ISSN No:-2456-2165

Comparative Evaluation of Marginal Fit and Internal Adaptation of G-Cam, Zirconia and PFM Crowns Fabricated using Cad-Cam: An in-Vivo Study

[1]Dr. Divya Bhartiya, [2]Dr. Deshraj Jain, 3Dr. Alka Gupta, [4]Dr. Mukesh Soni, [5]Dr. Suthakar P
[1,5]Post Graduate Student, [2]Professor and Head, [3]Professor, [4]Associate Professor,
Department of Prosthodontics, Crown And Bridge, Government College Of Dentistry, Indore, India

Abstract:-
Background:
The success of crown restorations relies on several crucial factors, including achieving pleasing esthetics, ensuring excellent resistance to fractures, and achieving a flawless marginal fit. When the luting agent dissolves and microleakage occurs, it is often linked to an escalation in marginal crown discrepancies. Insufficient marginal adaptation can result in secondary caries and have a negative impact on periodontal health by promoting greater plaque retention and causing alterations in the subgingival microflora. Marginal and internal adaptations were reported to be different depending on the type and material of indirect restorations.

Purpose: To evaluate and compare the marginal fit and internal adaptation of PFM, Zirconia and GCAM crowns fabricated using CAD-CAM.

Materials and methods: An experimental, comparative in-vivo study was conducted among 45 patients of age group 20-50 years each having a single molar crown replacement, and were randomly divided into three groups: Group I- G-CAM crowns, Group II – Zirconia crowns and Group II- PFM crowns. Ideal tooth preparations were performed and before cementation of the final prosthesis marginal fit was measured using the silicone replica method. The silicone replicas were extracted from the respective crowns with care, and then they were sectioned into four parts per specimen, both buccolingually and mesiodistally, using a razor blade. To assess their thickness, four measurements were taken at the marginal region and four measurements at the occlusal region of each replica. A stereomicroscope was employed for precise measurements in this process. The marginal fit and internal adaptation were assessed based on the thickness of the sections. The intergroup comparison for the difference of mean scores between independent groups was done using the One Way ANOVA and independent t test.The distribution of the data was assessed using the Shapiro-Wilk test, while the homogeneity of the variables was examined through Levene's test. The data was found to be homogeneous and normally distributed. For each variable, the mean and standard deviation (SD) were calculated.

Results: The mean Marginal Discrepancy in the Group I was 107.942µms, in Group II was 107.682µms, in the Group III was 117.312µms. The mean occlusal gap in the Group I was 210.842µms, in Group II was 259.762µms, in Group III was 154.862µms. The intergroup comparison between the three groups was statistically significant when analyzed using One way ANOVA at p value of 0.001.

Conclusion: Within the constraints of the study, all three groups of G-CAM, Zirconia, and PFM crowns exhibited marginal discrepancies and internal discrepancy values within an acceptable range. The occlusal regions demonstrated the highest values, while the marginal regions displayed the lowest values. Also the properties of newer metal free CAD-CAM materials need to be further studied to evaluate their use for long term esthetic restorations.

Keywords:- *Marginal fit, G-CAM, CAD-CAM, Internal adaptation, Stereomicroscope, silicone replica.*

I. INTRODUCTION

Current trends in dentistry show an increase in the rehabilitation and restoration of tooth defects by means of fixed prosthesis. The success of crown restorations relies on various essential requirements, including achieving pleasing esthetics, ensuring high resistance to fractures, and attaining a perfect marginal fit [1]. However, in cases where microleakage occurs, it can lead to irritation and inflammation of the underlying vital pulp, potentially causing endodontic problems [2]. Moreover, inadequate margin adaptation can result in areas of stress concentration within the restoration, which can compromise its strength and longevity due to variations in fit [3]. Therefore, achieving a precise and well-adapted marginal fit is crucial for the long-term success of crown restorations.[3] In addition to the external factors mentioned earlier, poor internal fit of crowns can also have significant consequences. It can result in reduced retention, making the crown more prone to dislodgement, and increase the risk of ceramic fracture.

