International Journal Dental and Medical Sciences Research
Volume 3, Issue 5, pp: 1546-1553 www.ijdmsrjournal.com ISSN: 2582-6018

Internal Adaptation of Implant Supported Fixed Partial Denture Frameworks Fabricated by Three Different Techniques

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Date of Submission: 20-11-2021 Date of Acceptance: 05-12-2021

ABSTRACT

Objectives: The aim of the current study to compare the internal adaptation of implant supported fixed partial denture frameworks fabricated by three 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 adaptation to the underlying abutments by using cross-sectioning method and examination under the digital microscope. Differences in internal adaptation 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 internal adaptation test. There was a significant increase in adaptation of frameworks fabricated by DMLS technique, followed by frameworks manufactured by conventional casting, whereas frameworks fabricated by milling of metal showed the least adaptation compared to the other techniques.

Conclusion: There was an effect of production technique on the fitness of the frameworks. As seen by the increase in adaptation of frameworks fabricated by DMLS technique compared to the hard metal milling and conventional casting techniques. The new additive methods of fabrication for implant supported metal frameworks have an effect on their adaptation to the underlying abutments.

Keywords: Internal adaptation, Implant supported frameworks, DMLS technique, Cross-sectioning.

I. INTRODUCTION

Implant-supported restorations have become a prominent treatment option for patients who are partially or completely edentulous. Dental implantation success, long-term service, and the ability to supply a prosthesis with low risk have all improved thanks to advances in dental materials and treatment procedures [1].

Fixed prostheses in different forms can be used predictably to rehabilitate patients with edentulous or partially dentate jaws [2]. Metal ceramic restorations, whether tooth supported or implant supported, are still considered the gold standard due to their high biocompatibility, esthetics, high strength, and adaption, despite the popularity of all-ceramic restorations [3].

Implant-retained restorations are classified into two categories based on how they are affixed to the implant: screw-retained implant restorations and cement-retained implant restorations [4]. Because they lack the hole necessary for the screw, cement-retained prostheses can be constructed to deliver occlusal force to the implant in a more vertical direction than screw-retained prostheses. Furthermore, they may be made with a more attractive form on the occlusal surface and require less procedures in clinics and dental laboratories. Poor retrievability, on the other hand, is a disadvantage if cement-retained implant prostheses need to be repaired [5].

Cement-retained restorations, on the other hand, are linked with difficulty of removing the cement and poor margin adaptation between the restoration and the abutment, which can lead to soft tissue complications [6].

For more than a century, casting metal alloys have been an important feature of prosthetic dental operations. Taggart's lost wax process, which was established in 1907, is often used in the dental laboratory to create these dental prostheses [7]. This old technique of manufacturing various forms of

DMLS (direct metal laser sintering) or SLM (selective laser melting) is preferred for alloys [14].

The advantages of this technique are that it reduces time and waste materials, requires less steps to produce an object, and produces complex details at a predictable price [19]. This technology is highly expensive in terms of materials and machinery, the health consequences of dust and nanoparticle condensate are unclear, explosion is possible, and the end result surface is rough. These are only a few of the system's flaws [20].

The fit of a fixed prosthesis is one of the most important aspects for optimal prosthetic therapy. The periodontium is harmed by a poor marginal fit, making it difficult to preserve the patient's health even after the implant has been put. Also, the retention of the prosthesis is improved by a good internal fit [21] [22] [23].

II. MATERIALS AND MEHODS

In this Invitro study, two implants were fixed in an acrylic model over which two abutments were 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 measuring the internal fitness 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) of 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.

prostheses is the traditional technique [8], However, it has lots of drawbacks like being time consuming and require many steps to fabricate certain object [9], Voids or porosity, Back pressure porosity, Marginal discrepancies, Dimensional inaccuracies, [7] [10].

CAD/CAM technology, on the other hand, can reduce the amount of labor necessary even within the whole processing system. Furthermore, systems that use network connections to outsource some specialized tasks to a processing center save even more labor time [11]

Lost wax casting is an old method of creating an exact duplicate of an object by pouring molten metal inside a mould of the object. This procedure in dentistry entails transforming a wax pattern of a dental restoration into a dental casting alloy or ceramic [12].

