made quickly and precisely reducing the time and the waste and avoiding many of the drawbacks of the casting and milling techniques [12] [10] [13].

These techniques have been used nowadays commercially for the production of different dental prostheses. The various methods produce alloys with various microstructures [12] [3].

II. MATERIALS AND MEHODS

In this Invitro study, two implants were fixed in an acrylic model over which two abutments placed to be digitally scanned and then to produce a 3D design of the frameworks that is to be manufactured by three different techniques; Conventional casting of wax pattern, hard metal machining or milling, and by direct metal laser sintering (DMLS).

Each Technique was used to manufacture eight frameworks, making a total of twenty-four. Eight frameworks of each manufacturing technique were used for testing the retention of the metal frameworks.

The Master Model: The study model (Master implant Model) used in this study was prepared by using cold cure acrylic resin. This model received two titanium dental implants (Dentium, South Korea) with the dimensions of 4.5 and 5.0 for the Premolar and Molar respectively with an inter implant distance of 14 mm from center to center to simulate a clinical condition of missing mandibular first molar and the second premolar and the second molar were the abutments. Placing the implants in their exact sites in the acrylic resin model was carried out by the aid of a paralleling device surveyor milling machine, a surveyor pin was used to set the abutment into a perfect 90 degrees angulation. Two straight titanium abutments (Dentium, South Korea) 4.5 mm diameter for the premolar & 5.5mm for the molar were screwed to the implants on the model by titanium screws which were torqued to 30 N/cm following the manufacturer recommendations using calibrated torque wrench and hex tool of the implant system. The abutments screw holes were sealed with cotton pellets and wax.

A 3D printed container was used to take an impression for the master model and its overlying abutments, the duplication silicon (Elite22, Zhermack, Italy) was used for this purpose. The material was mixed according to the manufacturer's instructions to obtain a homogenous mixture, then

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IV. DISCUSSION

The retention of implant-supported prostheses has been dealt with by many studies, however, investigating the effects of cement types, abutment surface topography, and the height and taper features of the abutment focusing mainly on crowns. Despite of that, the effects of new CAD/CAM based technologies on the prostheses retention to the underlying abutments are scarce.

The results of this research ascertain the fact of the higher retention abilities of frameworks produced by laser sintering compared to the lost wax technique, and hard metal milling technique. Which was clearly obvious when the specimens tried on their corresponding casts before undergoing the test.

The findings of this research contradict the findings of Lövgren *et al* (2017) [14] who discovered that there are no significant differences in terms of retention of the frameworks tested despite the different fabrication techniques employed, although the laser sintered group showed increased surface roughness and internal fit. When compared to other methods, the greater surface roughness of the specimens might explain the improved retention in DMLS specimens. Lövgren et al [14] proved this after microscopically examining the surfaces. The effect of increasing surface roughness of crowns on retention has already been demonstrated by Juntavee & Millstien (1992) [16]. Although it had not been extensively studied, this was also found in this study.

Alhamamy in (2021) [17] conducted research to test the retention abilities of copings fabricated by lost wax casting, hard metal milling, and DMLS techniques. Where it has been proven that the DMLS technique resulted in copings with significantly superior retention compared to the other techniques that has been attributed to the high surface roughness of the specimens produced, the same thing proved in this current research.

Chaar *et al* (2020) [18] conducted a study that found that DMLS-generated specimens had similar mechanical characteristics to those created by traditional techniques, with similar survival and retention rates. This isn't definitive in terms of directly confirming the present study, but it does demonstrate the new technique's validity in terms of retention.

However, this study correlates with another study [19], which discovered that DMLS specimens had considerably greater retention and suggested using them in circumstances when more retention is required. This finding could also be explained by the increased surface roughness of frameworks produced by laser sintering technique.

in (Figure,1). A tensile force was applied in pull mode via universal material testing machine at a crosshead speed of 5 mm/min. The load at which dislodgement of the restoration occurs was recorded in Newton.

Figure (1): Retention testing

Statistical Analysis: A software program was used to perform statistical analysis (IBM SPSS version 22). The results of the readings were statistically examined by using (One Way-ANOVA Test) was used to identify the existence or absence of a significant difference between groups, at the 0.05 level of significance, and to establish the significant difference between the groups, Duncan's Multiple Range-Test was performed.

III. RESULTS

According to the descriptive statistics, the study findings showed, that the mean values of the DMLS group have the highest values followed by conventional casting group, while the group of frameworks produced by milling showed the least values in this test. The analysis of variance One way ANOVA-test for all groups of retention test showed significant difference ($p \leq 0.05$) as listed in table (1). DMLS group has the greatest retention values with a significant difference ($p \leq 0.05$), followed by conventional casting group, according to Duncan's Multiple Range test findings as seen in table (2), while the milling group has the lowest retentive values, and also there was a significant difference between the casting and milling groups were seen.

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There was an obvious adhesion failure to the abutment in the laser sintered frameworks when compared to the other two groups, which implies an increase in cement retention to the framework owing to enhanced surface roughness. "When the internal surface of a restoration is very smooth, retentive failure occurs not through the cement but rather at the cement restoration interface" [20].

V. CONCLUSION

Within the limitations of the current study, there was an obvious increase in the retentive abilities of frameworks produced by laser sintering technique. The frameworks produced by metal casting were superior in terms of retention when compared to milled frameworks. Frameworks manufactured by hard metal milling showed the least retentive qualities compared to the other groups.

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Table (1) ANOVA Test for Retention Test.

	Sum of squares	df	Mean square	F	Sig.
Between groups	1409.253	2	704.626	29.184	.000
Within groups	507.034	21	24.144		
Total	1916.286	23			

DF: Degree of Freedom. Showed statistically differences

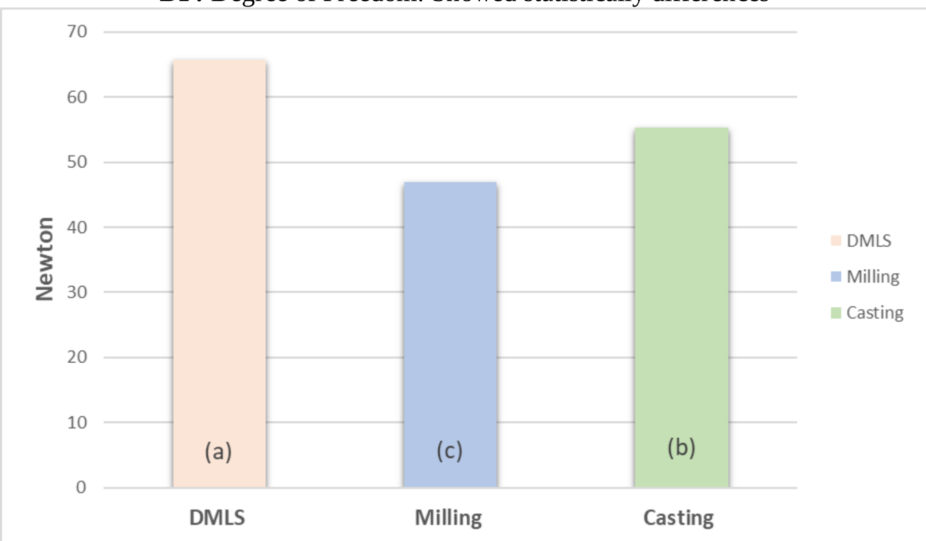

Figure (2): Duncan's Test of Retention.
Casting: Casting Technique; Milling: Milling Technique; DMLS: Direct Metal Laser Sintering Technique.