While the literature has extensively discussed the acceptable marginal fit for crowns, there is still no consensus on the maximum permissible marginal discrepancy [4]. McLean and von Fraunhofer suggested a threshold of 120 µm [5]. However, it is important to note that marginal fit values can vary depending on the location of measurement and the type of restoration [6]. Reported values for acceptable marginal discrepancies range between 50 and 200 µm [7,8].

It is crucial for clinicians to consider these variations and assess the marginal fit of crowns based on the specific circumstances and restoration type in order to achieve optimal clinical outcomes. Regular evaluation and monitoring of marginal fit are necessary to ensure the long-term success of crown restorations

In 1989, Holmes et al. proposed a classification system for evaluating the marginal gap in crown restorations. According to their classification, the internal gap refers to the perpendicular measurement from the internal surface of the casting to the axial wall of the preparation. On the other hand, the same measurement taken at the margin is referred to as the "marginal gap." This classification system helps in quantifying and assessing the fit and adaptation of the crown restoration at both the internal and marginal areas. By evaluating these gaps, clinicians can better understand and address any discrepancies or issues in the fit of the crown restoration [9]

The marginal and internal adaptations of indirect restorations vary based on the type and material used. Metal-ceramic restorations have been used in dentistry for their predictable results and favorable physical properties. CAD/CAM technology offers improved fabrication methods, including for metal restorations, overcoming the limitations of conventional techniques. In CAD-CAM PFM, metal milled copings are fabricated which significantly reduce the marginal discrepancies seen in conventional casted metal copings.[12]

In recent years, there has been a growing demand for all-ceramic restorations driven by the emphasis on esthetics and the recognition of their biocompatibility. Zirconia, a high-strength material, has gained popularity, particularly with the advancements in CAD/CAM technology [13]. However, when it comes to the marginal fit of zirconia restorations, conflicting reports have been documented, indicating variations in findings and conclusions across different studies [14,15]

Recently, graphene nanoparticles have been incorporated in several biomaterials for fabrication of fixed prosthesis. Graphene is a two-dimensional sheet of carbon atoms arranged in a honeycomb structure, known for its exceptional properties. These include high mechanical strength, electrical conductivity, molecular barrier abilities, and other remarkable physical characteristics [16]. Graphene's unique properties make it a promising candidate as a restorative material, primarily due to its high thermal and electrical conductivity, high traction resistance, low density, and low coefficient of thermal expansion [17]. The incorporation of graphene into PMMA resin is an innovative approach to enhance its mechanical properties. This includes increasing the elastic modulus and tenacity, reducing the occurrence and propagation of cracks, and minimizing shrinkage during polymerization. Graphene oxide incorporated in PMMA, known as GCAM is used as a definitive prosthetic material for crowns and bridges.

G-CAM is a biopolymer of graphene in CAD CAM millable discs which is used as a definitive indirect restorative material with properties that are comparable to all ceramics and zirconia.[18]

The purpose of this study is to compare and evaluate the marginal fit and internal adaptation of PFM, Zirconia and GCAM crowns fabricated using CAD-CAM.

The null hypothesis of this study is that there is no significant difference in the marginal fit and internal adaptation of single unit crowns of G-CAM, Zirconia and PFM fabricated using CAD-CAM.

II. METHODOLOGY

A. Study design:

An experimental, comparative in-vivo study was carried out in the PG Dept. Of Prosthodontics, Govt. College of Dentistry, Indore (2021-2022). The approval from institutional ethical committee was obtained before starting the study.

45 male and female patients of age group 20-50 years were selected for the study each having a single molar crown replacement, the inclusion criteria being first and second molar crowns with sound tooth structure, periodontally healthy teeth with no fractures and periapical pathology.

