Comparison of Marginal Fit of Zirconia Copyings Milled with 4-Axis and 5-Axis Milling Machines

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Abstract— Purpose: To compare the marginal fit accuracy of zirconia crown copings milled with 4-axis and 5-axis milling machines. Materials and Methods: 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. Results: 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. Conclusions: 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. Achievement: 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

I. INTRODUCTION

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 0.07mmb 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. 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.

Computer-aided design/computer aided manufacturing (CAD/CAM) is increasingly being used by dental laboratories to fabricate dental prostheses. The implementation of this digital method has decreased manufacturing costs by reducing technician time and material costs while increasing productivity. More recently, the use of intraoral digital scanners to create virtual impressions have allowed dentists to eliminate the use of impression materials, identify preparation margins, evaluate interocclusal space, and design prostheses. Francois Duret envisioned the use of digital technology in dentistry in 1973; specifically the use of an intraoral optical image to create a definitive prosthesis.

All-ceramic restorations have increased in popularity due to the increasing demand for improved esthetics and natural-looking teeth, and metal-free biocompatible options are preferred. The optimal marginal fit of a dental prosthesis is essential for its long-term success in the oral cavity. There are many all ceramic systems on the market today. Zirconium dioxide (ZrO_2), sometimes known as zirconia, is a white crystalline oxide of zirconium. Its most naturally occurring form, with a monoclinic crystalline structure, is the mineral baddeleyite.

The marginal fit of metal-ceramic crowns has been the focus of various investigations. An excellent marginal adaptation will minimize the plaque accumulation and reduce the chance for recurrent caries and periodontal disease. A good marginal fit seems to be one of the most important technical factors for the long-term success of metal-ceramic crowns.

II. MATERIALS AND METHODS

Firstly, **t**he impression of the selected premolar was prepared with the gypsum and the dental stone. Each master die was scanned using strip light projection and CAD/CAM software. The crown copings were designed with the CAD software. Using VHF K4 and VHF K5 milling machine crown copings were fabricated using zirconia. Marginal fit was measured at 4 different points in 3 parts i.e. nominal, actual and deviation.

Metal ceramics are still the most widely used material for fabricating complete coverage crowns and fixed partial dentures. The traditional technique for fabricating the metal substructure is the lost-wax technique and using various metal alloys for casting. Recently a new CAD/CAM 4 axis and 5 axis milling machines for the fabrication of metal copings for metal-ceramic crowns has been introduced (Figs. 1 and 2).

III. LITERATURE REVIEW

Philip L. Tan and David G. Gratton compared the vertical marginal gaps of CAD/CAM titanium and conventional cast restorations in 2007 and found out that there was a statistically significant difference between the WAX/CAST group and the remaining groups but the WAX/CAST technique resulted in smaller vertical marginal gaps than either CAD/CAM or WAX/CAM.

Balaji N Rajan, S. Jayaraman, B. kandhasamy evaluate the marginal fit and internal adaptation of Zirconia copings fabricated by two CAD-CAM systems and concluded that both the CEREC-In Lab MC XL and CERAMILL

copings demonstrated internal adaptation and marginal fit within acceptable discrepancy range. When corroborating both the internal adaptation and marginal fit, CEREC-In Lab MC XL was found to be better than CERAMILL.

However, no clinical data on the marginal and internal fit of metal-ceramic crowns produced by this method is available yet. Therefore, to evaluate the marginal fit of metal-ceramic crowns fabricated with 4-axis milling machine and 5-axis milling machine, GOM INSPECT V8 is used.

In order to evaluate and compare the gap dimensions between crowns fabricated with 4-axis and 5-axis milling machine and the stone die, scanning of die and the crown were carried out by using GOM INSPECT V8 scanner and software separately. Further, scanning data is imported in the software and the overlapping of crown copings was done on the die. Then 4 points were taken as reference points and the gap between the die and crown copings were measured.

Fig. 1: 4-axis milling machine VHF K4

Fig. 2: 5-axis milling machine VHF K5

Crowns copings fabricated with milling machines from zirconia yielded a comparable fit. After milling, a high resolution picture is taken by GOM INSPECT V8 scanner and then with help of a CAD software, marginal fit of the crown copings are measured. Mean marginal fit of crown copings was in the range of 0.07-0.10mm.

IV. 4-AXIS MILLED CROWN COPINGS

The below picture is taken from the GOM INSPECT V8 scanner, there are 4 reference points on which the marginal fit is measured. The marginal fits are measured with the help of CAD software and the reading is mentioned on the picture.

