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Marginal Gap Analysis of 4-axis and 5-axis Milled Crown Copings

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Abstract – *To compare the marginal fit accuracy of zirconia crown copings milled with 4-axis and 5-axis milling machines. Ten zirconia crown copings were milled on 4-axis milling machine and 5-axis milling machine by taking a single die. The crown copings were seated on the master die and high resolution photographs were made of the marginal area of crown copings by using GOM INSPECT V8. The marginal openings were then measured using a calibrated digital software program. The marginal gap was 4-axis milled crown copings: 0.05-0.10mm; 5-axis milled crown copings: 0.06-0.09mm. There was a statistically significant difference between the 4-axis milled crown copings and 5-axis milled crown copings. There was negligible difference between the crown copings manufactured by the same type of milling machine. The external marginal fit is nearly same for both type of crown copings. From comparison of marginal fit of crown copings milled on 4-axis and 5-axis milling machine, it was observed that the marginal gap for both 4-axis and 5-axis milled crown copings demonstrated within acceptable discrepancy range but the 5-axis milled crown copings resulted in smaller vertical marginal gaps than 4-axis milled crown copings.*

Key words: 4-Axis Milling Machines, 5-Axis Milling Machines

1. INTRODUCTION

CAD/CAM has become an increasingly popular part of dentistry over the past 25 years. With the continuous development of computerized engineering technology, digitized medical treatment modalities are becoming an integral approach for prosthodontics, orthodontics, and oral and maxillofacial surgery. CAD/CAM dentistry is the field of dentistry using CAD/CAM for improving the design and creation of dental restorations, especially dental prostheses and orthodontic appliances. The advancements in CAD/CAM dentistry have restored the patient's data into digital form for better-fitting, more durability and more natural looking than previously machined restorations.

Prosthodontics is defined as the dental specialty pertaining to the diagnosis, treatment planning, rehabilitation and maintenance of the oral function, comfort, appearance, and health of patients with clinical conditions associated with missing or deficient teeth and maxillofacial tissues using a biocompatible substitute, which is most commonly prosthesis. In order for prosthesis to fulfill its function, it should be durable, aesthetic, accurate, and comfortable. These requirements should be accomplished by any prosthesis fabrication method.

1.1 Crown Fabrication Using CAD/CAM

A tooth that has been structurally damaged by decay or trauma sometimes needs to be crowned or "capped" so that it can look good and function properly again. A crown is a durable covering that is custom-made to fit over the entire tooth from the gum line up. Crown fabrication traditionally takes place in a dental laboratory. But these days, there is a much more convenient alternative as same-day crowns made in the dental office.

CAD/CAM makes it possible to fabricate laboratory-grade crowns and other dental restorations in very short time. The process of crowning a tooth starts out the same way, whether it is a same-day crown or traditional crown that is with preparation of the tooth. This involves removing any decay that's present, and shaping the tooth with a dental drill so that it will fit perfectly inside the crown. If anyone getting a traditional crown, the next step would be to take an impression of teeth with a putty-like material, and use it to construct a model on which to create the crown. With a same-day crown, the teeth are simply given a light dusting of reflective powder and then a small scanning wand attached to a computer is used to take digital pictures inside mouth. The computer will generate a highly accurate 3D model of the teeth.

With the help of the CAD/CAM software, crown will be designed in some time. The software can even be used to create a mirror-image twin of the same tooth on the other side of your mouth, for the most natural-looking result possible. Then a block of dental ceramic material is chosen in the shade that most closely matches your own teeth. The computer's digital design is transmitted to a milling machine that carves the crown from the ceramic block in about five minutes. Once the crown's fit has been verified, and any necessary aesthetic enhancements have been made to the crown's surface, the crown will be bonded to your tooth.

1.2 Marginal gap in crown

The most coronal position of untouched tooth structure is referred to as the Marginal Gap. This marginal gap will be the future continual line of tooth-to-restoration contact, and should be a smooth, well-defined delineation so that the restoration can be properly adapted and not allow for any openings visible to the naked eye. An acceptable distance

from tooth margin to restoration margin is anywhere from 0.07-0.08mm.

