IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 18, Issue 2 Ser. 14 (February. 2019), PP 49-57
www.iosrjournals.org

"Comparitive Study of Marginal Fit of Zirconia Copings Prepared With Model-Less And Model Technique- An In Vitro Study"

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Date of Submission: 13-02-2019 Date of acceptance: 28-02-2019

I. Introduction

Dental crowns have been used for decades in dentistry to restore compromised or restored dentition, and for esthetic improvements. It's no surprise that dental crowns have grown in viability and popularity over the years, with advancemnt in materials and manufacturing techniques.

CAD/CAM has numerous advantages over the traditional manufacturing method, like the number of steps required for the fabrication of a restoration is less compared to traditional methods. Another benefit of CAD/CAM dentistry include the use of contemporary dental materials and data acquisition instruments, which represents a better method of saving impressions, restorations and information that are saved on a computer and constitute an extraordinary communication tool for evaluation. Along with manufacturing time and accuracy, dental CAD/CAM technology is also has its benefits in terms material savings, standardization of the fabrication process, and predictability of the restorations.

ZIRCONIA

Zirconium is a chemical element in the Periodic Table marked with the atomic number of 40 and with the chemical symbol Zr. Zirconia is used by dentists for the fabrication of restorations and has been very useful in posterior areas of the oral cavity were high occlusal masticatory forces are applied and there is limited inter-occlusal space.

Zirconia is a polymorphic material that can exist in different phases depending on the temperature: monoclinic at room temperature, tetragonal above 1170 °C, and cubic beyond 2370 °C.

One of the first systems that used zirconia in dentistry was In-Ceram Zirconia (VITA, Bad Sackingen, Germany), which is a modification of the In-Ceram Alumina but with the addition of partially stabilized zirconia oxide to the composition. More recently, Lava CAD/CAM System (3M ESPE, St. Paul, Minnesouta) was introduced. (Sirinivas,2015) (1)

COPY MILLING

Copy-milling of zirconia is a low cost manual alternative to CAD/CAM fabrication methods. One of the advantages of the copy-milling systems is that individualized components and restorations, such as endodontic posts and cores, can be fabricated.

In contrast to CAD/CAM systems, where the restorations are designed virtually, copy-milling requires a pattern of the restoration to be made followed by manual copy-milling of the restoration from presintered zirconia ceramic. Despite the low cost of the milling machines, the results are comparable to those of standard industrial fabrication, which has been, until now, unavoidable and expensive. (Sapna Rani 2017) (2)

This study compares the accuracy of an optical impression and the conventional impression model technique and the fit of the zirconia restoration manufacturd by CAD CAM technology and the traditional Copy milling method by evaluating the marginal and internal marginal gap.

MARGINAL FIT

Marginal fit of a restoration is considered a very important factor factor for clinical success and longitivity of a restoration. Christensen (1966)(3)reported that clinically acceptable margins gingivally are in a range of 34-119 microns. Dong-Yeon Kim (4)has mentioned that 120 microns should be the limit for clinically acceptable marginal discrepancies.
Poor marginal adaptation can result in alot of complications like-

-dissolution of cement
-increase plaque accumulation
-periodontal inflammation
-secondary caries (Bindl, et al. 2005)(5).
Holmes, et al. (1989)(6) defined absolute marginal discrepancy for the first time in a research study conducted for measuring the marginal fit of restorations. This concept states that the marginal fit should be considered as the angular combination of the vertical and horizontal error.

METHOD

CAD CAM COPING PREPARATION

30 typhodont (NISSAN) specimens were prepared to receive CAD CAM manufactured zirconia crowns following preparation guidelines for a mandibular pre molar (tooth number 35) (Schillinberg)(7):

• 2 mm occlusal reduction (Round end tapered diamond)
• 1.5-1.8 axial reduction (Round end tapered diamond) with 1.3-1.5 heavy chamfer finish line (torpedo diamond).
• All line angles and point angles were rounded to have a smooth rounded outline.

