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Comparative Evaluation Of Effect Of TwoDifferent Die Spacer Thickness On Internal Fit Of Metal Copings Fabricated By Computer-AidedMilling And Direct Metal LaserSinteringTechniques-An In-VitroStudy

Dr. Monika Shrihari Lokhande
MDS Prosthodontics
Nair Hospital Dental College, Mumbai
Postal Address- Infront of N.P. School No- 21, Near Narhari Sonar Mandir, Tambari Vibhag, Osmanabad (Dharashiv) 413501, state Maharashtra, Country India.

Dr. Arti P. Wadkar
MDS Prosthodontics, Former Head Of Department And Professor, Dept Of Prosthodontics, Nair Hospital Dental College, Mumbai

Dr. Pooja Krishna Shettigar
MDS Prosthodontics

Dr. Harsh Jani
MDS Prosthodontics

ABSTRACT
Background*-Conventional technique to fabricate fixed partial framework is lostwax techniques.In this technique fabrication of the wax pattern is a critical step. It is time consuming task and dependent upon the skills of the dental laboratory technician. So this has subsequently evolved into CAD CAM Techniques.There are several laboratory studies that provide data on effect of fabrication technique on marginal and internal fit but limited data is available on effect of different die spacer thickness on internal fit of metal coping fabricated by CAD CAM techniques.*
Aim *-Toevaluateandcompareinternalfitofmetalcopingsfabricatedby Millingand Direct MetalLaser SinteringTechniqueswithtwodifferentdiespacerthickness.*
Materials and Methodology *-Full stainless steel die was machined milled. The Digital impression of the standardized master die was made using MEDITT310labscannerfollowedbygenerationofSTLfilefor themasterdieusingCOLLAB20172.0.0.4software. The STL file of the master die was used to generate STL file of the CAD Milledcoping. Thethicknessofthecoping was set to 0.5 mm. A spacer thickness was set to 40 µm for 24 copingsand to 65 µm for 24 copings respectively. Milling was performed using ZUBLER DC5 millingmachine.The generated STL file of master die was used for generating the STL file of the DMLS coping using 3M Designing software version 7 for DMLS. A spacer thickness of 40 micronswas used as a virtual die spacer for 24 copings and 65 microns for 24 copings. Total sample size was 96. The measurement of three dimensional internal fit of CoCrcopings wereperformed using a Triple Scan Protocol developed by Holst.*
Results*-Mean internal gap value for Subgroup A1 was* ***25.917µm****with* ***5.7959µm****asstandard deviationand for SubgroupA2 it was found to be* ***29.519µm*** *with* ***5.9908µm****as standard deviation. Mean internal gap value for Subgroup B1 was* ***23.116µm*** *with standard deviation of* ***2.7302µm*** *whereas forSubgroupB2itwas found to be* ***21.264µm*** *with standard deviation of* ***0.8954µm****.Mean Internal gap values observed in Milling technique was statistically nonsignificant whereas, mean internal gap values observed in DMLS techniqueshowedstatisticallysignificantdifferencewith40and65µmdiespacerthicknessfollowingan order of B2<B1.*
Conclusion *-Inthecurrentstudy,DMLStechnique incomparisonwithMilledtechniqueshowedlowestinternalfitdiscrepancyforboth40and 65 µm die spacer thickness. However, within the DMLS technique, 65 µm diespacer thickness showed least internal fit discrepancy followed by 40 µm die spacerthickness.*
Keywords*-CAD CAM, DMLS, Milling, Co Cr coping, Internal fit, Die spacer thickness*

