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Comparison of retention of Selective Laser Sintered and Conventional Cast full metal crown prepared with a constant taper- An In Vitro Study

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Abstract

Background: *Retention is a key factor essential for a successful fixed dental prosthesis and is directly related to the geometric configuration of the tooth preparation. The present study aimed to compare the retention of crowns fabricated by Direct Metal Laser Sintering (DMLS) and Conventional Casting Technology against a constant taper of 24 degree with a standardized cement space.*

Methods: *A standard metal die simulating prepared mandibular first molar was fabricated through CAD-CAM technology. Impression of the standard metal die was made using two stage impression technique - heavy body with light body using addition silicone impression material. 20 casts were duplicated from the single cast obtained and each one was first scanned for DMLS Crown and the same casts were then used for Conventional Casting procedure. Both were provided with a standardized cement space of 24 microns and the space was evaluated with Scanning electron microscope using Fit checker. Retention of the crowns was studied as a measure of tensile force with a universal testing machine.*

Results: *The mean tensile strength of crowns fabricated by DMLStechnology was higher than the crowns fabricated using Conventional technology (p= 0.028) at a constant combined taper of 24^{o}.*

Conclusion

Crowns fabricated by DMLS Technology provide significantly more retention than conventional casting technology for this particular taper. DMLS technology promises in preserving the provided cement space for effective flow of luting agent thereby enhancing the retention.

Keywords*: Direct metal laser sintering, Conventional casting, Retention*

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I. INTRODUCTION

The use of crowns for fixed partial dentures to restore or replace teeth has gained its importance over the years. [1]The lack of retention was shown to be one of the common causes for fixed prosthesis failure. [2] This may happen primarily due to over tapering of the preparation. The smaller the taper the higher will be the retention [3], a range of 5-12^{0} taper is considered as optimal. [4] Crowns for fixed partial dentures are commonly fabricated in the dental laboratory using the lost wax technique. [5] Though conventional casting procedure has advanced, a more superior, single-stage dental laboratory process would be helpful to replace the currently employed multi-stage technique for preparing cast restorations. Advances in computer-aided design and computer aided manufacturing (CAD/CAM) have provided a new alternative technique for producing dental restorations. This radical shift is due to the advent of digital dental technology on an unprecedented scale through automation.

Computer aided designing technology help us to provide prosthesis with good quality, standardization, economy,and success**.** This digital technology which bypasses the traditional lab procedures by directly fusing the powdered metal particles at 20micron level and fabricating the metal components is known as Direct metal laser sintering (DMLS). It is an additive metal fabrication technology [6]developed by Electro Optical Systems (EOS) of Munich, Germany. It also referred by the terms selective laser sintering (SLS) or selective laser melting (SLM) .It is a new promising technology which may replace conventional casting of base metal alloys [7] and envisages the use of a high-power laser which can rapidly fuse small particles on the surface of a powder bed of the base metal alloy into a mass representing the desired three-dimensional object. This is achieved from a CAD file or another file created from scanned data of crosssections generated from a three-dimensional digital description of the part.

Hence by replacing the casting of base metal alloys with direct metal laser sintering we can overcome the casting errors and thereby improve the quality of the prosthesis. Only limited studies have been conducted on the retention of the prosthesis fabricated by this technique. Thereforeit is important to find out whether this promising technology can improve the retention of a commonly clinically seeing taper which gives less retention than ideal. This research was designed to compare the retention of crowns fabricated by SLS and Conventional Casting Technology against a constant taper of 24^{o} with standardized cement space.

II. MATERIALS AND METHODS

An Invitro study was conducted in the department of Prosthodontics & Crown & Bridge at Annoor Dental College & Hospital, Muvattupuzha and National Institute of Technology, Kozhikode for a period oftwo years .Raw materials required for the study was procured from the dental material distributor through online services.

Fabricationofmastermodel:

A Cobalt Chromium metal die with a uniform $24^{0}$of taper (12^{o} on either side), CervicoOcclusal dimension of 6.5mm lingually and 6.0 mm buccally, Mesiodistally 10mm and labiolingually 9.5mm ,360^{o} chamfer margin with 0.5mm thickness a simulating prepared mandibular molar tooth was milled by CAD-CAM technology (Figure 1).

Fabricationofworkingmodels:

To standardize the conventional crowns and DMLS crowns the working models were made (Figure 2).To standardize the samples of working models, model duplication was done with addition silicone duplicating impression material.

PreparationofDMLScrown:

The working models were numbered as AI, A2, and A3 till A20. They were first scanned for SLS crown and then followed by conventional casting procedure, providing a standardized cement space of 24 microns.A totalof20DMLS crowns with extension werefabricated and they were numbered as D1 to D20 (Figure 3).