All the preparations were scanned using laser-based intraoral scanner (CEREC Blue Cam, Sirona) after coating the preparation with scanning powder (CEREC Optispray, Sirona) (Fig:1).
Zirconia coping were designed on the SIRONA CAD software (Fig:2). A uniform thickness of 0.4mm for the copings with 10 µm of virtual spacer was pre set in the CEREC software. The digital designed files were sent via Cerec-Connect the CAM nesting software for the milling process.

Fig No: 1(CAD CAD Scanning)

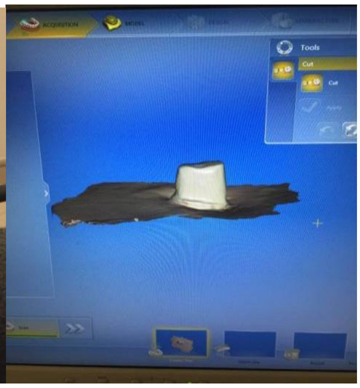


Fig No:2 (CAD/CAM Designing)

For milling of the copings, SIRONA chair side milling machine (CEREC Chairside MC XL machine) (Fig:3) was used for the blank size 65*25 (UPCERA)(Fig:4) . Milled copings were sintered at 1530-1560oF degrees for 8 hours in Ceramill furnace (Fig:5).

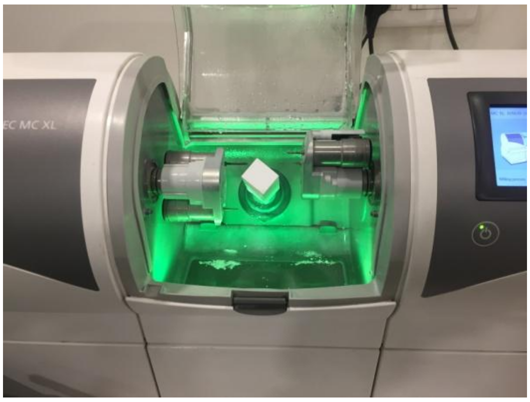


Fig No:3 (Milling)

Fig No:4 (CAD/CAM Zirconia)

Fig No:5 (Amann Gilbach Furnace)

COPY MILLING COPING PREPARATION

Simultaneously thirty single step impressions (Fig:6)of the prepared typhodont teeth using custom tray were obtained with an addition silicone impression material (Aquasil Dentsply) using a automixing gun (3M-ESPE) and poured with modelling wax (Y DENTS) . Each wax die was carefully removed from the impression and acrylised with heat cure clear acrylic (DPI). Die spacer (Ceramill) and separator (Ceramill) was applied to the dies above the cervical end of the preparation to ensure good marginal fit.

Thirty resin patterns for coping zirconia copings are manufactured with Ceramill multi-X manual milling-machine (Amann Girbach)(Fig:7), following manufacturer's instructions using (UPCERA) zirconia blanks (Fig:8) and similarly sintered for 8 hours at the same temperature.

A total of 60 samples were prepared.

	CONVENTIONAL IMPRESSIONS/ COPY MILLING	OPTICAL IMPRESSION/ CAD CAM MILLING
SAMPLES	30	30

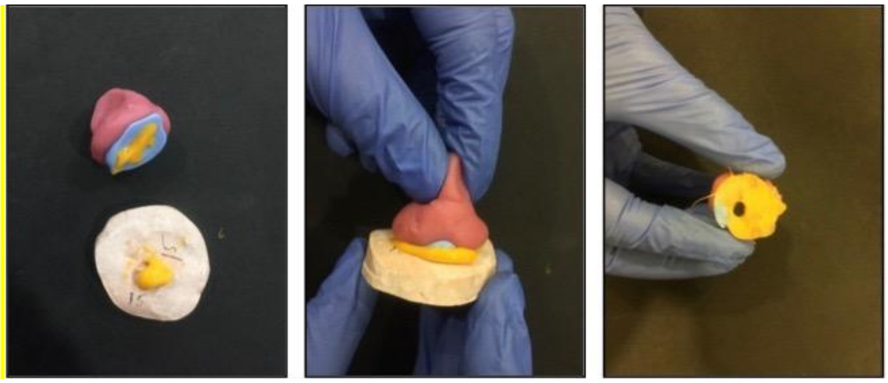


Fig :6 (Putty-light body single step impression)