The tooth-to-restoration marginal gap is an unsightly thing to have exposed on the visible surface of a tooth when the tooth exists in the esthetic zone. In these areas, the dentist would like to place the margin towards the root tip of the tooth, even below the gum line. While there is no issue, with placing the margin at the gum line, problems may arise when placing the margin too subgingival. There might be issues in terms of capturing the marginal gap in an impression to make the stone model of the prepared tooth and also issue of biologic width. Biologic width is the mandatory distance to be left between the height of the alveolar bone and the margin of the restoration. In situations where the margin cannot be placed towards the root tip of the tooth to provide proper retention of the prosthetic crown on the prepared tooth structure, the tooth or teeth involved should undergo a crown lengthening procedure.

The minimization of marginal gaps in crown and fixed partial denture is an important goal in prosthodontics. Smaller marginal gaps produce less gingival irritation and cement washout which improving the clinical outcome and longevity of the restoration. The absolute value of the vertical marginal gap deemed that clinically acceptable has been debated in the literature with proposed values ranging from 0.07mm to 0.08 mm. A definitive value has not been identified as the benchmark for clinical acceptability, because clinical identification and quantification of the gap can be difficult depending on location and instrumentation used. Multiple techniques have been used for measuring the marginal gap values of partial and full coverage restorations. This emphasizes the need for fabrication techniques that can produce restorations with minimal vertical marginal gaps in a repeatable fashion. The vertical marginal gaps of full cast restorations and porcelain shoulders have been reported to be statistically similar and are the current benchmark for emerging technologies.

2. METHODOLOGY

To perform this work, some processes were applied like impression taking, jaw making, scanning, fabrication of crown copings and scanning of crown copings for measurement. The above processes are given below.

2.1 Impression

The first step was to take impression of the tooth whose crown to be fabricated. Impression of the second premolar of lower jaw was taken by manual method with the help of custom tray.

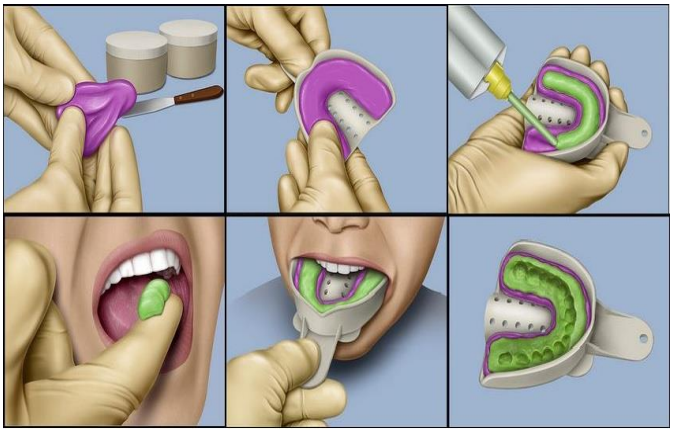

Fig - 1: Manual Impression Process

2.2 Jaw Making

After taking impression with stock tray, lower jaw was fabricated with the manual method. Dental stone and gypsum were used for making the jaw as shown in figure 2.

Fig - 2: Lower Jaw

2.3 Scanning

The impression was scanned with the optical scanner to digitize the impression for fabrication of the crown copings with milling machine. After scanning the digital data was sent to 4-axis and 5 axis milling machine to fabricate crown copings.

2.4 Fabrication of Crown Copings

Ten crown copings were fabricated with the help of 4-axis milling machine and 5-axis milling machine. 4-axis milling machine used was VHF K4 and 5-axis milling machine used was VHF K5 as shown in figure 3 and 4

Fig - 3: 4-axis milling machine

Fig – 4: 5-axis milling machine

2.5 Scanning of Crown Copings for Measurement

After fabrication of crown copings, the GOM INSPECT scanner was used to scan the jaw and the zirconia crown copings in 3D separately. For scanning, firstly some reference points were marked on the jaw so that after scanning it helped to position the scanned image.

Fig – 5: Scanning of jaw and crown copings

2.6 Measurement

After scanning the jaw and the crown copings separately, overlapping of crown copings on the second premolar was done with the GOM software and marginal fit was measured by taking four reference points.