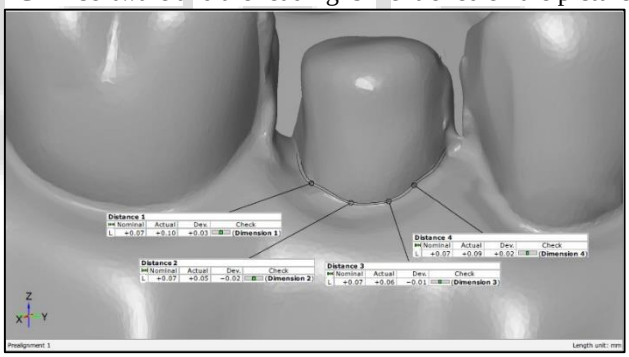

Fig. 3: 4-Axis radius curve distance

Crown No	P 1			P 2			P 3			P 4		
	Nom.	Actual	Dev.	Nom.	Actual	Dev.	Nom.	Actual	Dev.	Nom.	Actual	Dev.
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

Table 1: 4-axis marginal fit

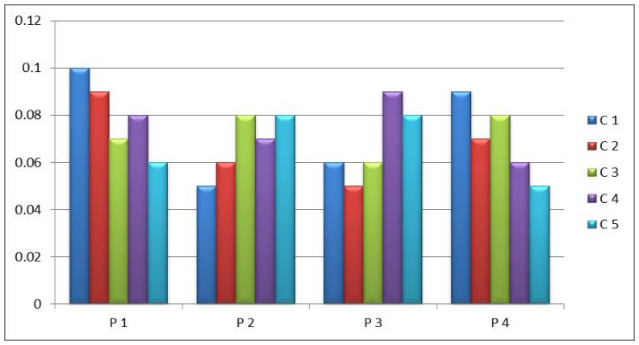

Fig. 4: Graph for marginal fit of crown copings manufactured with 4-axis milling machine.

The graph 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 colors 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.

The following graph shows the deviation between the nominal and actual marginal fit for the crown copings milled on 4-axis milling machine.

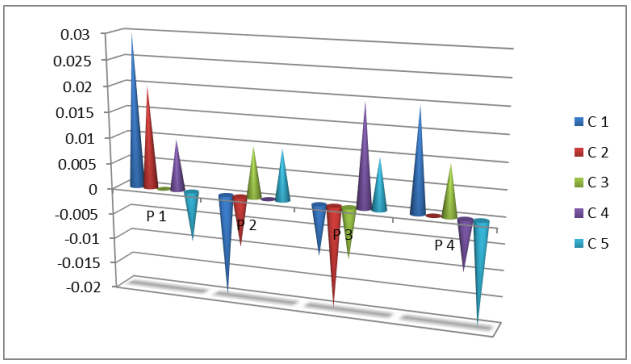

Fig. 5: Graph of deviation for 4-axis milled crowns

V. 5-AXIS MILLED CROWN COPINGS

The below picture is taken from the GOM INSPECT V8 scanner and there are 4 reference points on which the marginal fit is measured. The marginal fits are measured with the help of CAD software and the reading is mentioned on the picture.

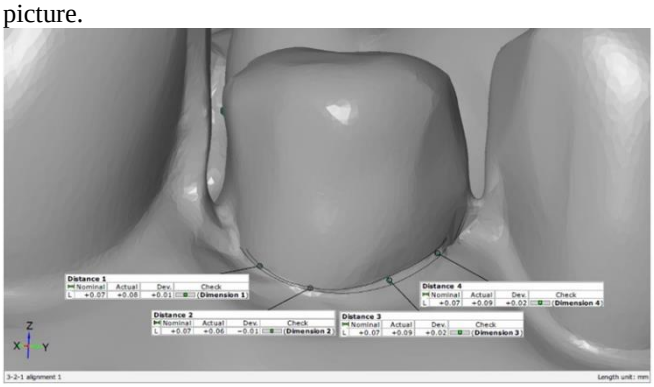

Fig. 6: 5-axis cap radius outside

The following table is of marginal fits and the deviation of crown copings milled with the 5-axis milling machine at 4 different reference points. The marginal fit value varies from 0.05 to 0.09mm.

Crown No	P 1			P 2			P 3			P 4		
	Nom.	Actual	Dev.	Nom.	Actual	Dev.	Nom.	Actual	Dev.	Nom.	Actual	Dev.
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

Table 2: 5-axis marginal fit

The graph shows the marginal fit of the crown copings milled with 5-axis milling machine at 4 different reference points. All the crown copings are shown by 5 different colors and on the y-axis the value of marginal fit is given.

