ISSN: 0975-833X

Available online at http://www.journalcra.com

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 13, Issue, 04, pp.17038-17043, April, 2021

DOI: https://doi.org/10.24941/ijcr.41071.04.2021

REVIEW ARTICLES

OPEN ACCESS

COMPARATIVE STUDY OF FRACTURE RESISTANCE OF CERAMIC IN METAL CERAMIC RESTORATIONS BY USING THREE DIFFERENT METAL COPING DESIGNS FABRICATED BY DIRECT METAL LASER SINTERING TECHNOLOGY: AN IN VITRO STUDY.

[*]Dr. Shweta. V. Annaldasula, Dr. Naisargi. P. Shah, Dr. Saloni. S. Mistry, Dr. Praveen. V. Badwaik and Dr. Sangeeta. G. Yadav

Department(s) and institution(s) : Department of Prosthodontics, TPCT's Terna Dental College and Hospital, Navi Mumbai, Maharashtra, India ,[1]Department of Prosthodontics, G.D.POL YMT dental college, Navi Mumbai, Maharashtra, India

ARTICLE INFO

Article History:
Received 25th January, 2021
Received in revised form
08th February, 2021
Accepted 19th March, 2021
Published online 27th April, 2021

Key Words:

Collarless Metal Ceramic Crowns,
Labial Metal Collar,
Direct Metal Laser Sintering.

ABSTRACT

Aim: The aim of this study was to compare the effect of different metal coping designs on fracture resistance of porcelain in metal ceramic restorations fabricated by direct metal laser sintering technology. **Settings and Design**: Comparative - *In vitro* study. **Methods and Material:** An ivorine central incisor tooth was selected and prepared according to biomechanical principles followed by fabrication of nickel-chromium dies according to conventional casting method. The direct metal laser sintered copings on the dies were made and divided in three groups consisting of metal coping extending up to gingivo-axial line angle of finish line, metal coping extending 1mm short of gingivo-axial line angle of finish line, metal coping having 0.4mm wide labial metal collar respectively. Ceramic layering of the metal copings was done and fracture resistance of the specimens were measured. **Statistical analysis used:** Data for the fracture load for all the groups were evaluated and compared and was tested for normality using Shapiro-Wilk test. The 3 groups were compared using the Kruskal-Wallis test (Non-parametric ANOVA). **Results:** The mean fracture resistance of Groups A, B, C was 971.8N, 705.2N, 531.66N respectively. **Conclusions:** The mean fracture resistance of the specimens with shoulder porcelain labial margins having metal coping design extending up to gingivo-axial line angle of the finish line was highest as compared to other groups.

Citation: Dr. Shweta. V. Annaldasula, Dr. Naisargi. P. Shah, Dr. Saloni. S. Mistry, Dr. Praveen. V. Badwaik and Dr. Sangeeta. G. Yadav. "Comparative study of fracture resistance of ceramic in metal ceramic restorations by using three different metal coping designs fabricated by direct metal laser sintering technology: An in vitro study.*", 2021. International Journal of Current Research, 13, (04), 17038-17043.*

INTRODUCTION

In this era of digitalization, the increasing requisition to aesthetic restorations as well as questionable role of some dental alloys makes the development of newer non-metal restorations justifiable. However, metal-ceramic restorations have been the gold standard in making fixed dental prosthesis (FDP's) and single crowns.

Corresponding author:** ***Dr. Shweta. V. Annaldasula,
Department(s) and institution(s) : Department of Prosthodontics, TPCT's Terna Dental College and Hospital, Navi Mumbai, Maharashtra, India ,1Department of Prosthodontics, G.D.POL YMT dental college, Navi Mumbai, Maharashtra, India

The metal ceramic restorations combine the physical properties of metal i.e. rigidity and impact strength, with aesthetic qualities, abrasion and strain resistance of dental ceramics. The success of metal-ceramic restorations depends on preparation design, coping design and optimum ceramic thickness[1]. The earliest design recommended for PFM restorations was thin labial cervical collar of metal. The metal collar serves as a truss that strengthens the casting and overlying ceramic material and enables it to resist deformation during the ceramic firing cycles[2] but having a disadvantage of having an unaesthetic appearance. So, the alternative is to eliminate the unsightly metal collar by collarless metal ceramic restoration with porcelain labial margin.