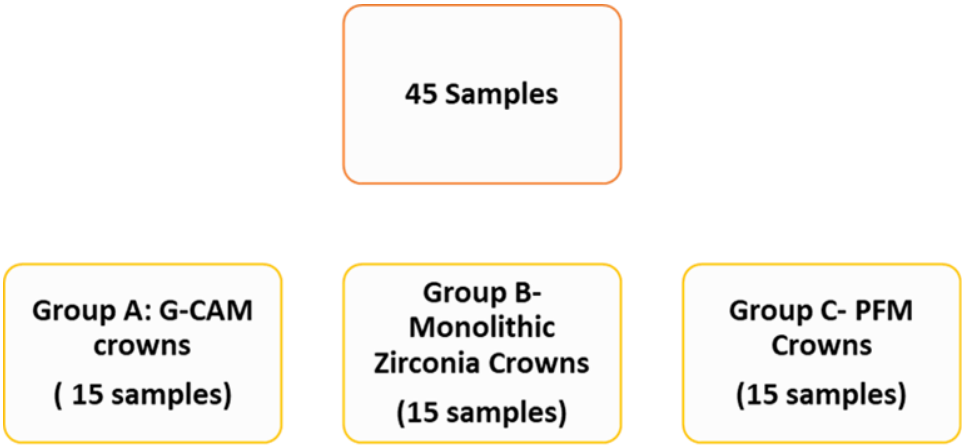


Fig. 1: 45 male and female patients of age group 20-50 years

B. Method of data collection:

The selected tooth were prepared according to the standardized protocols for each type of material. The preparation depths were 1.5mm axially and 2mm occlusally. The shoulder finish line margins were equi-gingival and the tooth preparation had a convergence angle of six degrees. The silicone index was used as a guide for the amount of tooth reduction which was measured using a William's probe.(Fig 1a) The index was sectioned buccolingually and later mesiodistally to verify the amount of tooth reduction.(Fig 1b) Optimal occlusal and axial reduction was done for adequate bulk of the restorative material. The tooth preparation was finally finished using finishing burs. (Fig 1c).

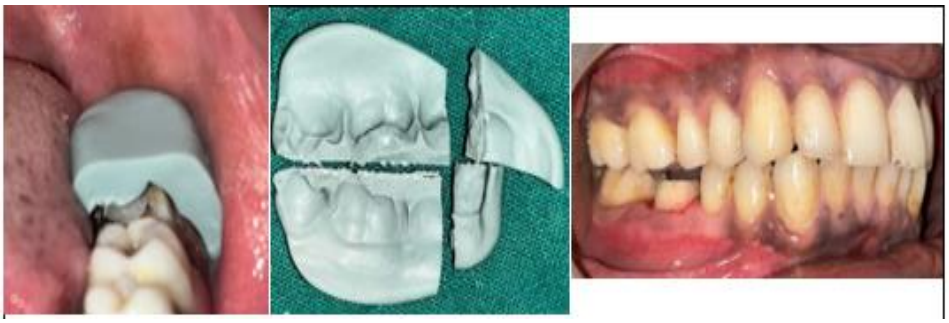


Fig. 2: (Fig. 2a) The index was sectioned buccolingually and later mesiodistally to verify the amount of tooth reduction. (Fig 2b) Optimal occlusal and axial reduction was done for adequate bulk of the restorative material. The tooth preparation was finally finished using finishing burs. (Fig. 2c).

Before final impression, gingival retraction was performed using Magic Foam Gingival retraction material (COLTENE/WHALEDENT)(Fig 2a). Final impression was made using double mix double stage technique. Addition silicone putty and light body (Flexceed, GC India) were used for making final impressions(Fig 2b). The impression was removed from the mouth at manufacture's recommendations of setting time, rinsed with running tap water and disinfected for 10 mins in glutaraldehyde. Shade selection was done with the help of Vita classic shade guide.

Fig. 3: (Fig 3a). Final impression was made using double mix double stage technique. Addition silicone putty and light body (Flexceed, GC India) were used for making final impressions(Fig 3b).

The models were scanned using extraoral scanner (Medit Identica Blue). All the crowns were fabricated using CAD-CAM with a uniform cement thickness of 120 microns in each crown except on the margins and on the occlusal table(Fig 3)

Once the final prosthesis is fabricated (Digident LLP, Indore), the crowns are evaluated in patient's mouth. Crowns were tried in, and proximal contacts were adjusted as needed to the best fit.