Preparationofconventionalcrown:

Twentyworkingmodelswhich were previously scanned for DMLS crown was used for the preparation of the conventional crown and were castedin a centrifugal induction casting machine. Conventional casted crowns were numbered as numbered as C1 to C20 (Figure 4).

Evaluationof available cement space (cement thickness)

Asiliconeindicatorpastewasusedforchecking thecement space for all the forty samples. The indicatorpastewasplacedinsidethecrown uniformly andthecrown was placedonthestandardizedmetal die. Onremoval ofmetalcrown,thesiliconeindicator pasteremained adhered tothemetal diesurface, over impression wasmade using a putty siliconeimpressionmaterialofdifferentcolour. Twopointscorresponding tomid marginalridgeofmesialanddistalsurfaceoftheputty body.Thewholeassembly wasremovedcarefully usingsectional tray.

Thesiliconeindicatorpasteandputtyassemblywascarefullyfilledwitha layeroflight bodymaterial. Alinewasdrawn connectingthemesialanddistalmarks.Theassembly wassectionedinamesiodistal direction.Thewidthofsiliconeindicatorpasteintheassembly wasrecordedfrom three areas, first from mid mesial, secondfrom mid occlusal and third one from mid distal area of using a scanning electron microscope and thickness of the silicone indicator paste was assessed. This procedure is repeated for all the forty samples.

Cementationofcrownstoworkingmodel:

The cement of choice for conventionaland directmetallasersinteredcrown cementation waszinc phosphate cement. Mixing of cement was done by measuring powder and liquid components according to the manufacturer's instruction. The mixed cementappliedto theintagliosurface ofthe crown and pressed against the die until the margin of the crown merge with finish line using light finger pressure.Individualcrownswereseatedonthe metal die withfirm finger pressureby thesameoperatorfortwominutes.Excesscementwasremovedwithan explorer.Aftercementation,thespecimenswereattached to the Universal testing machine keeping the metal extension in between the two holding compartments in the Universal testing machine.

Measurementofretention:

Retentionwasmeasuredin Mega Pascal (MPa)byseparating themetal crowns fromthe metal die undertensiononauniversal testing machine (Figure 5). Retention of conventional crownsandDMLScopingswerestudied as a measure of tensile force (Figure 6). Tensile testing of the samples was done at 25 ±2^{0}C according to ASTM D-412 method with dumb-bell shaped test specimens at a cross head speed of 500 mm/min using a series IX automated material testing system 1.38 by Instron Corporation (Model 441). The measurementsweremadeinMPaandweretabulatedforstatisticalanalysis.

III. RESULTS

20 samples were taken in each of the study groups.The measured values were recorded and subjected to statistical analysis by paired t-test to know any significant difference between the two variables. The 'mean, 'standard deviation' and p-values were calculated for the variables. In this present study p <.05 was considered as the level of significance. The mean and standard deviation and median were higher for the DMLS FDP than the Conventional FDPas shown in Table 1. Statistically significant difference was observed for the mean retention values between two study groups with a P value of .028 as depicted in Table 2.

IV. DISCUSSION

Theaimof the present studywastocompare andevaluate theretention of conventional and DMLS crownsagainst a constant taper of 12^{0}or total occlusal convergence angle of 24^{0}. Results of the study provided enough evidence to support the claim thatDMLS crowns were of a superior quality compared to conventional crowns .This was found to be statistically significant. Retention is the feature of tooth preparation that resists dislodgement of a crown along the path of placement. [8]According to Ohm and Silness [2]the lack of retention was shown to be a common cause of fixed prosthesis failure. There are so many factors that are directly associated with retention such as factors related with tooth preparation, factors related with cementing medium , and factors related with casting.[1] Luting cements fill the space between prepared tooth surface and the interior of the castings and provide direct link. Most popular cements available for cementation of casting namely the zinc phosphate cement, zinc poly carboxylate cement, glass ionomer cement, and the resin cement. According to Yamashita et al.[9]Zinc phosphate cement has been the most popular luting material for more than 90 years and whichis usedroutinelybyalmost one-thirdofpractitioners. [10]