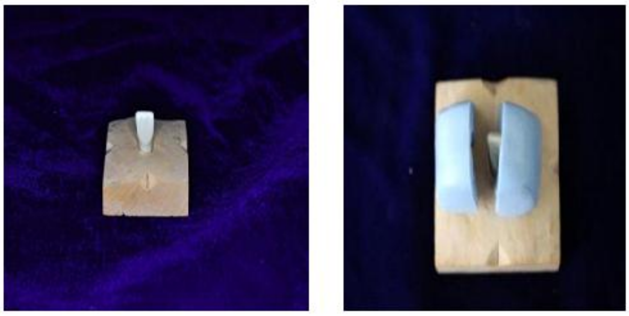
In-spite of these advantages, little information is documented in literature[3] regarding the fracture resistance of the restoration with shoulder porcelain labial margin. The adoption of automated systems has in turn facilitated the development of a diverse range of fabrication methods, including the computer-aided milling and direct metal laser sintering (DMLS) systems rather than relying on multi-level conventional casting. Comparatively, Cobalt-Chromium (Co-Cr) alloys rather than Nickel-Chromium (Ni-Cr) alloys have been used with DMLS technology because of their high mechanical strength, corrosion resistance, biocompatibility, and cost efficiency[4]. However, literature reflects that not many studies have been carried out to evaluate the fracture resistance of ceramic in metal-ceramic restorations using DMLS technology which is a significant criterion for functional, esthetic and biological success of any fixed restorations. Hence, this study was planned to evaluate and compare the fracture resistance of ceramic in metal ceramic restorations by using three different coping designs by direct metal laser sintering technology.

MATERIAL AND METHODS

The methodology is divided into the following headings:

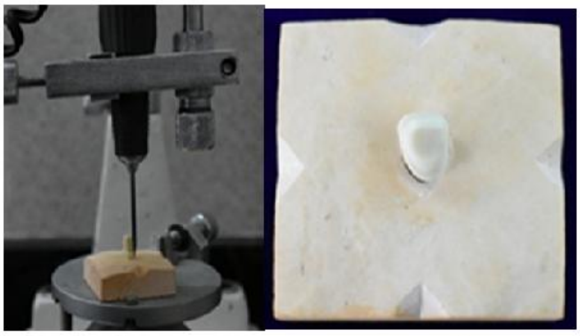
- Preparation of ivorine tooth according to biomechanical principles
- Impression of the prepared tooth for fabrication of resin dies:
- Fabrication of nickel chromium dies by conventional casting method
- Direct metal laser sintered copings (DMLS) on the metal dies.
- Modification of the prepared ivorine tooth for fabrication of dies and copings for Group C.
- Ceramic layering of all the metal copings.
- Testing the fracture resistance of all the specimens.

Step 1 - Preparation of ivorine tooth according to biomechanical principles: The Ivorine maxillary central incisor (Typodont) was mounted in die stone and putty index of this ivorine tooth was made. The index was sectioned in labial and lingual halves, which were later used for contouring the ceramic build-up [Figure1]. The ivorine central incisor was then prepared with airotor handpiece mounted on the surveyor to receive metal ceramic crown with shoulder facial margin according to standard norms recommended by Shillinburg et al[5] The tooth was prepared with a 90^0, 1.5mm shoulder on the facial surface that was carried to the mid-proximal region both mesially and distally and blended to a 0.8mm chamfer finish line on the lingual surface. [Figure 2]



a b

Figure 1 : a) An Ivorine tooth (11) mounted in die stone, b)the sectioned putty index made before toothpreparation.



a b

Figure 2. a) Tooth prepared with airotorhandpiece mounted on a surveyor, b) The occlusal view of the prepared tooth.

Step 2- Impression of the prepared tooth for fabrication of resin dies: To fabricate resin dies, an impression of the prepared ivorine tooth was made with polyvinyl siloxane impression material by two step putty wash technique using a custom tray. [Figure 3].

a. b. c.