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I. INTRODUCTION

The fixed partial denture (FPD) is a common treatment available for the restoration of partially edentulous ridges, as it serves as excellent means of replacing missing teeth, where the dentalimplant iscontraindicated.[1] Conventional technique to fabricate fixed partial framework is lost-waxtechnique. Thepossibleproblemswiththistechniquearemakingimpressions in the oral cavity which may cause discomfort for patients and inaccuratefit may result from dimensional change of impression material, distortion of waxpatterns orirregularitiesinthecastmetal.[2] The adoption of automated systems has in turn facilitated thedevelopment of a diverse range of fabrication methods, including the computer-aidedsubtractive technique milling and additive techniques such as Rapid manufacturing,Rapid prototyping, Stereo-lithography, Direct Metal Laser Sintering.[3,4]TheadvantagesofCAD/CAMtechniquesaresimplicity,reducedcostsandmanufacturingtime.[5,6]Co-Cr based alloys are almost exclusively usedfor the production of metallic frameworks of RPDs and for the production of PFMprosthesis.[7] Conventionally casted Co-Cr alloy based prostheses are difficult tofabricateduetohighmeltingrangesandlowlaboratoryusability.Theseinconveniences canbeovercome by computer-aideddesign/computer-aidedmanufacturing (CAD/CAM) technique in which metal blocks are manufactureddirectly.[8]

Die spacing is a commonly used technique to provide space for the luting agent during cementation of prosthesis.[9]Computer-aideddesign(CAD)technologyprovidestheabilitytovirtuallyprogramthedie spacer thickness.[10] Success of fixed restorations depends on the ability of cementedrestorationstoresist dislodgementfromtoothpreparation. Theinteractionof3primary factors influence the potential for dislodgement: (1) Design of the toothpreparation, (2) Fit of the casting and (3) Nature of the cement. Close internal fit is one of the most important factors affecting the accuracy and the long-term success ofthefixedprostheses.[11]Iwaietal.concludedthatzirconiacopingswithacementspacesetto60μmshowedbettermarginal andinternalfitthancopingswithcementspacesetto10μmand30μmwhileYildrimetalfoundclinicallyacceptablemarginalandinternaladaptationvaluesforpolymerinfiltratedceramicnetworkmaterialcrownsusingspacersettingof40μm.[12]

There are somelaboratory studies that provide data on internal fit of metal copings fabricated by different CAD CAM techniques, limiteddataisavailableoneffectofdifferentdiespacerthicknessoninternalfitofmetalcopings fabricated by different CAD CAM techniques. Thus aim of this study was to compare effect of two different die spacer thickness oninternal fit of metal copings fabricated by Computer- Aided Milling and Direct MetalLaserSinteringtechniquesconsideringanullhypothesisthat'Thereisnodifference in the internal fit of metal copings with different die spacer thickness fabricated byComputer-AidedMillingand DirectMetalLaser Sintering Techniques'.

II. MATERIALS AND METHODOLOGY

Thisstudywasplannedtocomparetheeffectoftwodifferentdiespacerthickness (40 and 65 micrometer) on internal fit of metal copings fabricated by Subtractivetechnique (Computer-AidedMilling)andAdditivetechnique (DirectMetalLaser Sintering).

Study Duration- 4 December 2020 to January 2022

Sample size - 96

Sample size calculation -Totalof96samplesofCoCrcopingswerefabricatedwhichincluded 48 samples for each group and 24 samples for each subgroup (Fig 5).

Sample sizewascalculatedusing theformula as $n=\frac{2(Z\alpha+Z\beta)^2[s]^2}{d^2}$

where Zα is the z variate of alpha error i.e. a constant with value 1.96, Zβ is the z variate ofbetaerror i.e. aconstantwith value. All samples wereprepared from the Stainless steel Master die which was machined milled.

1 GroupA –CopingsfabricatedbyMillingtechnique(48samples)

SubgroupA1–Copingswith40micrometerdiespacerthickness(24samples)

SubgroupA2–Copingswith65micrometerdiespacerthickness(24samples)

2 GroupB–Copings fabricatedbyDMLStechnique(48samples)

SubgroupB1–Copingswith40micrometerdiespacerthickness(24samples)

SubgroupB2–Copingswith65micrometerdiespacerthickness(24samples)

Totalsample size-96

Procedure methodology-

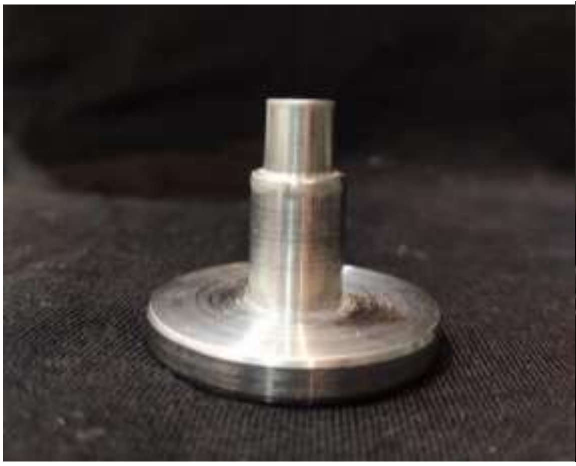
1 FabricationofMasterDie:

Full stainless steel die was machined milled (Fig 1) according to Shaikh SA et al (2014) with specific dimensions which were as follows[13]:

Length of die: 26.19 mm,Diameter at base: 12.70 mm,Crown height: 9.27mm,Diameterofcrown:9.22mm, Widthofshouldermargin:1.74mm, Angleof convergence:2½degreeperwall.

2Digitalimpressionofthe MasterDie:

The Digital impression of the standardized master die was made using MEDITT310labscanner (Fig 2).TheMEDITT310seriesScanner hasascanaccuracyof9microns:ISO12836andANSI/ADA-specificationno.132,VDI-2634.Thescanningofthediewasperformedfollowedbygenerationof STLfilesfor themasterdieusingCOLLAB20172.0.0.4software.[14]



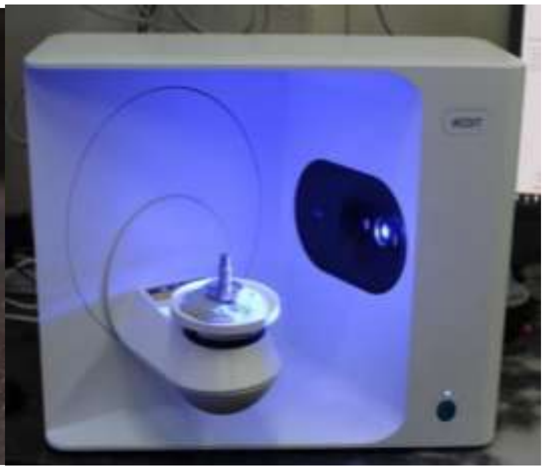


Fig1:Stainless SteelMasterDieFig2:Scanning ofmaster die with Medit T310 lab scanner

3 FabricationofCoCrMilledcopings (GroupA):

The STL file of the master die was used to generate STL file of the CAD Milledcoping. The generated STL file of the coping was used to mill non-presintered softCoCrblocks(Ceramillsintronblanks;AmannGirrbach,Germany)toobtainCoCrcopings by using software (ExocadV2.2,exocadGmbH,Darmstadt,Germany).Thethicknessofthe coping was set to 0.5 mm. The spacer thickness was set to 40 µm for 24 copingsand to 65 µm for 24 copings. Milling was performed using ZUBLER DC5 millingmachine (Fig 3) which is a 5-axis milling machine.

Fig 3:ZUBLERDC5MillingMachine

Fig 4: Direct Metal Laser Sintering EOS Germany Machnine

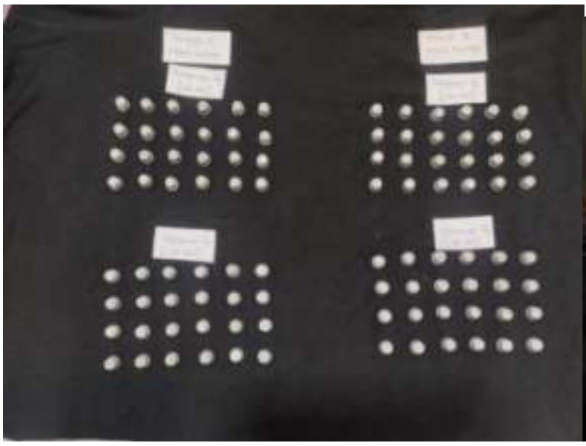


Fig 5: Co Cr Copings by Milling and DMLS

Fig6:Scanningof Co-CrCopingsTechniques

4 Fabricationof Co CrDMLS Copings (GroupB) :

The generated STL file of master die was used for generating the STL file of the coping using 3M Designing software version 7 for DMLS. A spacer thickness of 40 micronswas used as a virtual die spacer for 24 copings and 65 microns for 24 copings.The STL files, thus generated were used to obtain DMLS copings by Direct Metal Laser Sintering System EOS GERMANY (Fig 4). Thus total 48 Co Cr copings wereobtainedbyDMLS technique.