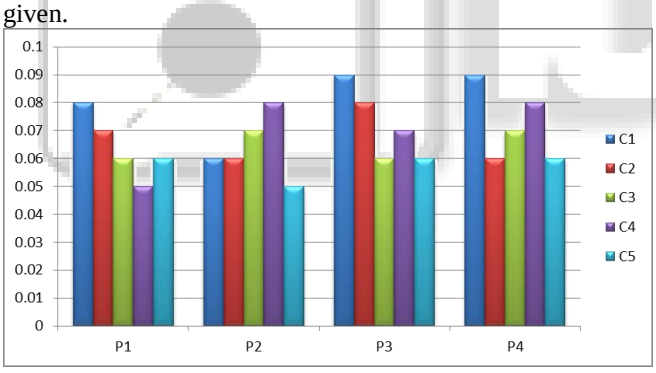

Fig. 7: Graph for marginal fit of crown copings manufactured with 5-axis milling machine.

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.

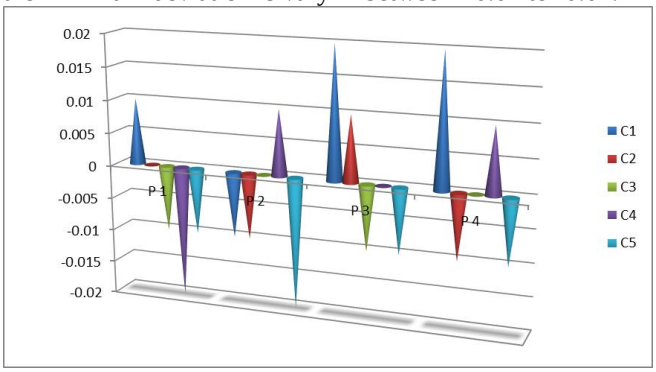

Fig. 8: Graph of deviation for 5-axis milled crowns.

VI. RESULTS AND DISCUSSION

After manufacturing crown coping, there are many methods to measure the marginal fit like by using electron microscope, image microscope. But we used GOM INSPECT V8 scanner and software. In first process, scanning of die is done and in second process scanning of all the crown copings is done. Then with the help of GOM software overlapping of die and the crown coping is done and we get the following results.

The following chart shows the deviation between nominal marginal gap and the actual marginal gap. The nominal gap is 0.07mm. We took 4 reference points for 5 crown copings and then measure marginal gap of them, after that we compare the results with nominal gap and find out the deviation. Following graphs show the deviation for crown copings fabricated 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 the 4-axis and 5-axis milled crown copings. It is easily be found out that the marginal fit for the 4-axis is varying more in comparison with 5-axis milling machine. The deviation for 4-axis is vary from 0.05 to 0.10mm whereas it varies from 0.05 to 0.09mm for 5-axis milling machine.

There were two graphs which indicated the deviation between the nominal and the actual marginal fit. One is for 4-axis milled crown coping whereas another is for 5-axis milled crown copings. Here, we can analyze that the deviation for the 4-axis milled crown copings is more than the deviation for crown copings milled with 5-axis crown copings.

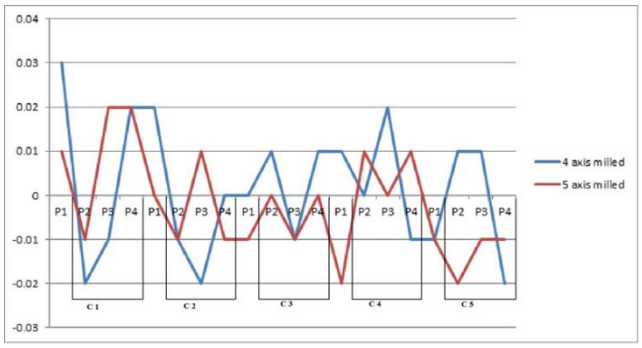

Fig. 9: Comparison of deviation of crown copings milled with 4-axis and 5-axis milling machine.

The above graph compares the deviation between nominal and actual marginal fit of 4-axis milled crown copings and 5-axis milled crown copings. It is analyzed that the deviation for the 4-axis milled crown copings are more than 5-axis milled crown copings.

VII. Conclusion and Remarks

It is concluded from the measurement of the marginal fit of both type of crown copings that the accuracy of crown copings milled with 5-axis milling machine is more than the 4-axis milling machine because the deviation for the 4-axis milled crown copings is less whereas for 4-axis milled copings it is larger. It is also concluded that the nominal fit for 5-axis milling machine is more close to the actual marginal fit.

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