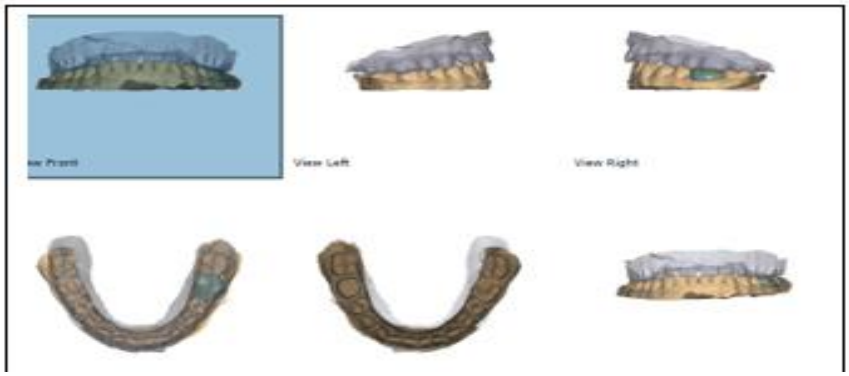


Fig. 4: All the crowns were fabricated using CAD-CAM with a uniform cement thickness of 120 microns in each crown except on the margins and on the occlusal table(Fig 4)

ISSN No:-2456-2165

Using the silicone replica technique, the internal adaptation and marginal fit were assessed. Prior to crown cementation, the intaglio surface of the crowns was filled with a fast-set extra light-body VPS material (PRESIDENT, COLTENE/ WHALEDENT, GERMANY). The crowns were then firmly pressed onto the tooth preparation with consistent finger pressure for 3 minutes, following the manufacturer's guidelines. Once the fast-set VPS material had fully set, the crown was detached. Subsequently, a fast-set VPS heavy-body impression material was injected into the intaglio surface to provide support for the thin layer of extra light-body VPS. The impression material was allowed to set for 2.5 minutes. Careful removal of the silicone replicas from the corresponding crowns was done, and subsequent measurements were taken. Finally, the crowns were cemented using established protocols.(Fig 5a,5b and 5c)

Fig. 5: The crowns were cemented using established protocols.

C. Sectioning of samples and measurement

The silicone replicas were sectioned buccolingually and mesiodistally with a razor blade to produce 4 sectioned parts per specimen- mesiobuccal, distobuccal, mesiolingual and distolingual sections. The sectioned VPS material was placed parallel to a horizontal plane. A stereomicroscope (Fig 6a) with 10x lens at 30x magnification (MAGNUS TZM6, OLYMPUS OPTO SYSTEMS, INDIA) was used to measure the replica samples. Each sectioned sample was measured at 2 points marginally and 2 points occlusally and a total of 16 measurements were obtained for each replica: 8 marginal points and 8 occlusal points. (Fig 6b and 6c)