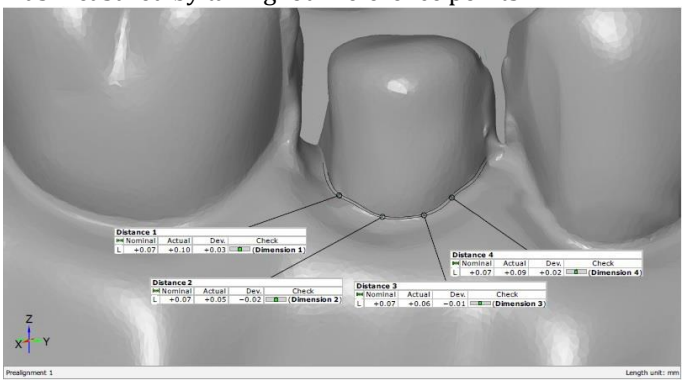

Fig – 6: Measurement of marginal fit

3. EXPERIMENTATION

Impression was taken to fabricate the crown copings. After taking the impression, total 10 crown copings were fabricated, five with 4-axis milling machine and five with 5-axis milling machine in EPICA LAB, New Delhi. After fabrication of crown copings, the impression jaw and the crown copings were scanned using GOM INSPECT in PEC University, Chandigarh. Firstly, some reference points were marked on the jaw as shown in the figure 7. These reference points were helped for arranging the right position of images after the 3D scanning.

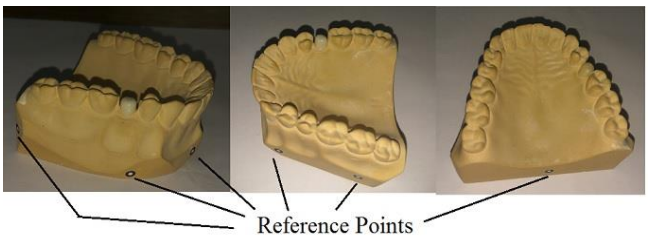

Fig – 7: Reference points for scanning

After marking of reference points, scanning was done using GOM INSPECT. As scanning was done, the digital data is sent to the computer and with the help of GOM software we measure the marginal gap of crown copings. After measuring marginal gap, marginal gap of 4-axis milled crown copings was compared with the marginal gap of 5-axis milled crown copings.

4. RESULTS

4-axis milled crown copings and 5-axis milled crown copings were scanned by GOM INSPECT separatly. Marginal gap of crown copings is measured by the GOM INSPECT V8 scanner and the software for comparison of marginal fit of crown for both type of crown copings.

4.1 4-AXIS Milled Crown Copings

GOM INSPECT V8, scanned the die and 4-axis milled crown copings in 3D data and the soft copy was generated in computer and the image was look like as figure 8. The outside view of overlapped 4-axis milled crown coping is shown in figure 8.

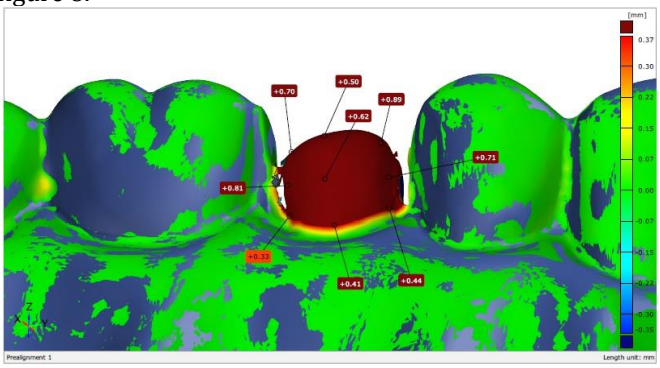

Fig – 8: 4-axis milled crown copy overlap on die outside view

This is the pictures generated by the GOM INSPECT scanner. For measuring the marginal gap of zirconia crown copings, GOM INSPECT software was used and the 3D images were generated and by taking four reference points the marginal gap was measured with the help of software. A picture of measurement of marginal gap is shown in figure 9.