Figure3: a)Vaccuform sheet as a spacer over the prepared tooth, b) The Custom tray isfabricated, c) The elastomeric impression of the prepared tooth

The self-cure auto-polymerizing polymethyl methacrylate (PMMA) polymer and monomer (Pattern Resin, Dentsply) was mixed in Powder/Liquid (P/L) ratio of 3:1. It was then poured in the obtained elastomeric impression and after complete setting of the material it was retrieved. Thus, a duplicate resin die of the prepared ivorine tooth was obtained. In the similar fashion 30 resin dies were prepared – 15 dies for Group A and B each [Figure 4].

Figure 4 :A resin die (poly methyl methacrylate) of the prepared ivorine tooth was fabricated, group A and B – 15 specimens each

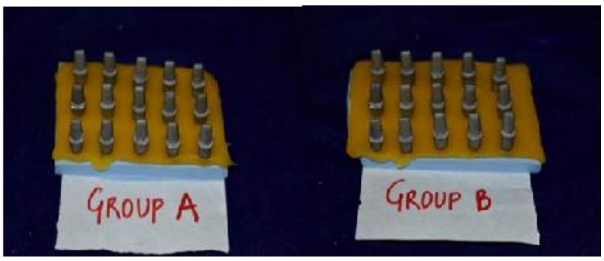


Figure 5 :The 30 metal dies (group A and B) were casted in Ni-Cr alloy accordingto the standard casting protocol in conventional method

Step 3 - Fabrication of nickel chromium dies by conventional casting method: The 15 resin die specimens of Group A & B each were casted in Ni-Cr alloy according to the standard casting protocol. These investments were heated in a burn out furnace and the casting were done in induction casting machine at 750-1030^0 C using Ni-Cr alloy[6] [Figure 5].

Figure 6 Scanning of metal dies for DMLS coping

Step 4 - Direct metal laser sintered copings (DMLS) on the metal dies: These 30 metal dies were positioned in the scan holder and checked with the positioning template. It was then scanned and designed on the computer to receive the patterns for the coping. [Figure 6].

Group A: 15 Metal copings extending up to gingivo-axial line angle of finish line. [Figure 7].

Figure 7 :Group A : 15DMLS copings extending up to gingivo-axial line angle offinish line.

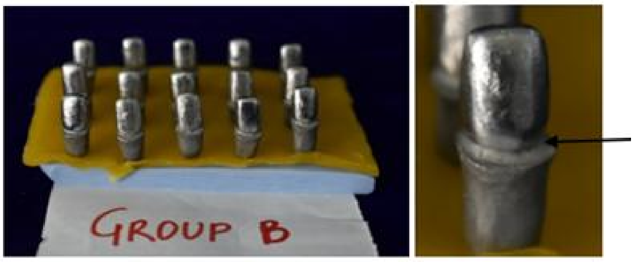


Figure 8: Group B : 15DMLS copings extending 1mm short of gingivo-axial line angle of the finish line.

Group B: 15 Metal copings extending 1mm short of gingivo-axial line angle of the finish line overall. [Figure 8].

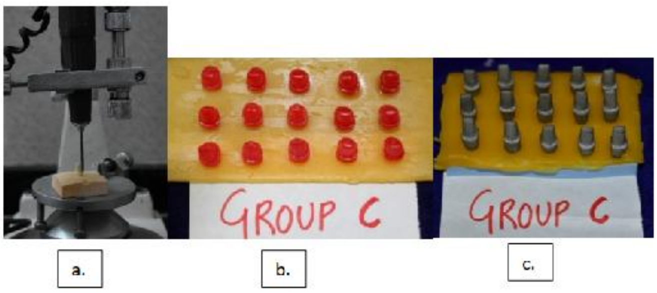


Figure 9 : Group C : a) The labial shoulder of the mounted prepared ivorine tooth was modified to shoulder with 45^0 bevel on the surveyor, b)15 resin dies (PMMA) and c) The consequent 15 metal dies copings were casted using conventional casting technique.