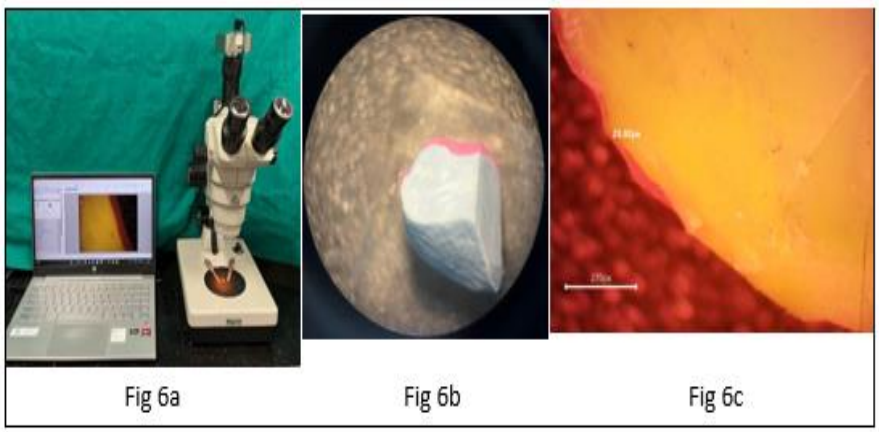


Fig. 6: (Fig 6a) with 10x lens at 30x magnification (MAGNUS TZM6, OLYMPUS OPTO SYSTEMS, INDIA) was used to measure the replica samples. Each sectioned sample was measured at 2 points marginally and 2 points occlusally and a total of 16 measurements were obtained for each replica: 8 marginal points and 8 occlusal points. (Fig 6b and 6c)

III. RESULTS

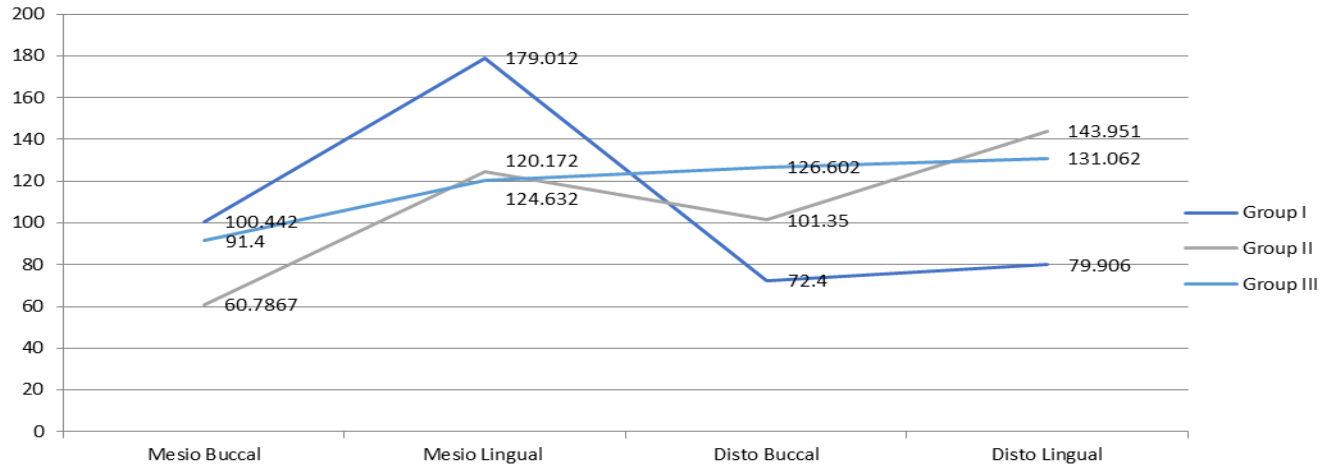
To compare the marginal fit and internal adaptation between the three groups, the following measurements were done:

- Measurement of marginal discrepancy and occlusal gap in G-CAM crowns.
- Measurement of marginal discrepancy and occlusal gap in Zirconia crowns.
- Measurement of marginal discrepancy and occlusal gap in PFM crowns.
- Comparison between the three groups.

ISSN No:-2456-2165

Table 1: Intergroup comparison of marginal discrepancy in microns

		Mean	Std. Deviation	Std. Error	Minimum	Maximum	P value
Mesio Buccal	Group I	100.442	4.00365	1.03374	.10	.33	0.001 (Sig)
	Group II	60.7867	4.29628	1.10929	.52	1.27	
	Group III	91.4000	3.51451	.90744	.54	.96	
Mesio Lingual	Group I	179.012	13.59334	3.50979	.09	.33	0.001 (Sig)
	Group II	124.632	4.77788	1.23364	.51	1.06	
	Group III	120.172	2.64032	.68173	.48	.98	
Disto Buccal	Group I	72.400	3.26223	.84230	.11	.34	0.001 (Sig)
	Group II	101.35	4.57552	1.18139	.46	1.02	
	Group III	126.602	2.94294	.75986	.46	.98	
Disto Lingual	Group I	79.906	2.75926	.71244	.11	.56	0.001 (Sig)
	Group II	143.951	5.20204	1.34316	.55	1.05	
	Group III	131.062	3.06975	.79261	.47	.82	