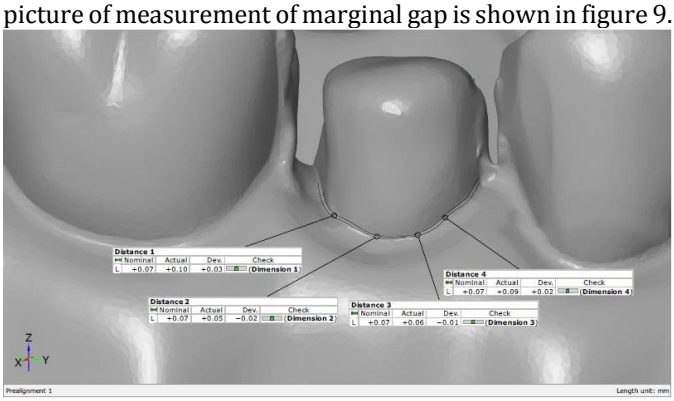

Fig – 9: Marginal gap of 4-axis milled crown coping

The marginal gap for all five 4-axis milled crown copings was given in the table 1. There are three measurements nominal, actual and the deviation. Nominal value is the standard value which is satisfactory value for the marginal fit whereas actual value is that value which is calculated by software. Deviation is the distance between nominal value and the actual value.

Table – 1: Marginal gap of 4-axis milled crown copings

Crown No	P 1			P 2			P 3			P 4		
	N	A	D	N	A	D	N	A	D	N	A	D
1	0.07	0.10	0.03	0.07	0.05	-0.02	0.07	0.06	-0.01	0.07	0.09	0.02
2	0.07	0.09	0.02	0.07	0.06	-0.01	0.07	0.05	-0.02	0.07	0.07	0.00
3	0.07	0.07	0.00	0.07	0.08	0.01	0.07	0.06	-0.01	0.07	0.08	0.01
4	0.07	0.08	0.01	0.07	0.07	0.00	0.07	0.09	0.02	0.07	0.06	-0.01
5	0.07	0.06	-0.01	0.07	0.08	0.01	0.07	0.08	0.01	0.07	0.05	-0.02

N—Nominal, A—Actual, D-- Deviation

The following figure 10 shows the marginal fit of the crown copings milled with 4-axis milling machine at 4 different reference points. All the crown copings are shown by 5 different colours and on the y-axis the value of marginal fit is given. Crown copings are denoted by C and reference points are denoted by P.

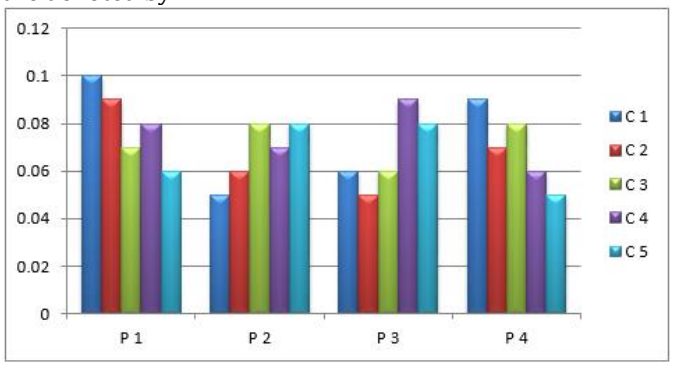

Fig – 10: Marginal fit of crown copings fabricated with 4-axis milling machine

The following figure 11 shows the deviation between the nominal and actual marginal fit for the crown copings milled on 4-axis milling machine. The deviation for 4-axis milled crown copings was varied between 0.03 to -0.02.

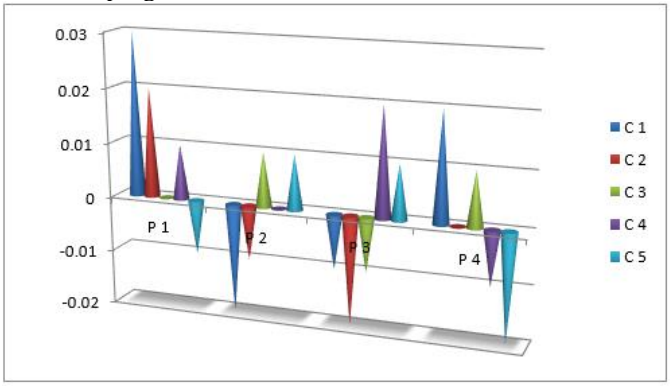

Fig – 11: Deviation for 4-axis milled crown copings

4.2 5-AXIS Milled Crown Copings

Crown copings milled with 5-axis milling machine and the die were also scanned with GOM INSPECT and 3D image is produced with the help of GOM software. The outside view of overlapped 5-axis milled crown coping is shown in figure 12.