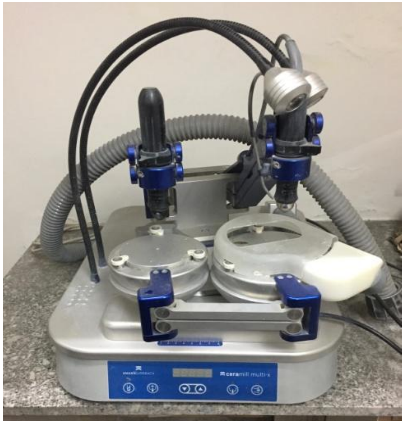


Fig:7 (Copy Milling)

Fig:8 (Copy Milling Zirconia)

LUTING OF COPINGS

All the 60 copings were luted with resin modified Glass ionomer cement (Rely Lute 2, 3M ESPE, Seefeld, Germany) (Fig:9) on the typhodont teeth (Fig:10) and acrylic dies (Fig:11), respectively. The cement was mixed according to the manufactures instruction. The mixed cement is dispensed and it is coated on to the inner surface of the prosthesis and it is cemented and finger pressure is applied for 10 s and the frameworks were subjected to static load of 5 kg for 7 min (8).

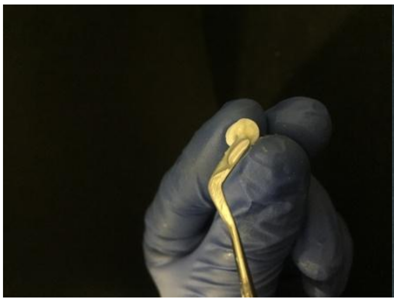


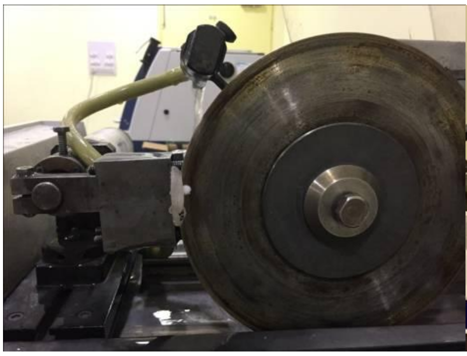
Fig No:9 (Luting)

Fig No:10 (CAD/CAM sample)

Fig No:11(Copy Milling sample)

All crowns that were completely bonded to stone dies and typhodont teeth were embedded with a base for observation. The copings were cut in the middle of buccopalatal direction with the help of a diamond linear preision saw (BUEHLER) (Fig:12).

Four reference points (2 mesial and 2 distal) were measured under microscope (Carl Ziess) (Fig:13) . The vertical gap measurements for marginal gap and internal gaps were made according to criterion proposed by Holmes et al. (6)to measure the marginal fit (Fig:14). The perpendicular measurement from internal surface of the crown to the edge of the tooth finish line was defined as marginal gap. The distance from the inner of the crown to the inner surface of the tooth finish line was defined as internal gap.



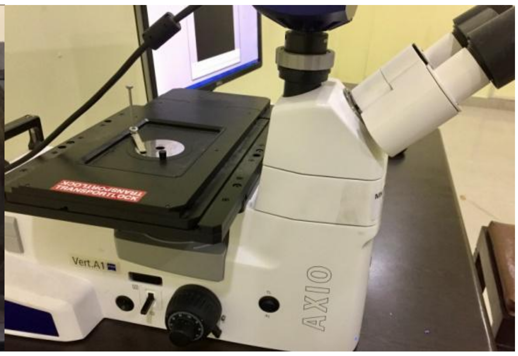


Fig: 12 (Linear Precision Saw) **Fig: 13** (Carl Zeiss Microscope)

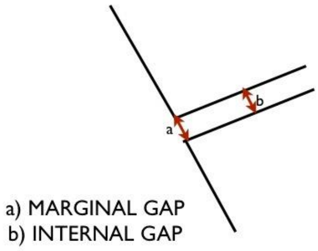


Fig: 14 (Holmes criteria)

Each reference point of every sample was measured three times using a digital optical microscope equipped with a digital camera and magnified by a factor of 100 (Carl Zeiss) (Fig: 15).