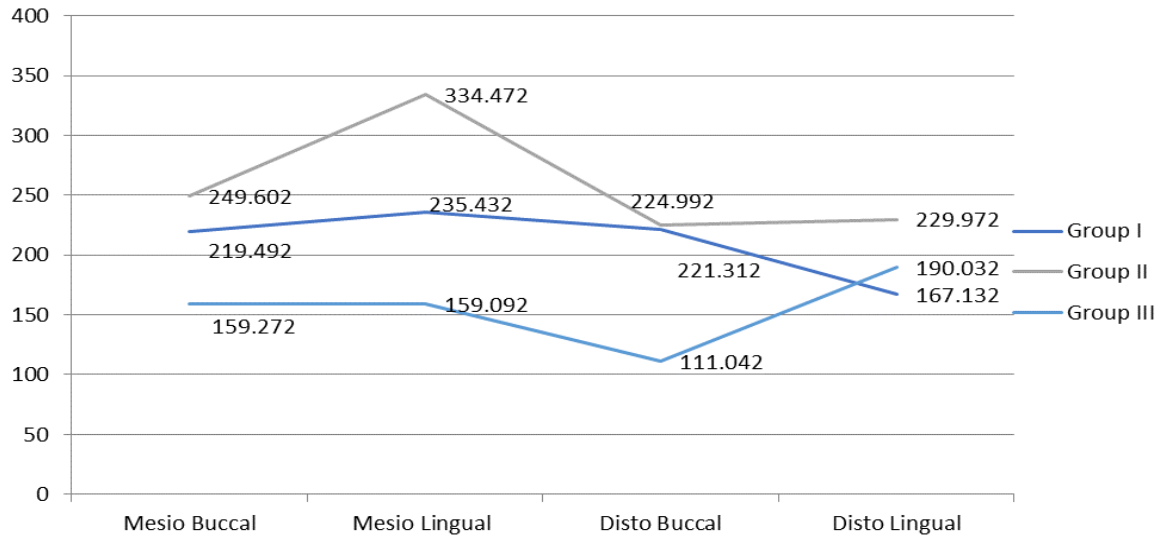
Graph 1: Intergroup comparison of marginal discrepancy in microns

The mean marginal discrepancy at the mesio buccal region in the Group I was 100.44µms, in the mesio lingual region was 179.012 µms, in the disto buccal region was 72.400 µms in the disto lingual region was 79.906 µms In the Group II marginal discrepancy at the mesio buccal region was 60.78 µms, in the mesio lingual region was 124.63 µms, in the disto buccal region was 101.35 µms, in the disto lingual region was 143.951 µms In the Group III marginal discrepancy at the mesio buccal region was 91.4000 µms, in the mesio lingual region was 120.172 µms, in the disto buccal region was 126.602 µms, in the disto lingual region was 131.062 µms. The intergroup comparison between the three groups was statistically significant when analysed using One way ANOVA at p value of 0.001.

Table 2: Intergroup comparison of occlusal gap (in microns)

		Mean	Std.Deviation	Std.Error	Minimum	Maximum	P value
Mesio Buccal	Group I	219.492	6.392	1.650	209.40	229.30	0.001 (Sig)
	Group II	249.602	2.927	0.755	244.75	256.55	
	Group III	159.272	4.389	1.133	150.45	167.95	
Mesio Lingual	Group I	235.432	4.341	1.121	230.30	244.65	0.001 (Sig)
	Group II	334.472	3.380	0.872	328.85	341.10	
	Group III	159.092	3.574	0.922	154.00	165.50	
Disto Buccal	Group I	221.312	4.107	1.060	216.95	229.40	0.001 (Sig)
	Group II	224.992	3.062	0.790	219.80	228.70	
	Group III	111.042	3.409	0.880	103.85	116.85	
Disto Lingual	Group I	167.132	4.556	1.176	160.10	175.10	0.001 (Sig)
	Group II	229.972	5.244	1.354	222.25	237.20	
	Group III	190.032	3.766	0.972	184.95	196.65	