Figure 10. Group C : 15 DMLS copings having 0.4mm wide labial metal collar.Step 5- Modification of the prepared ivorine tooth for fabrication of dies and copings for Group C:

The labial shoulder of the mounted prepared ivorine tooth was modified to shoulder with 45^0 bevel to receive a metal ceramic crown with a 0.4mm wide metal collar on the surveyor, followed by similar steps described above, the DMLS copings were fabricated. [Figure 9].

Figure 11. The 45 specimens were embedded in acrylic resin blocks followed by cementation of the ceramo-metal crowns to respective dies using resin modified glass ionomer agent. 15 specimens each for groups A,B,C

Group C: 15 Metal copings having 0.4mm wide labial metal collar. [Figure 10].

Figure 12. Specimens of each - Group A, B, C were tested on an universal testing machine

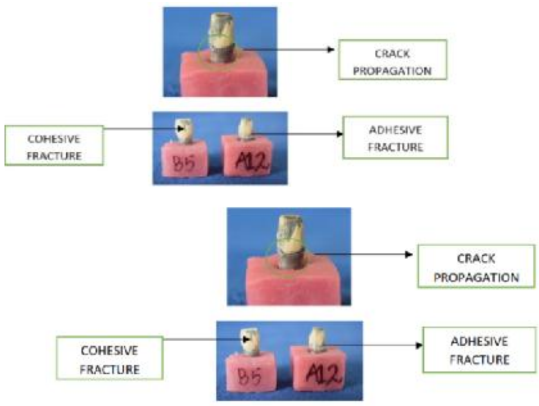


Figure 13. Fractured specimens from group A,B,C (cohesive and adhesive fracture seen)

Step 6 - Ceramic layering of all the metal copings: Ceramic layering of these 45 copings divided in Group A, B, C was simultaneously done by consecutive stages of preheating, opaquer and shoulder application (direct lift technique). The dentinal and enamel porcelain was applied and contoured with the help of sectional putty index. The measurements were made to ensure that the total thickness of the facial margin is uniformly 1.5 mm. The crowns were then glazed, the porcelain application and condensation were standardized as much as possible within the confines of usual laboratory procedures for fabricating metal ceramic crowns [Figure 11].

Step 7 - Testing the fracture resistance of all the specimens: All the 45 metal dies of group A, B, C were embedded in acrylic resin block in vertical position for convenience of holding the samples on the Instron Universal testing machine. The finished crowns of all three groups were luted to the respective metal dies with resin modified glass ionomer luting agent and was allowed to set for 24 hours following the necessary manufacturer's instructions. [Figure 12] Load was applied at linguo-incisal line angle, at 130^0 to the long axis of the specimen until porcelain fracture occurs. This position was used to represent the occlusal forces directed to a maxillary central incisor in natural dentition. Load was applied by a 6.35mm diameter rod with the center of the rod in contact with porcelain surfaces. A crosshead speed of 2.5mm per minute was used to apply the load. The specimens were tested on an Instron testing machine. The results were obtained in Kilo-Newton but to compare the results with the previous studies, values were converted to Newton by using following formula: 1 Kilonewton = 1 Newton x 1000.

RESULTS

A total of 45 specimens were obtained and divided equally amongst the three groups. MedCalc[7] Statistical Software version 18.10 was used. Data for the fracture load for 45 specimens (Group A, B, C) were evaluated and compared and was tested for normality using Shapiro-Wilk test. Since the data was non-normal, non-parametric tests were used for analysis. The 3 groups were compared using the Kruskal-Wallis test (Non-parametric ANOVA).

Table 1. Peak fracture load of group a, b, c specimens in newton (n)

Groups	Maximum load	Minimum load	Mean load	Standard deviation
A	1400	672	971.8	230.5
B	950	587	705.2	120.2
C	691	385	531.6	86.37

Table 1 demonstrated the mean fracture load and standard deviation for Group A, B, C specimens. The data was collected, compared and was tested for normality using Shapiro-Wilk test. The group A specimens showed mean fracture load of 971.8 N with a standard deviation of 230.5 N and the range of fracture load was 672 N to 1400 N. The Group B specimens showed mean fracture load of 705.2 N with a standard deviation of 120.2 N and the range of fracture load was 587 N to 950 N. The Group C specimens showed mean fracture load of 531.66 N with a standard deviation of 105.29 N and the range of fracture load was 385 N to 691 N.