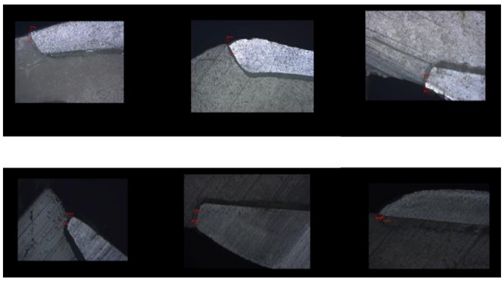


Fig:15 (Microscope Pictures)

All measurements were computed and organized in a Microsoft Excel document for statistical analysis. Descriptive statistics were performed comparing the medians for each group.
A reliability analysis was performed by re-measuring 4 randomized selected images for each sample and performing intra-class correlations to determine any systematic bias in the measurements.

II. Results

All outcomes showed that there was a statistically significant difference between the marginal gap and internal gap of copings prepared by copy milling method which was found to be larger as compared to copings prepared by CAD CAM method.

Table 1: Comparison of marginal gap on mesial side between CAD CAM and COPY MILLING groups

Group	N	Mean	SD	Median	Min.	Max.	't' value	'p' value*
CAD CAM	30	39.67	29.11	29.50	15.3	123.4	7.114	<0.001
COPY MILLING	30	117.00	51.94	90.77	50.4	239.65		

*Unpaired 't 'test

Table:1 shows a comparison of marginal gap on mesial side between CAD CAM and COPY MILLING groups.The average marginal gap was found to be 117.0 µm for copy milled copings whereas CAD CAM showed a marginal gap of 31.21 µm, with a standard deviation of 29.50 µm for CAD CAM and 51.94 µm for copy milling. The maximum and minimum marginal gap for a CAD CAM milled restoration was found to be 123.4 µm and 15.3 µm respectively, whereas for a copy milled restoration it was 239.65 µm and 50.4 µm.

Table 2 : Comparison of marginal gap on distal side between CAD CAM and COPY MILLING groups

Group	N	Mean	SD	Median	Min.	Max.	't' value	'p' value*
CAD CAM	30	31.21	12.69	28.88	13.3	55.67	9.723	<0.001
COPY MILLING	30	117.08	46.68	104.64	54.76	243.76		

*Unpaired 't 'test

Table:2 shows a comparison of marginal gap on distal side between CAD CAM and COPY MILLING groups. For copy milled copings the marginal gap was found to be 117.08 µm and for CAD CAM milled coping the marginal gap was 31.21µm.
Standard deviation for CAD CAM was found to be 12.69 µm and 46.68 µm for copy milling. The maximum and minimum marginal gap for a CAD CAM milled restoration was found to be 55.67 µm and 13.3 µm respectively, whereas for a copy milled restoration it was 243.76 µm and 54.76 µm respectively.

Table 3: Comparison of internal gap on mesial side between CAD CAM and COPY MILLING groups

Group	N	Mean	SD	Median	Min.	Max.	't' value	'p' value*
CAD CAM	30	37.46	25.90	29.01	15.2	121.4	6.419	<0.001
COPY MILLING	30	104.39	50.90	89.26	23.45	243.11		

*Unpaired 't 'test

Table:3 shows a comparison of internal gap on mesial side between CAD CAM and COPY MILLING groups. Internal marginal gap of copy milled coping was found to be 104.39 µm which is larger as compared to marginal gap of CAD CAM milled copings which is 37.46 µm.
Standard deviation for CAD CAM was found to be 25.90 µm and 50.90 µm for copy milling. The maximum and minimum marginal gap for a CAD CAM milled restoration was found to be 121.4 µm and 15.2 µm respectively, whereas for a copy milled restoration it was 243.11 µm and 23.25 µm respectively.