5MeasurementofThree-DimensionalInternalFitofCoCrCopings:

The measurement of three dimensional internal fit of CoCrcopings wasperformed using a Triple Scan Protocol developed by Holst.[15]

This Process of obtaining data involved: 1) Scanning of MasterDie (Fig 2) 2) Scanning of the Co CrCoping (Fig 6) 3) Scanning of the Co Cr Coping placed onthemasterdie inaclinicallycorrectposition. Thescanofthemasterdie and CoCrCoping obtainedinthestudyforfitassessmentweresuperimposedwitha commonoriginpoint. ThescanoftheCo-Crcopingoverthemasterdieandthescanofmasterdieweredigitally superimposed using multiple reference points for performing best fitalignment. Following that, the scan of the Co-Cr coping and Co-Cr copingover the die were digitally superimposed. The scan of Co-Cr coping over the diewasdigitallysubtractedtothusgetthesuperimpositionofthescanCo-Crcoping over the scan master die in best possible alignment to provide theinternalgapincutsectionsforMilledand DMLSCo-Crcopings.

Since it is a three dimensional internal fit evaluation multiplevalues wereobtainedatdifferent points (buccopalatal section was divided into 3 subsectionsbuccal, occlusal, palataland mesiodistal sectionwas divided into 5 subsectionsmesial,mesio-occlusal,occlusal,disto-occlusal and distal) and mean of those values was considered as internal fitdiscrepancy for that particular sample.Thesoftware used for assessment of the discrepancy was EXOCAD 2.3 MATERAsoftwarewhichhelpedinthesuperimpositionandprovidedfordiscrepanciesincutsectionsbetweentheCo-Crcopingandthemasterdie.[15]

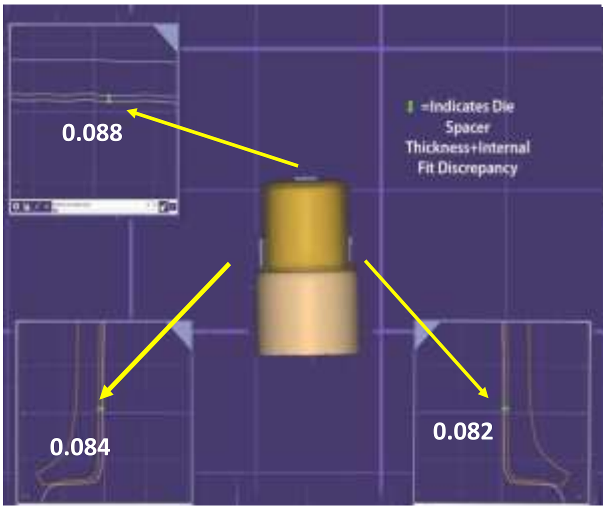


Fig 7: Cut Section of Internal Fit analysis for Milled Co Cr copings with 65 µm die spacer thickness

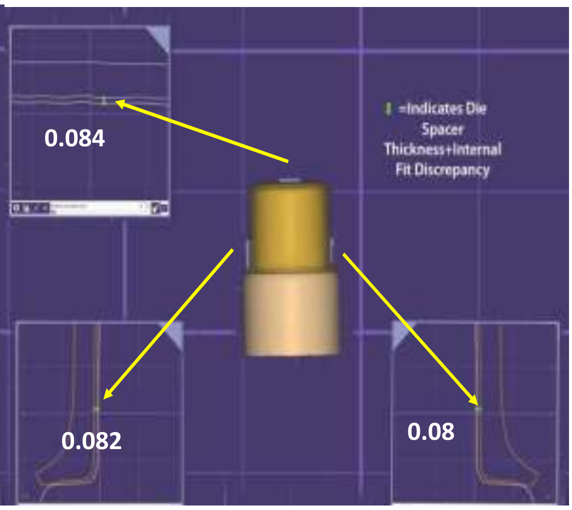


Fig 8: Cut Section of Internal Fit analysis for DMLS Co Cr copings with 65 µm die spacer

Statistical analysis

DataobtainedwascompiledonaMSOfficeExcelSheet(v2019,MicrosoftRedmondCampus,Redmond, Washington, United States).DatawassubjectedtostatisticalanalysisusingStatisticalpackageforsocialsciences(SPSSv26.0,IBM).DescriptivestatisticslikeMean&SD,Medianfor numericaldatahasbeendepicted.Normalityof numericaldatawascheckedusing Shapiro-Wilktest& wasfoundthatthe data did not followanormal curve; hence**non-parametrictests**were used for comparisons.