ISSN No:-2456-2165



Graph 2: Intergroup comparison of occlusal gap (in microns)

The mean occlusal gap at the mesio buccal region in the Group I was 219.49 µms, in the mesio lingual region was 235.43 µms, in the disto buccal region was 221.312 µms in the disto lingual region was 167.132 µms In the Group II occlusal gap at the mesio buccal region was 249.602 µms, in the mesio lingual region was 334.472 µms, in the disto buccal region was 224.992 µms, in the disto lingual region was 229.972 µms In the Group III occlusal gap at the mesio buccal region was 159.272 µms, in the mesio lingual region was 159.092 µms, in the disto buccal region was 111.042 µms , in the disto lingual region was 190.032 µms .The intergroup comparison between the three groups was statistically significant when analyzed using One way ANOVA at p value of 0.001.

IV. DISCUSSION

Fixed prosthodontics is concerned with the rehabilitation of the form, function and esthetics of teeth and the orofacial structures by means of restorations which are fixed in the mouth and cannot be removed by the patient. Essential requirements for successful crown restorations are such things as good esthetics, high fracture resistance and perfect marginal fit and internal adaptation[1]. As reported by several authors, poor marginal fit of the fixed prosthesis can lead to harmful effects on the tooth and periodontal tissues.[19] So for the long term success of the prosthesis proper marginal fit and adaptation is of utmost importance.

Over the last three decades, CAD/CAM technology (computer-aided design and computer-aided manufacturing) has become increasingly popular and trusted among dental professionals and patients [20]. Restorations created using CAD/CAM technology demonstrate enhanced durability, improved marginal adaptation, aesthetically pleasing outcomes, and faster fabrication compared to conventional restorations.[21]

Marginal and internal adaptation values were reported to be different depending on the type and material of indirect restorations, on the method of fabrication, on the impression technique, on the preparation type and on the method of evaluation of marginal and occlusal discrepancies.[3]

Multiple studies have examined the accuracy of fit for crowns produced through conventional and digital workflows, but the findings across these studies are inconsistent. Authors have presented varying conclusions regarding the acceptable range of marginal discrepancy and internal adaptation. According to some studies, marginal discrepancies ranging from 40-120 µm are considered clinically acceptable for the longevity of a restoration [13]. McLean and von Fraunhofer established a threshold of 120 µm, but it's important to note that marginal fit values can differ based on the location of measurement and the type of restoration, with reported values varying between 50 and 200 µm.[14]

Marginal fit and internal adaptation of fixed prosthesis has been evaluated and measured by different techniques both in vivo and in vitro for assessing the outcome and longevity of the prosthesis.

The present study was conducted to comparatively evaluate the marginal fit and internal adaptation of G-CAM, zirconia and PFM crowns fabricated by CAD-CAM technique.

The silicone replica technique was utilized to measure the marginal fit in this study. This technique is widely used in both in vivo and in vitro studies due to its non-destructive nature, accuracy, and reliability [22,23]. Laurent et al. reported that with appropriate silicone materials, the cement space can be replicated, and its thickness can be measured irrespective of the location [8]. Moreover, there was no significant difference found between the silicone replica technique and sectioning technique in measuring the marginal gap [4]. The replica technique was chosen for pre-cementation studies due to its shorter production time, lower cost, and the requirement of less complex equipment [24].

However, it should be noted that the replica technique has limitations, such as the possibility of tearing of the elastomeric film upon removal from the crown and the difficulty in identifying the crown margins and finish lines.[25]

In accordance with the study conducted by Khaled Q. Al Hamad [26,27], the silicone replicas were sectioned buccolingually and mesiodistally using a razor blade, resulting in four sectioned parts per specimen.