Table 4: Comparison of internal gap on distal side between CAD CAM and COPY MILLING groups

Group	N	Mean	SD	Median	Min.	Max.	't' value	'p' value*
CAD CAM	30	30.98	10.96	28.76	13.4	53.24	8.566	<0.001
COPY MILLING	30	107.84	47.91	99.99	32.5	231.45		

*Unpaired 't 'test

Similarly on comparing the internal gap on distal side between CAD CAM and COPY MILLING groups in Table:4, it was found that for copy milled copings the internal marginal gap was found to be 107.84 µm and for CAD CAM milled coping the marginal gap was 30.98 µm with a standard deviation of 10.98 µm for CAD CAM and 47.84 µm for copy milling. The maximum and minimum marginal gap for a CAD CAM milled restoration was found to be 53.24 µm and 13.4 µm respectively, whereas for a copy milled restoration it was 231.45 µm and 32.5 µm respectively.

III. Discussion

This thesis consisted of in vitro evaluation of the marginal fit of zirconia copy milled and zirconia CAD/CAM milled restorations as zirconia is one of the most common restorative material used for crowns and bridge specially in the posterior region. We also evaluated the accuracy of a conventional impression versus a fully digital scanning technique.

Data from this study revealed statistically significant differences in marginal adaptation when restorations were fabricated with CAD/CAM or manual copy milling. The average marginal gap on mesial side was found to be 117.0 µm for copy milled copings whereas CAD CAM showed a marginal gap of 31.21 µm (Table:1). Similarly for copy milled copings the marginal gap on distal side was found to be 117.08 µm and for CAD CAM milled coping the marginal gap was 37.46 µm (Table: 2).

The results of our thesis were similar to a study conducted by Abdolhamid Alhavaz (2015) (9) to compare the marginal fit of single-tooth mandibular molar zirconia-based copings fabricated by CAD/ CAM process (Cercon; Degudent) and Copy Milling (Dentium). One *in vitro* prepared abutment from one mandibular molar model served as a template for replication of 40 epoxy resin (highly filled) dies, which had been taken by polyvinyl siloxane impression material. Copings were manufactured on epoxy replicas by two processes: the CAD/CAM (Cercon; Degudent) (n = 20) and the Copy-Milling (Dentium) (n = 20) processes. Four measurements were performed for each surface coping (Buccal, Lingual, Mesial, and Distal). Data were analyzed by SPSS 16 statistical software using independent t-test. There was a significant difference in the marginal gap values between CAD/CAM and Copy-Milling groups ($P < 0.001$). The mean value of the marginal gap (SD) for CAD/CAM Copings (56.87 μm) was significantly less than that of Copy-Milling (136.12 μm) ($P < 0.001$).These results can be compared to the results from our study.

Similarly in another study done by Baig (2010)(10), impressions were made of premolar dies prepared with shoulders or chamfers with a 20-degree total occlusal convergence (n=30). Type IV stone dies were then distributed into test groups (n=10) for the fabrication of Cercon Y-TZP, IPS Empress II, and complete metal (noble type IV alloy) crowns. The crowns were then subjected to marginal gap and overhang evaluation at 6 designated margin locations using a computerized digital image analysis system. The data were calculated and statistically analyzed. The overall mean (SD) marginal gap at the marginal opening for the crowns was 42.2 μm for Cercon (zirconia) which very close to the results obtained in our study. For IPS Empress II in was 36.6 μm and 37.1 μm for complete metal (control). The ANOVA revealed significant effects by material and no significant effects by marginal configuration for marginal gap.

For internal gap measurement in our study, results were similar to marginal gap. On the mesial side the gap for copy milled coping was found to be 104.39 μm which is larger as compared to CAD CAM milled copings which is 37.46 μm (Table:3).