III. RESULTS

The mean internal gap value for Subgroup **A1**(Milled copingswith40µmdiespacerthickness)was**25.917µm**with**5.7959µm**asstandard deviationand for Subgroup**A2**(Milled copingswith65 µmdiespacerthickness) it was found to be **29.519µm**with **5.9908µm**as standard deviation (Table 1). The values suggestthat there is a statistically highly significant difference with higher values in Subgroup A2 as compared to Subgroup A1, suggesting thatthe Internal gap values are higher for Milled metal copings with 65 µm die spacerthickness when compared with Milled metal copings with 40 µm die spacer thickness.

Mean internal gap value for Subgroup **B1**(DMLS copingswith40µmdiespacerthickness)was **23.116µm** with standard deviation of **2.7302µm** whereas forSubgroup**B2** (DMLS copingswith65 µmdiespacerthickness)itwas found to be **21.264µm** with standard deviation of **0.8954µm**(Table 1). These values suggest that therewere highervalues in Subgroup B1 as compared to Subgroup B2, suggesting that the internal gap values arehigher for metal coping fabricated by DMLS technique with 40 µm die spacer thickness whencomparedwithmetalcopingfabricatedbyDMLStechniquewith65µmdiespacerthickness.

	Mean	Standarddeviation	Standard error mean	Chi Squarevalue	P value ofKruskal-WallisTest
SubgroupA1	25.917	5.7959	1.1831	43.651	0.000**
SubgroupA2	29.519	5.9908	1.2229		
SubgroupB1	23.116	2.7302	0.5573		
SubgroupB2	21.264	0.8954	0.1828		

Table 1:Inter-SubgroupcomparisonofinternalgapsbetweenmetaI copings fabricatedbyMillingandDMLS techniques with40µmand65µmdie spacerthickness (Kruskal-Wallis Test)

Mean internal gap value for Subgroup **A1**(Milled copingswith40µmdiespacerthickness)was **25.917µm**with standard deviation of **5.7959µm**whereas forSubgroup**B1** (DMLS copingswith40µmdiespacerthickness)it was found to be **23.116µm**with standard deviation of **2.7302µm**(Table 1). These values suggest that thereisastatisticallyhighlysignificantdifferencewithhighervaluesinSubgroupA1ascomparedtoSubgroupB1,suggestingthattheinternalgapvaluesformetalcopings with 40 µm die spacer thickness were higher with copings fabricated by Milling technique than thatofcopingsfabricated byDMLS technique.

Mean internal gap value for Subgroup **A2**(Milled copingswith65 µmdiespacerthickness) was **29.519µm**with standard deviation of **5.9908µm**whereas forSubgroup**B2** (DMLS copingswith65 µmdiespacerthickness) it was found to be **21.264µm**with standard deviation of**0.8954µm**(Table 1). These values suggest that thereis a statistically highly significant difference with highervalues in Subgroup A2 as compared to Subgroup B2 suggestive that the internal gap values formetalcopingswith65µmdiespacerthickness were higherwithcopingsfabricatedbyMillingtechnique thanthat of copingsfabricatedbyDMLStechnique.

Table 2:Inter-Subgrouppairwisecomparisonofinternalgaps(Mann-WhitneyU Test)

Subgroup	Vs Subgroup	Mann-WhitneyUvalue	Zvalue	pvalueofMann-WhitneyU test
A1	A2	200.000	-1.815	0.070#
B1	B2	112.000	-3.641	0.000**
A1	B1	156.00	-2.725	0.000**
A2	B2	22.000	-5.486	0.000**

SubgroupA1v/sSubgroupA2Pvaluewas>0.05sostatisticallynonsignificantdifferenceseen.SubgroupB1v/s SubgroupB2P value was < 0.01 so statistically highly significantdifferenceseen.SubgroupA1v/sSubgroupB1P value was < 0.01 so statistically highly significantdifferenceseen.SubgroupA2v/sSubgroupB2Pvaluewas<0.01sostatisticallyhighlysignificantdifferenceseen (Table 2).