Rosenstiel study reflected that one of the advantages of Zinc Phosphate cement was that the removal ofexcess cement was easy compared to other cements [11] hence repeated luting on thesame die was quite easy. In addition to the luting cements retention is directlylinked with the geometrical configuration like taper. Taper, which is a main feature ofthe geometry of the preparation, is the convergence of two opposing external walls ofa tooth preparation as viewed in a given plane.[12]Taper has been a featureinvestigated and discussed widely [4], whereas the convergence angle is the extensionof average lines within that plane.[13] Smaller is the taper, higher the retention.[3] Thechoice of cement for crowns prepared within this ideal range (0–6^{o} taper) might be oflimited clinical significance.[14] Study conducted by Jorgensen [4] suggested that theideal angle was 5-10^{o} and an angle greater than 10^{o} decreased retention 50%. But in astudy conducted by Nodlander [15] the mean convergence angle of crown preparationmade by general dental practitioners and by specialists was reported to be 20 degrees.The cement of choice and taper of choice and their relation with retention were welldocumented but the role of fabrication technology on retention is not welldocumented. Hence in this study a convergence angle of 24^{o} which providecompromised retention was selected to approximate the clinical situation. In thisscenario it is always preferable to find out whether fabrication technology has a rolein increasing the retention. Many of the critical laboratory variables like master castfabrication, die spacing, casting can be omitted by CAD-CAM technology.According to Savencu et al.[16]CAD/CAM technologies, both additive and subtractive, represent an excellent option to produce time-effective, precise metal-ceramic crowns with excellent adaptation.Thestudy done by Kim et al.[17]reported thatSLS groupcores had higher values of marginal and internal gaps than the casting group cores,and the difference was statistically significant. Ucar et al.[18]reported that the totalamount of internal gap measured by weight of filled light body silicone wassignificantly larger in direct metal laser sintered system compared to the conventionalmethod. Bindl and Mormann[19] reported internal gap widths of 81µm to 136µmfor different all ceramic CAD/CAM crowns. The finished metal ceramic crowngap values were also significantly higher in the SLS groupcompared to the conventional casting group. All these summarize that the fit ofDMLS crown compared with the conventional crown is inferior. Even though fit ispoor, DMLS crowns will provide more retention compared to conventional crown.This is because it provides a uniform cement spacethroughout the prepared tooth surface and thus enhance a secondary retentionthrough luting cement. Mehl et al.[20]suggested that cement film thickness has aninfluence on the retentive strength of cemented implant-retained crowns. According toAnusavice [5] to be effective, a luting agent must be sufficiently fluid to flow in to acontinuous film of 25 μm thickness or less without fragmentation. For lutingapplication, the maximum available thickness is 25μm; a low value of film thickness ispreferred because excess cement can be expressed more easily. Here DMLS providesa more uniform cement space, because the metal particle fusion is occurring at a rangeof 20 micrometer. Hence metal shrinkage can be bypassed by continuous fusion ofparticle at this range where as in conventional it is not possible. By providing aDMLS fabrication technology, a uniform space for luting cement is achieved whichenhances retention. DMLS technology also bypasses some of the laboratory variablesthat lead to casting shrinkage which provides less cement space. The main laboratoryvariables being master cast fabrication die spacing and casting. DMLS technique could minimize some of these variables since fewer criticalmanual steps are present and hence can reduce processing errors.

However, since the DMLS system is relatively new,further studies are indicated to evaluate the system. Future research should includemeasurement of the mechanical properties and surface characteristics of thelaser-sintered Co-Cr alloy, along with investigation of the biocompatibility of thecrowns prepared by laser sintering.

V. CONCLUSION

Crownsfabricated by DMLS technology showed a significantly more retention than conventionally casted crowns for this constant combined taper of 24^{o}. DMLS technology retains the provided cementspace for the effective flow of luting agents thus enhancing the retention.To conclude, this study has deepened our understanding about the latesttechnologies available for a better and successful treatment.We thus recommend the use of crowns fabricated by the DMLS technology evenin compromised cases. Further clinical evidences are needed for to pursue soundopinion and universal consensus that could offer predictable outcomes for patients.

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Table 1: Descriptive statistics of study variables

Variable	Count	Mean	SD	Minimum	Median	Maximum
Conventional FDP (MPa)	20	2.0245	0.3849	1.46	1.965	2.83
DMLS FDP (MPa)	20	2.1715	0.2321	1.67	2.2	2.6

SD –standard deviation

Table 2: Comparison of mean retention values of study variables

Variable	Count	Mean	SD	P value	t value	
Conventional FDP (MPa)	20	2.0245	0.3849	0.028*	- 2.38	
DMLS FDP (MPa)	20	2.1715	0.2321			

* denotes statistical significance

Figure 1

Figure 2

Figure 3

Figure 4

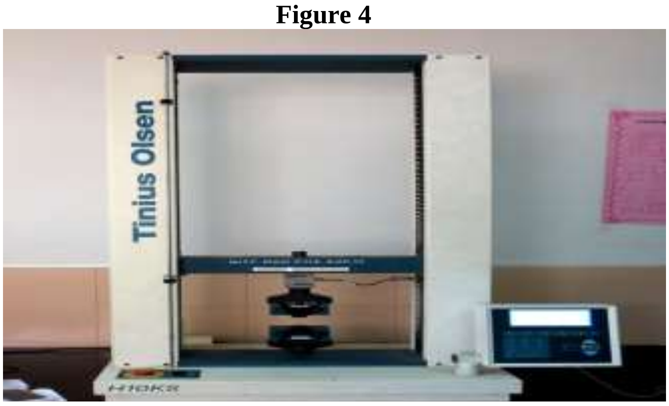

Figure 5

Figure 6