Similarly on comparing the internal gap on distal side between CAD CAM and COPY MILLING groups it was found that for copy milled copings the marginal gap was found to be 107.84 μm and for CAD CAM milled coping the marginal gap was 30.98 μm (Table:4).

These results were similar to a study done by Beurer(2008)(11). He evaluated the effects of different preparation angles on the precision of fit of zirconia crown frameworks. Dies were fabricated with three different preparation angles: 4, 8, and 12 degrees total taper. Ten copings were fabricated for each angle by a laboratory and a milling-center CAD/CAM system. After cementation, cross-sections were obtained and cement gaps were measured.

For copings fabricated by the laboratory CAD/CAM- system, the mean (SD) marginal openings were 37.5 (37.0) μm in the 4-degree group, 42.3 (44.4) μm in the 8-degree group, and 36.8 (30.9) μm in the 12-degree group. For copings fabricated by the milling center system, the mean (SD) marginal openings were 45.5 (35.7) μm in the 4-degree group, 36.6 (28.9) μm in the 8-degree group, and 40.3 (37.2) μm in the 12-degree group. The measurements include the internal fit of the restorations. The results for CAD CAM restoration fit can be compared to our thesis (internal gap for CAD CAM mesial 37.46 um and 30.98 um).

Due to lack of literature avaliable on differnce in the marginal and internal fit of CAD CAM and copy milled restorations in relation to mesial and distal sides, the possible reasons for the results of our study can be following :

1. IMPRESSION INACCURACIES

The copy milled restorations are prepared on dies poured in conventional putty light body impressions which can be a reason for the difference in the fit as impressions can lead to alot of inaccuracies in the final model; also the fact that CAD/CAM restorations were fabricated through the complete digital Cerec workflow, whereas copy milling is a manual preparation of the copings whose accuracy may vary due to human error.

The impression procedure used for copy milled copings must reproduce accurately the oral structure details to allow the manufacturing of accurate stone casts.The fitness precision of a prosthetic device is a key factor that contributes to long-term prosthetic treatment success.(12)

2. MANUFACTURING PROCEDURE

Another reason why copy milled zirconia restoration showed larger margial gap as compared to CAD CAM can be that manual copy milling is based on pantographic principle that is used to duplicate keys, to copy or enlarge paintings and for engraving. It is a precise technique with a well-known working process: after making a model, an oversized duplicate is made in a block of raw zircon, using burs and sculpturing technique with a pantograph named Zirkograph. Then it undergoes an adapted heat treatment or sintering returning it to the exact dimension, all the while endowing it with exceptional physicochemical properties.The chances of inaccuraies during this entire manual procedures are more as compared to a digital workflow.(Moussaoui, H.2018) (13)

On the other hand, restorations designed on the CAD software require a direct optical scan of the prepared tooth. This eliminates the chances of inaccuaries which are incorporated during the impression making and pouring procedure and designing as human and material errors can be eliminated.

3.SPACER THICKNESS

The restoration parameters during the designing of the restoration in CAD can also influence the marginal adaptation. The virtual configuration of the die spacer between the tooth and the restorations is essential for the accuracy of the marginal adaptation. Campbell 1990(14) stated that the die spacer should be uniform and facilitate seating. The marginal configuration of the restoration and the dimensions of the space before cementation will affect the flow of the luting agent and can therefore negatively influence the seating of the restoration. Several studies have looked at the effect of die spacer on the retention and physical properties of crowns. The difference of fit between CAD/CAM restorations is directly related to the gap parameters from the computer design and also related to the intrinsic properties of the CAD/CAM system. Therefore it has to be kept uniform.

In this thesis, a default internal parameter of 50 microns for crown fabrication was proposed by the CEREC software. It was similar to the study byNakamura, et al (2003) (15), in which the marginal and internal fit of all ceramic crowns was examined using three different luting space settings (10, 30 and 50 microns); marginal gaps of a luting space of 10 microns tend to show greater marginal gaps than when it was set at 30 or 50 microns; crowns with a luting space of 30 and 50 microns showed a good fit regardless of the occlusal convergence angle of the abutments. There similarly for our study, the spacer was pre set to 50 microns for the copings.