The CAD/CAM technologies have developed the metal restorations manufacturing techniques which includes either subtractive or additive manufacturing techniques [9] [13].

Machining and milling, commonly known as subtractive manufacturing, is a process that involves using a controlled material removal technique to carve a block of raw material into a desired end shape [14]. Power-driven sharp cutting instruments such as saws, lathes, and drill presses of various sizes are used to remove tiny chips from the block of material until the final desired form is achieved [14][15].

High accuracy, standardized manufacturing process, quality control system, fast production time are all advantages to milling process [16] while the flaws of this method are high cost of the equipment, it is considered a wasteful procedure, the precision depends on the diameter of the bur [14] [15] [17].

On the other hand, additive techniques of manufacturing are a new cad/cam based technology. As an example of additive CAD/CAM technology, laser sintering is a solid manufacturing technique. Layering metal powders to produce a three-dimensional (3D) substructure that follows a computer-aided design is how it works. A high-energy carbon dioxide laser beam is used to fuse particles of cobalt-chromium (Co-Cr) metal powder together during sintering. After one layer of powder particles has fused, another layer of powder is applied on top, and the process is repeated. The method is carried out again and again until the desired item is obtained [18]. With SLS being the most increasingly used for the fabrication of dental restorations in prosthetic dentistry. The term SLS has been preferred for non-metallic materials (primarily ceramic or polymers), whereas the term type IV dental stone (Elite Stone, Zhermack, Italy) [24].

Testing the Marginal Fitness: The internal gap is the perpendicular measurement from the internal surface of the casting to the axial wall of the preparation, whereas the marginal gap is the same measurement at the margin [25].

A-Seating of the Frameworks:

The 24 stone duplications of the master model were used. Each duplication with its corresponding framework, was checked for proper seating with a microscope viewing the margins of the framework. Then a luting agent prepared (Zinc polycarboxylate) which was mixed according to manufacturer's instructions. Each framework was seated at first with a finger pressure on each abutment then axially directed load (5 Kg) for 10 minutes was applied. This was sufficient for the luting cement to reach its complete setting time [26] [27] [28]. The excess luting cement was removed after setting using a dental probe.

B-Boxing of the specimens: After setting had completed, the luted Frameworks on the stone models were placed inside a 3D printed resin box. The box was custom made with determined dimensions. A layer of blue type IV dental stone was poured to bury the framework and create a block of dental stone with the framework embedded inside (Figure,1).

C- Cross-Sectioning the specimens: A cutting machine was used to dissect the blocks at the midline of each abutment to obtain two identical halves of each abutment. The block was placed in a metal housing with the same dimensions of the block, which has two slots consistent with the midlines of the framework abutments to provide a standardized reproducible pathway for the cutting machine disc to cut all the stone blocks in the same exact positions. All of this was held on magnet table fixed on the cutting machine. Each half of each framework abutment (total 4 halves for each framework, total of 96 halves for the whole bridges classified into 3 groups) was cleaned with a soft brush to remove the debris and dust (Figure,2).

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 the silicone was poured in the container in which the block and its abutments were placed. The produced impression of the model and its abutment 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 which are 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

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Volume 3, Issue 5, pp: 1546-1553 www.ijdmsrjournal.com ISSN: 2582-6018

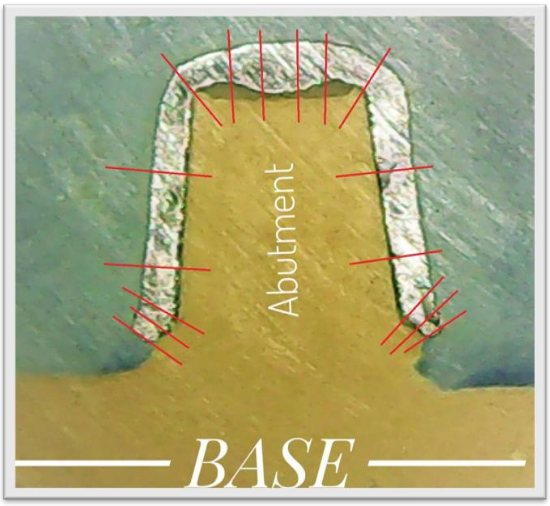

Figure (3): Cross Section of One Abutment with Marks Representing Measurement Points for Internal Fitness.