The literature lacks consensus on the number of measurements required for accurate results. Gassino et al. recommended 18 measurement points for experimental crowns and 90 for clinical crowns to achieve a sample mean value within ±5 µm of the true mean [28]. Groten et al. suggested 50 measurement points [29], while Nawafleh et al. proposed testing a minimum of 30 specimens with 50 measurements per specimen for reliable results [6].

In this study, following the approach of Jin-Young Park [30], 16 measurements were made for each crown, resulting in a total of 720 measurements for all 45 crowns

The results in our study concluded that the mean Marginal Discrepancy in the Group I was 107.942µms, in the Group II was 107.682µms, in the Group III was 117.312µms. The intergroup comparison between the three groups was statistically significant when analyzed using One way ANOVA at p value of 0.001 showing that the least mean marginal discrepancy was seen in Zirconia crowns in accordance with the study done by Yadel Hazır Tekin which concluded that PFM groups exhibited a significantly higher marginal gap than the MZ groups ($p=0.005$, $P < .05$). According to the study, all marginal gaps were found to be clinically acceptable, although the PFM crowns had the highest marginal gap [31].

Another study conducted by Nayana Paul (2020) also reached a similar conclusion, stating that CAD/CAM fabricated zirconia crowns exhibited better accuracy of fit compared to metal-ceramic crowns [32].

MariaDel Piñal (2021) concluded that the marginal fit in all groups was within the clinically acceptable range and both CAD-CAM PFM and Zirconia groups showed similar marginal gaps with no differences among them.[33]

But Yolande Freire (2019) concluded that the CAD-CAM PFM crowns showed less marginal discrepancy as compared to Monolithic ceramic crowns which is inconsistent with our study.[34]

The mean occlusal gap in the Group I was 210.842µms, in the Group II was 259.762µms, in the Group III was 154.862µms. The intergroup comparison between the three groups was statistically significant when analyzed using One way ANOVA at p value of 0.001 which was in accordance with the study done by Khaled Q. Al Hamad where the occlusal gaps for all the groups were in the range of 150-290 µms.[26] The occlusal gaps were significantly higher in all the groups because of the complex anatomy of the occlusal surface.Consistent findings have been observed in various studies, and one contributing factor to these results is reported to be the "total occlusal preparation angle" [35]. Elie E. Daou's study also reported comparable values for marginal and internal discrepancies, with the occlusal regions displaying higher values and the marginal regions showing lower values [36].

This study was done to evaluate the influence of Material Selection on the Marginal Accuracy of CAD/CAM-Fabricated Metal fused to ceramic, zirconia and G-CAM Single Crowns in accordance with the study done by Matthias Rödiger where they checked the influence of material on the marginal fit of CAD-CAM copings all processed with the same technique.[37]

There are some limitations to this study.

- Lack of standardisation of intergroup measurements because different crowns were made on different patients.
- The replica technique is subject to certain limitations, including the possibility of tearing the elastomeric film when removing it from the crown and challenges in accurately identifying the crown margins and finish lines.
- Influence of Processing errors in milling units which are different for Metal and Zirconia.
- Also, the quality of the crowns with regard to the proximal, occlusal, and shade reproductions were not investigated due to the time limitation of the clinical set-up.
- Furthermore, the effect of variations in marginal and internal discrepancy on the strength of the crown was not studied.

V. CONCLUSION

- The conclusions that can be drawn from this study, within its limitations, are as follows:
- All the three groups of G-CAM, Zirconia and PFM crowns showed acceptable range of marginal discrepancies and internal discrepancy values, with the highest values in the occlusal regions and the lowest in the marginal regions.
- The mean Marginal Discrepancy in the Group I was 107.942µms, in Group II was 107.682µms, in the Group III was 117.312µms. The intergroup comparison between the three groups was statistically significant when analyzed using One way ANOVA at p value of 0.001.
- The mean occlusal gap in the Group I was 210.842µms, in Group II was 259.762µms, in the Group III was 154.862µms. The intergroup comparison between the three groups was statistically significant when analyzed using One way ANOVA at p value of 0.001.
- Also the properties of newer metal free CAD-CAM materials need to be further studied to evaluate their use for long term esthetic restorations.

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