Table 2. kruskal-wallis test (non-parametric) for three groups

Test statistic	30.4037
Corrected for ties ht	30.4197
Degrees of freedom (df)	2
Significance level	P < 0.000001

Table 2 showed, comparison of the three groups using Kruskal-Wallis test, as the data obtained was non-normal, Anova (Parametric) test could not be used. A non-parametric test – Kruskal-Wallis test was used to compare the three groups. The degree of freedom obtained was 2, and the significance level obtained after comparison was P < 0.00001. Thus, P value is highly significant.

Table 3. Post hoc analysis using mann whitney 'u' test (Between Group A &B)

Average rank of group a	21.0667
Average rank of group b	9.9333
Mann-whitney u	29.00
Test statistic z (corrected for ties)	3.464
Two-tailed probability	P = 0.0005

Table 3 showed, comparison of the fracture resistance between group A and B, using Post-HOC analysis. It is observed that the P value is 0.0005, which is very highly significant.

Table 4. Post hoc analysis using mann whitney 'u' test (between group a & c)

Average rank of group a	22.9333
Average rank of group c	8.0667
Mann-whitney u	1.00
Test statistic z (corrected for ties)	4.625
Two-tailed probability	P < 0.0001

Table 4 showed, comparison of the fracture resistance between group A and C, using Post-HOC analysis. It is observed that the P value < 0.0001, which is significant.

Table 5. Post Hoc Analysis Using Mann Whitney 'U' Test (Between Group B & C)

Average Rank of Group B	21.5000
Average Rank Of Group C	9.5000
Mann-Whitney U	22.50
Test Statistic Z (Corrected For Ties)	3.733
Two-Tailed Probability	P = 0.0002

Table 5 showed, comparison of the fracture resistance between group B and C, using Post-HOC analysis. It is observed that the P value < 0.0002, which is highly significant.

DISCUSSION

The metal ceramic crown restoration was first described by Brecker[8] in 1956. He described the use of a circumferential metal collar in which cervical aesthetics can be improved by eliminating the cervical metal collar and fabricating the restoration with porcelain cervical margins. But it produces dark line or shadow beneath the gingival tissue hampering the aesthetic appearance. Availability of shoulder porcelain made it possible to reduce the metal substructure from the facial margin but one concern with the collarless metal ceramic restoration with different metal coping design in the facial margin area has been its questionable ability to withstand load at the facial porcelain margin. The base metal (Ni-Cr and Co-Cr) casting alloys have gained popularity because of their excellent performance and effective cost considerations. Though Ni-Cr have limitations with regards to formation of excessive oxides and bio-compatibility that has led to allergic reactions in patients. Therefore, Co-Cr alloys have been suggested as better alternatives because of their higher mechanical strength, corrosion resistance, biocompatibility and cost efficiency. Laser sintering process was first introduced by Deckard and Beaman[9]. Laser sintering is also referred to as ‘‘3D printing’’ because it builds up framework in a series of successively thin layers (0.02–0.06 mm)[10]. Direct metal laser sintering technology (DMLS) having a primary composition of Cobalt-Chromium alloy for fabrication of metal copings has been seen to reduce distortion as compared to conventional casting and produces stronger copings with practically no voids. Preliminary research[11] suggests that the composition of the Co-Cr alloy for laser sintering does not contain tungsten and has lower molybdenum content, compared to the composition of Co-Cr alloy for casting as laser sintering is facilitated by the absence of such refractory metals, which have much higher melting temperatures than cobalt and chromium. Though few studies have been done in terms of fracture resistance by Co-Cr made copings with laser sintering technology. The present study suggests that fracture resistance of shoulder porcelain margin (Group A and B) was significantly higher than that of porcelain fused to metal collar margin (Group C). The comparison of fracture resistance between group A and B i.e. crowns with shoulder porcelain margins was only statistically significant. Visual examination of the fractured specimens showed remarkably similar failure modes between the three groups, failing through a shear fracture of porcelain from load point to facial margin of the crown. Few specimens fractured within the ceramic and some showed the fracture at the porcelain metal interface, seen by the exposure of the metal. On evaluation, the failures were appeared to have the features of both adhesive and cohesive failure for all the three groups [Figure 13]. When PFM restorations were first introduced in the 1960s the metal collar was considered to represent the ideal margin for reasons of marginal seal, periodontal health and rigidity. The most commonly-prescribed finishing line to accommodate this type of margin was the beveled shoulder, based on the notion that its use would reduce the marginal opening of the gold casting. This design has, over time, replaced the beveled shoulder as the resulting butt joint permits the use of a bulk of porcelain at the margin, thus removing the need for a metal collar. A shoulder width of 1mm to 1.5mm at a 90^0 to 100^0 angle to the root surface is ideal, offering optimal rigidity (by virtue of support provided by the underlying metal coping) and resistance against porcelain shrinkage[15].