Statistical Analysis: A software program was used to perform statistical analysis (IBM SPSS version 26). 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 lowest internal gap values followed by conventional casting group, while the group of frameworks produced by milling showed the highest values in this test. The analysis of variance One way ANOVA-test for all groups of internal adaptation test showed significant difference ($p \leq 0.05$) as listed in table (1). DMLS group has the lowest internal gap 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 (Figure,4), while the milling group has the highest internal gap distance values, and also there was a significant difference between the casting and milling groups was seen.

IV. DISCUSSION

The internal adaptation of the frameworks was evaluated utilizing cross sectioning method and then measuring the gaps made under digital microscopy. Although there are technical complications associated with this method, it is

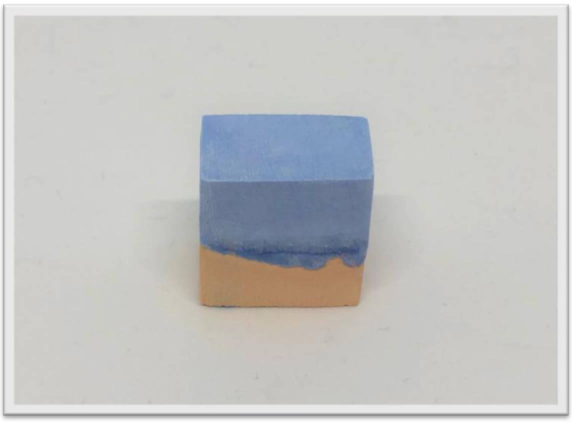

Figure (1): The stone before sectioning

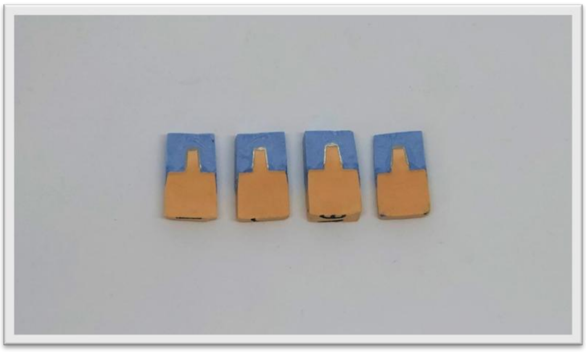

Figure (2): The stone block after sectioning

D- Examination under microscope: Each half was placed under a digital microscope to be examined (Figure,3). Sixteen points in each half block were examined making a total of 32 readings for each abutment and a total of 64 points for the whole framework. For 8 frameworks 512 readings were obtained and 1536 readings for all the techniques which were recorded using ImageJ image processing software, dedicated for image analysis [24] [29] [30]. The cement gap was measured on each point and the reading in µm was recorded, the recorded gap values were then transferred for statistical analysis.

Nesse et al, (2015) [9] found that the laser sintered fixed prostheses had the poorest internal and marginal fit, whereas the milling method had the best results which contradicts this research.

Kim et al, (2014) [36] discovered that milling technique yielded internal adaptation that is more precise than laser sintered or casting groups. This agrees with the later study by M. J. Kim et al (2017) [37] that measured the weight of the silicone material in order investigate the marginal and internal fit, in which the casting group had the lowest silicone weight. The laser sintered group showed the highest vertical discrepancy and marginal, occlusal, and average internal gaps. The CAD/CAM milled group revealed a significant high axial internal gap. However, the laser sintered group revealed clinically acceptable marginal accuracy and internal fit.

When the three elements that influence fit, including the accuracy of the scanner that scans the abutments, the software's ability to transform the scanned data into the computer, and the accuracy of the system that manufactures the objects from 3D data, are considered then the variation in assessing the technique which gives the most superior fitting qualities becomes [38] [39].