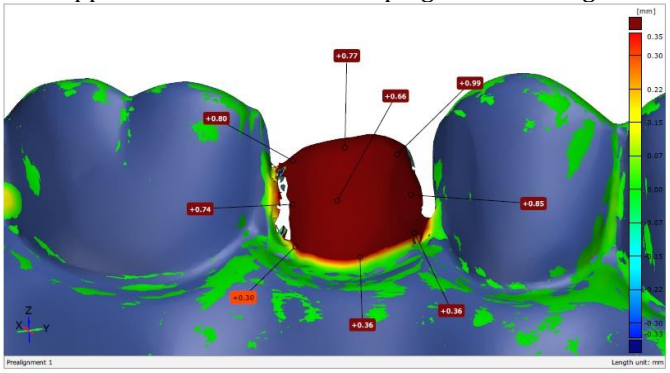

Fig – 12: 5-axis milled crown copy overlap on die outside view

After scanning, the 3D image is produced and for measuring the marginal gap, four reference points on the marginal gap area were taken as shown in the figure 13 and the marginal gap is measured with GOM software.

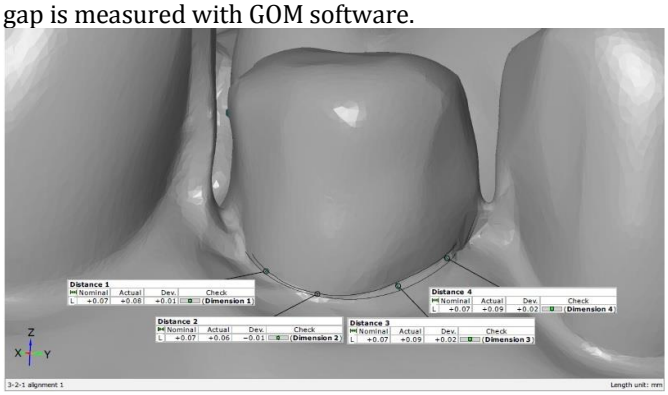

Fig – 13: Marginal gap of 5-axis milled crown coping

The marginal gap for all five 5-axis milled crown copings was given in the table 2. There are three measurements nominal, actual and the deviation. Nominal value is the standard value which is satisfactory value for the marginal fit whereas actual value is that value which is calculated by software. Deviation is the distance between nominal value and the actual value.

Crown

Table – 2: Marginal gap for 5-axis milled crown copings

Crown No	P 1			P 2			P 3			P 4		
	N	A	D	N	A	D	N	A	D	N	A	D
1	0.07	0.08	0.01	0.07	0.06	-0.01	0.07	0.09	0.02	0.07	0.09	0.02
2	0.07	0.07	0.00	0.07	0.06	-0.01	0.07	0.08	0.01	0.07	0.06	-0.01
3	0.07	0.06	-0.01	0.07	0.07	0.00	0.07	0.06	-0.01	0.07	0.07	0.00
4	0.07	0.05	-0.02	0.07	0.08	0.01	0.07	0.07	0.00	0.07	0.08	0.01
5	0.07	0.06	-0.01	0.07	0.05	-0.02	0.07	0.06	-0.01	0.07	0.06	-0.01

N—Nominal, A—Actual, D-- Deviation

Figure 14 shows the marginal fit of five crown copings denoted by C milled with 5-axis milling machine at 4 different reference points denoted by P. The crown copings are shown by 5 colours and value of marginal fit is mentioned on y-axis.

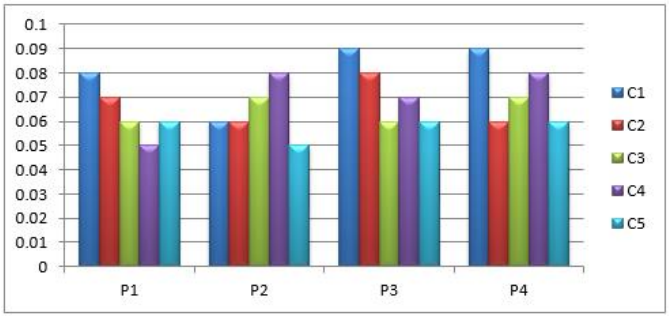

Fig – 14: Marginal Gap of crown copings fabricated with 5-axis milling machine.