The axial line angle should be rounded to reduce stress concentration in that area. Also, the 90^0 internal line angle of the finish line is believed to provide internal buttressing of the shoulder porcelain and it remains under compression. According Sozio[16] the major force distribution upon the labial margin of collarless metal ceramic restoration is compressive in nature and not tensile. Under compressive load the dental porcelain is highly resistant to rupture almost ten times than under tensile load. In addition, the shoulder porcelain has higher content of crystalline alumina. Because of the crystalline nature it has better packability, reducing the firing shrinkage and pyro-plastic flow of the shoulder porcelain. The alumina has high modulus of elasticity and is the toughest oxide.

The glazed porcelain is effective in reducing crack propagation within the outer surface because the surface flaws may be bridged by glazed porcelain and maintains the surface under a state of compression[17]. The higher fracture strength of the crowns with shoulder porcelain labial margins may be because of the higher crystalline alumina content of shoulder porcelain, compressive nature of the forces acting on the labial margin area, sufficient bulk of shoulder porcelain at the labial margin area along with metal support covering almost the entire tooth except in the labial margin area. The maximum load required to fracture the test specimens observed in this study were exceeding the normal biting forces i.e. the range of load was 385 N to 1400 N. Gibbs et al[18] stated that the occlusal loads were 263 N during normal chewing and 297 N during swallowing. In another study Waltimo and Kononen[19] reported that the mean maximal incising force to be 263 N for men and 243 N for women. Thus, the results emphasize that the metal ceramic restorations with cervical shoulder porcelain with the 1 mm cervical metal reduction can withstand masticatory forces without failure. The results of the present study were in compliance with earlier authors, O’Boyle et al[20] who stated that no significant decrease in fracture resistance was recorded from crowns with up to 2 mm of framework reduction and having a shoulder porcelain. Goodacre et al[2], Prince and Donovan et al[3] and Warpeha and Goodkind[21] collectively agreed on value of fabrication of metal ceramic restorations without cervical metal collar to enhance the aesthetics and increased fracture strength. Potiket et al[22] suggested that a 1 mm deep shoulder finishing line with a rounded internal line angle has good fracture strength for the natural teeth restored with porcelain fused to metal and all ceramic crowns.

FURTHER SCOPE OF THE STUDY

It would be beneficial to couple the in vitro studies with a long-term in vivo evaluation to assess the clinical accuracy of the fracture resistance by including more coping designs and adding parameters to validate the use of DMLS technology.

CONCLUSION

Within the limitations of this in-vitro study, following conclusions were drawn:

- This in-vitro study supports the rejection of the null hypothesis as it was observed that there is significant difference between the three groups.
- The fracture resistance was highest in the DMLS coping extending up to gingivo-axial finish line and lowest in the DMLS coping extending up to gingivo-axial finish line with 0.4mm labial metal collar.
- The mode of the porcelain fracture i.e. adhesive as well as cohesive fracture was similar for all the three types of margins with nearly all specimens failing through a shear fracture of porcelain starting from the load point to facial margin.