V. CONCLUSION

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

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considered the gold standard in evaluating and measuring these gaps specifically when the more precise and advanced techniques are not available for use. The biggest drawback of the cross-sectioning procedure is that specimens are destroyed. Another limitation is that due to technical difficulties, only one sectioning plane for the specimen is possible which limits the freedom to explore more than one plane of the specimen. Standardization was achieved by employing the same approach for all specimens in terms of luting, sitting, and determining the section line, and sectioning which reduced the amount of human error.

The internal gap measurement or internal adaptation in this research proved to be significantly higher in frameworks produced by DMLS to those produced by the other two techniques such as the hard metal milling and the conventional casting. Also, there was a significant difference recorded in internal adaptation between the milled frameworks & conventionally casted frameworks.

A study conducted [31] to investigate the marginal and internal adaptation of Co-Cr alloy copings fabricated by lost wax, hard metal milling, and DMLS techniques. The lost wax and DMLS groups showed better marginal fit compared to the other group; however, the milling group was superior to the lost wax group in relation to axial fit. All of the methods used for fabrication, however showed similar inter-marginal and occlusal fit.

In consistence with this study, Lövgren et al (2017) [32] found that copings made with the DMLS method fit better than those made using casting or hard metal milling. A previous study in (2011) by Örtorp et al [33] backed up this claim, demonstrating that the DMLS gave the best match of the three methods examined.

Gunsoy & Ulusoy (2016) [34] used the same method employed in this research by taking digital images and observing them using a microscope to investigate the marginal and internal adaptation of fixed prostheses produced by 3 techniques, conventional casting, DMLS, and hard metal milling. The study found that DMLS group has the best fit between the three groups and that the marginal demonstrated best fit. However, the occlusal gap was the largest. These results are consistent with the findings of the current research.

Ullattuthodi et al, (2017) [35] discovered that the internal fitting of copings generated by the conventional approach was superior than those produced by DMLS. They related this superiority to software or scanning mistakes that may have happened during the digital processing.

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Table (1) ANOVA Test for Internal adaptation.

	Sum of squares	df	Mean square	F	Sig.
Between groups	17792.477	2	8896.239	126.956	.000
Within groups	1471.542	21	70.073		
Total	19264.019	23			

DF: Degree of Freedom. Showed statistically differences

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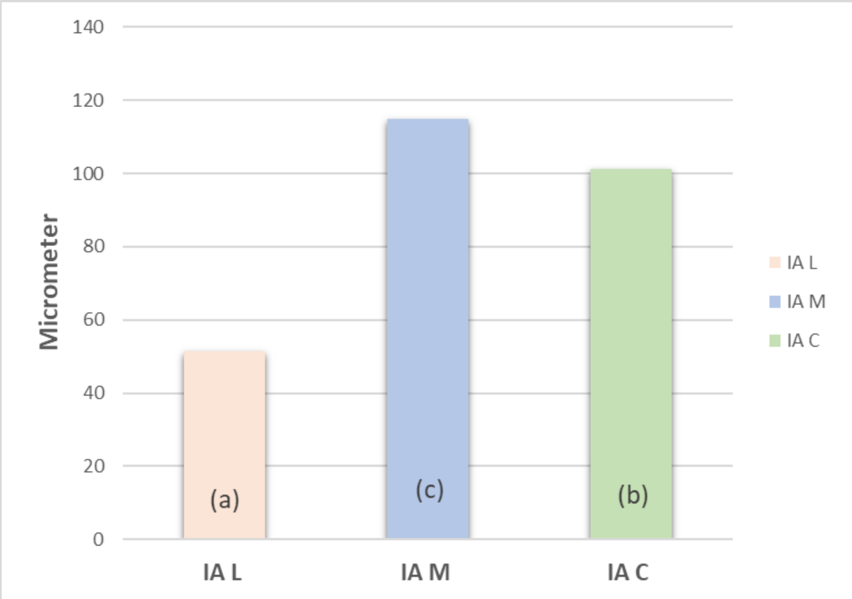

Figure (4): Duncan's Test of Internal Adaptation.
Casting: Casting Technique; Milling: Milling Technique; DMLS: Direct Metal Laser Sintering Technique.