IV. DISCUSSION

Zuskova L et al[4]in 2019 studied effect of CAD/CAM proceduresontheoverallfitofmetalcopings.Diespacer thicknesswas55µm.Milledgroupdisplayedameanoffitdiscrepanciesof42.20 µm,whilethelaser-sinteredgroupshowedameanof42.24µmfitdiscrepancies which was in agreement with the results found in this study.**Vojdani et al[16]in 2016** stated a study that had clinically acceptable results of 23 µmfor the internal gap in the CAD/Milling group and 46 µm for the internal gap in theCAD/ Ceramill Sintron.**Bhaskaran et al[17]in 2013** reported internal gap of Co-Crcopings cast from 3D printed resin patterns to be 36.15 µm. Similarly **Park J K et al[19]in 2015** evaluated the Overall mean gap for Co-Cr coping fabricated by the computer-aided milling and DMLSmethods were 88.9 µm and 103.3 µm respectively. An explanation of the lack of agreement may be due to differenceinmeasurement approaches and criteria's used while measuring the internal fit anddifferenceindie spacer thickness.DifferencesintheCADCAMfabricationtechniquesofcrownshavedirectinfluenceontheir internal fit. **According to Koutsoukis T et al [20]in 2015** DMLS performs betterthanthe milling and casting techniques in the primary economic areas, includinglabor,time,wasteofmaterialsandconsumables,recyclingandproductivity.According to **Venkatesh K V et al[21] in 2013** three main factors affecting the fit are:precision of the scanner, how effectively software can transform the scanning dataintoa3Dmodel in thecomputerandthe precisionofthe millingmachine.

Inthecurrentstudy,DMLStechniqueincomparisonwithMilledtechniqueshowedlowestinternalfitdiscrepancyforboth40and 65 µm die spacer thickness. However, within the DMLS technique, 65 µm diespacer thickness showed least internal fit discrepancy followed by 40 µm die spacerthickness. Though the Milling technique, showed a higher internal fit discrepancy forboth 40 and 65 µm die spacer thickness, the observed values were within clinicallyacceptable range. Thereby the results of the study reject the nullhypothesis statingthat, there exists a significant difference in theinternal fit of metal copings with twodifferent die spacer thickness (40 and 65 µm) fabricated by Computer- Aided Millingand Direct Metal Laser Sintering techniques. Thus, the current study was conductedtohelp the clinician to make achoice among the above mentionedCAD CAMfabricationtechniquesandthediespacerthicknessforfabricationof Co-Crcopings. Mean Internal gap values observed in Milling technique was statistically nonsignificant whereas, mean internal gap values observed in

DMLS techniqueshowedstatisticallysignificantdifferencewith40μmand65μmdiespacerthicknessfollowingan order of B2<B1.

There were some limitations in this study. Sincethisisanin-vitrostudysoitdoesnotdirectlysimulatetheintraoralcondition. Studies with a larger sample size need to be carried out to obtain more accurateresults. The present study was conducted with two different die spacer thickness (40 and65 μm) but in order to achieve greater accuracy in the results these die spacerthickness(40and65μm)shouldbefurthercomparedin differentdiespacer thickness.

V. CONCLUSION

Abovestudy providesdiscrete data and direct comparisonon theinternaladaptation of Metal copings fabricated by Milling and DMLS techniques with 40 μmand65μmdiespacerthickness.

The internal fit discrepancies found in this study were within the clinically acceptable standard (120 μm). In the current study DMLStechniqueincomparisonwithMilledtechniqueshowedlowestinternalfitdiscrepancyforboth40and 65 μm die spacer thickness. However, within the DMLS technique, 65 μm diespacer thickness showed least internal fit discrepancy followed by 40 μm die spacerthickness.

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