The following figure 15 shows the deviation between the nominal and actual marginal fit for the crown copings milled on 5-axis milling machine. The deviation between the nominal and actual marginal fit for the crown copings milled on 5-axis milling machine is shown by the following graph. The maximum and the minimum deviation is vary in between +0.02 to -0.02.

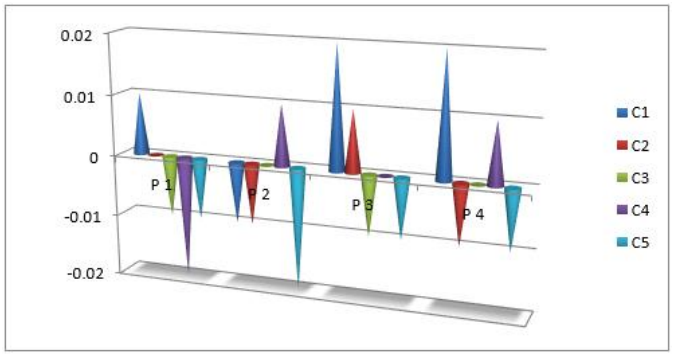

Fig – 15: Deviation for 5-axis milled crowns

4.3 Comparison

Comparison of marginal gap of zirconia crown copings milled with 4-axis and 5-axis milling machine was carried out. The zirconia crown copings were fabricated with 4-axis and 5-axis milling machines and scanned with the GOM INSPECT in 3D. With the help of GOM software, the marginal gap of crown copings was measured.

By taking four reference points for each crown copings, the marginal gap was measured. After measuring the marginal gap for each crown copings, marginal gap was compared with nominal gap and deviation was calculated. The graph 16 shows the comparison of deviation of crown copings milled with 4-axis and 5-axis milling machines.

There are 3 different graphs showing the marginal fits of the crown copings, another show the deviation between the nominal size and the actual size of the marginal fit for both type of milled crown copings and the last one gives a clear view of comparison of marginal fit for both 4-axis and 5-axis milled crown copings. It was revealed that the marginal fit for the 4-axis milled crown copings was varying more compared to 5-axis milled crown copings. The deviation for 4-axis milled crown copings was varied from 0.05 to 0.10mm whereas it varied from 0.06 to 0.09mm for 5-axis milling machine.

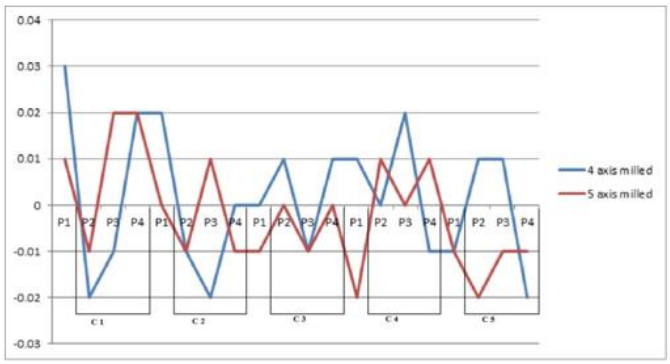

Fig – 16: Comparison of deviation for crown copings milled with 4-axis and 5-axis milling machines

5. CONCLUSION

It was revealed that the marginal fit for the 4-axis milled crown copings was varying more compared to 5-axis milled crown copings. The deviation for 4-axis milled crown

copings was varied from 0.05 to 0.10mm whereas it varied from 0.06 to 0.09mm for 5-axis milling machine.

In this work, CAD/CAM has been successfully implemented in prosthodontics as theme. As the initial cost of setup of lab of crown fabrication with CAD/CAM is high but the overall cost of crown fabrication is very low using CAD/CAM technology. Time consumption is very less and the accuracy is very high. Therefore, this work is towards to provide the product to patients at a very satisfactory price in very less time with more comfort.

As the marginal gap with 5-axis milling machine is in the nominal range, the cement washout and the gingival irritation will be negligible and the life of crown increases.

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