REFERENCES

1. Bulbule N, Motwani BK. 2014. Comparative study of fracture resistance of porcelain in metal ceramic restorations by using different metal coping designs-an in vitro study. Journal of clinical and diagnostic research: JCDR. Nov;8(11): ZC123.
2. Goodacre CJ, Roekel NV, Dykema RW, Ullmann RB. 1977. The collarless metal ceramic crown. *J Prosthet Dent.,* 38: 615-22.
3. Prince J, Donovan T. 1983. The aesthetic metal-ceramic margin: A comparison of techniques. *J Prosthet Dent.,* 50: 185-92

4. Shillingburg HT, Hobo S, Fisher DW. 1973. Preparation design and margin distortion in porcelain-fused-to-metal restorations. *J.Prosthet Dent.*, Mar 31;29(3):276-84
5. Shillingburg HT, Sather DA, Wilson EL, Cain JR, Mitchell DL, Blanco LJ, Kessler JC. 2013. Fundamentals of fixed prosthodontics. Quintessence Publishing Company; 2012.
6. Anusavice KJ, Shen C, Rawls HR. Phillips' science of dental materials. Elsevier Health Sciences.
7. MedCalc Statistical Software version 18.10.2 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2018)
8. Brecker SC. 1956. Porcelain baked to gold a new medium in prosthodontics. *J Prosthet Dent.,* 6:801-10.
9. Deckard C, Beaman J. 1988. Process and control issues in selective laser sintering. ASME Prod Eng Div. (Publication) PED 33:191–197
10. Traini T, Mangano C, Sammons RL, Mangano F, Piattelli A. 2008. Direct laser metal sintering as a new approach to fabrication of an isoelastic functionally graded material for manufacture of porous titanium dental implants. Dent Mater 24:1525–1533.
11. Yurdanur Ucar, Tolga Akova, Musa S. Akyil, and William A. Brantley. 2009. Internal fit evaluation of crowns prepared using a new dental crown fabrication technique: Laser-sintered Co-Cr crowns. *J Prosthet Dent.,* 102:253-259
12. Panno FV, Vahidi F, Gulker I, Ghalili KM. 1986. Evaluation of the 45-degree labial bevel with a shoulder preparation. *J Prosthet Dent.,* Dec;56(6):655-61.
13. Yoshinari M, De′rand T. 1994. Fracture strength of all-ceramic crowns. *Int J Prosthodont.,* 7:329-38
14. Zalkind. M. 1984. A labial porcelain butt joint in ceramometal restorations. Quint Int.11:1117–20.
15. Campbell SD, Pelletier LB. 1992. Thermal cycling distortion of metal ceramics. Part I. Metal collar width. *J Prosthet Dent.,* 67: 603-608.
16. RB Sozio. 1977. The marginal aspect of the ceramometal restoration: The collarless ceramometal restoration. *Dent Clin Am.,* 21:787–801
17. Anusavice KJ, Shen C, Rawls HR. 2013. Phillips' science of dental materials. Elsevier Health Sciences.
18. Gibbs CH, Mahan PE, Lundeen HC, Brehnan K, Walsh EK, Holbrook WB. 1981. Occlusal forces during chewing and swallowing as measured by sound transmission. *J Prosthet Dent.,* 46: 443-9
19. Waltimo A, Ko¨no¨nen M. 1993. A novel bite force recorder and maximal isometric bite force values for healthy young adults. *Scand J Dent Res.,* 101:171-5.
20. O'Boyle KH, Norling BK, Cagna DR, Phoenix RD. 1997. An investigation of new metal framework design for metal ceramic restorations. *The Journal of prosthetic dentistry*. Sep 1;78(3):295-301.
21. Warpeha WS, Goodkind RJ. 1976. Design and technique variables affecting fracture resistance of metal-ceramic restorations. *Journal of Prosthetic Dentistry*. Mar 1;35(3):291-8.
22. Potiket N, Chiche G, Finger IM. 2004. In vitro fracture strength of teeth restored with different all-ceramic crown systems. The Journal of prosthetic dentistry. Nov 1;92(5):491-5.

****