This is another reason why the zirconia copings prepared by optical scan have a better fit as in the copings prepared by Copy milling, the die spacer and and separator are applied manually. This can also lead to a non uniform thickness of the spacer around the coping which causes difference in the marginal and internal gap.

4. FINISH LINES

In this study an axial reduction with heavy chamfer finish line of about 1.3-1.5 mm was chosen because according to most studies there is no significant difference in the marginal gap when a chamfer and shoulder margin configurations are used. For example in the study done by Baig, et al. (2010) (16) impressions were made of premolar dies prepared with shoulders or chamfers with a 20-degree total occlusal convergence.Cercon Y-TZP, IPS Empress II, and complete metal (noble type IV alloy) crowns were prepared and cemented. No significant differences were found in marginal overhang among the 3 material groups.

5. ZIRCONIA

In this thesis the materials used for both the manufacturing technique is uniform (UPCERA Zirconia) and therefore has no relation with the difference in marginal fit.

Studies have proven that there is no change in the fracture resistance of zirconia despite different manufacturing procedures. Partiyan et al (17) compared the fracture resistance of three-unit zirconia fixed partial denture with modified framework fabricated using the two techniques: CAD/CAM technology and manual copy milling. The result of the study indicated that the type of milling technique has no additional impact on the fracture resistance of the restorations .

This did not affect the results of our study as for both the milling procedures the shrikage factor was already incoorporated in the system as per the manufacturers instructions and same Ceramill multi-X Hand milling machine (Amman Gilbach) furnace was used for sintering.

6. LUTING CEMENT

In this study all the restorations were cemented to each preparation adding another possible factor that could affect the marginal adaptation of the restorations. As stated in previous studies (14) when restorations are cemented the cement space should be uniform and facilitate seating without compromising the marginal adaptation (May, et al. 1998)18. The specimens could potentially loose the precision of the primary marginal adaptation due to the influence of factors like cement type, viscosity, and cementation technique.

For CAD-CAM copings, a default uniform luting cement space of 50 microns was set. However it is difficult to obtain a uniform spacer on poured dies for copy milled restorations as the spacer is applied manually. This can lead to a larger marginal gap.

To eliminate any discrepencies related to the cement, similar cement (Relyx Lute 2, 3M ESPE) was used to lute all 60 samples.

The approach employed in the present study was to somehow recreate a more realistic environment to evaluate restorations made by clinicians in a daily basis using different samples. Therefore the samples were cemented with finger pressure for 10 s and then subjected to static load of 5 kg for 7 min(8). In human, mean swallowing and chewing force is 40 N and maximum chewing force at posterior teeth varies 200 to 540 N (5).

IV. Conclusion

The study can be concluded by saying that the results obtained for the model and model-less technique showed a significant differences. During the fabrication process dental laboratories use stone or printed models as a traditional method to check proximal contacts, occlusal contacts and contours. The digital workflow and fabrication process is very standardized and predictable; most digital design programs can be learned in days and most design softwares have tools that facilitate the design process (Fasbinder, 2002)(19). When comparing digital versus traditional impressions the time required to take impressions can be reduced because rescans of the missing areas can be acquired in 1 to 2 minutes in comparison to retaking traditional impressions with rubber base materials which usually takes around 5-7 minutes for each impression using polyvinyl siloxane impression materials (Lee, et al. 2013)20.

In todays era of digitilisation, there is a need to shift from the conventional dentistry to technologies like CAD CAM and 3D printing which helps the dentist and the patient save time, money and makes the procedure more comfortable, accurate and hassle free.

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Dr Tanvi Thaper. ""Comparitive Study of Marginal Fit of Zirconia Copings Prepared With Model-Less And Model Technique- An In Vitro Study"." IOSR Journal of Dental and Medical Sciences (IOSR-JDMS), Vol. 18, no. 02, 2019, pp. 49-57.