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Comparative Evaluation of Marginal and Internal Fit of CAD/CAM-Fabricated Zirconia and Cobalt-Chromium Copings- An In- Vitro Study

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KEYWORDS

cobalt-chromium copings, cobalt-chromium marginal gap, CAD/CAM marginal fit, scanning electron microscope marginal fit, zirconia copings

ABSTRACT:

Background: Marginal and internal adaptation of dental copings is a critical factor influencing the longevity and success of fixed prostheses. Inadequate fit may lead to cement dissolution, microleakage, secondary caries, and periodontal complications. With the increasing use of CAD/CAM technology, zirconia and cobalt-chromium (Co-Cr) copings have gained popularity; however, their precision of fit remains a subject of comparison.

Purpose: To evaluate and compare the marginal fit and internal fit of zirconia copings and cobalt-chromium copings fabricated using CAD/CAM technology.

Materials and Methods: This in-vitro study was conducted on forty extracted mandibular premolars, randomly divided into two groups: Group I (n=20) – zirconia copings and Group II (n=20) – Co-Cr copings. Standardized tooth preparations were performed and scanned using an intraoral scanner. The obtained STL files were used to design copings, which were milled and luted with resin cement. All samples were sectioned and evaluated for marginal and internal fit under a scanning electron microscope. Data were analysed using the Mann–Whitney U test and independent t-test, with statistical significance set at $p<0.05$.

Results: Statistically significant differences were observed between the groups. The mean marginal gap was **37.18 ± 18.21 µm** for zirconia and **95.33 ± 22.04 µm** for Co-Cr copings. The mean internal gap was **88.58 ± 34.61 µm** for zirconia and **126.40 ± 31.77 µm** for Co-Cr copings.

Conclusion: Zirconia copings exhibited superior marginal and internal fit compared to cobalt-chromium copings fabricated by CAD/CAM technology.

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1. Introduction

Fixed prosthodontics combines science with artistry to rehabilitate and enhance extensively damaged and/or restored teeth to replicate the original morphology and function of the tooth.

Historically, gold alloys were the primary choice for posterior restorations due to their excellent biocompatibility and corrosion resistance. Due to its increased cost, base metal alloys became more popular. Cobalt-chromium alloys exhibit high strength, durability, and corrosion resistance, making them a suitable choice for use in fixed and removable prostheses. The demand for more aesthetically pleasing restorations led to the development of metal-free crowns and zirconia gained popularity. [1]

The marginal fit and internal fit of a crown are of paramount importance for a successful fixed partial denture (FPD). Poor marginal fit can lead to bacterial infiltration and plaque accumulation invariably leading to secondary caries at the margins and cement dissolution ultimately resulting in the failure of the restoration. A good internal fit is essential to ensure proper seating, even stress distribution to prevent cracks or fractures in the crown or tooth structure. To achieve optimal marginal and internal fit, the dentist practices precise tooth preparation techniques combined with meticulous impressions or digital scans that accurately capture the tooth structure. [2-5]

The advent of Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) technology in dentistry has revolutionized dental restorations. Digital design replicates tooth preparation margins accurately, improving the marginal seal between restoration and tooth. Using the CAD/CAM software the restoration can be designed so that it precisely fits the internal contours of the prepared tooth, thereby optimizing the surface contact. The digital software also allows corrective adjustments before milling.[6]

However, the ultimate fit of CAD/CAM restorations can still be influenced by several factors, including the quality of the digital impression, the accuracy of the milling or 3D printing devices, the materials used, and the software algorithms. Despite these variables, the CAD/CAM technology has raised the standards for marginal and internal fit of fixed prostheses, leading to better clinical outcomes. [7]

Previous studies have been conducted where the marginal fit of zirconia and cobalt-chromium crowns have been compared. This study leverages the advanced capabilities of the scanning electron microscope (SEM) to evaluate and compare the marginal fit and internal fit of zirconia and cobalt-chromium copings manufactured using CAD/CAM technology. The high-resolution magnification provided by the SEM gives a more accurate and precise results measurement of the marginal fit and internal fit in copings. [8]

2. Material & Methods

The study was conducted at the Department of Prosthodontics and Crown & Bridge, Institute of Dental Studies & Technologies, Modinagar after obtaining the mandatory ethical clearance from the ethical committee. Forty extracted natural mandibular premolar teeth were gathered from the Department of Oral and Maxillofacial Surgery of the same teaching hospital and preserved in normal saline.

The sample size was calculated using G power software (version 3.1). A minimum total sample size of 20 was found to be sufficient for an alpha of 0.05, power of 80%, 0.8 as effect size. A total study sample of 40 was divided into two groups of twenty samples each for the study.

Caries free mandibular premolars were used. Extracted teeth with previous restorations or anomalies were excluded. The samples were prepared by mounting the extracted teeth in self-cure acrylic resin blocks. The samples were then divided into two groups of twenty teeth each. Group I contained twenty samples of extracted natural mandibular premolars prepared to receive zirconia copings. Group II contained twenty samples of extracted natural mandibular premolars prepared to receive cobalt-chromium copings.

TOOTH PREPARATION-_Using a 213R torpedo bur (Shofu, Kyoto, Japan), each tooth in both groups was prepared to create a chamfer finish line of 0.5mm and an occlusal reduction of 2mm with rounded internal line angles throughout. The steady jet of water spray of the high-speed handpiece (NSK, Shingawa city, Japan)

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ensured that the teeth were not desiccated due to high heat and pressure.

SCANNING AND GENERATION OF STL IMAGES- Each sample was scanned using a 3-D Optical Scanner and CAD/CAM unit, Upcera (GmbH, Pforzheim, Germany) (Fig. 1). The 3D scanned images were then converted to stereolithographic files stored in two separate folders. The respective folders were sent to two different laboratories that excel in the manufacturing of the respective materials. Zirconia copings were manufactured at Delhi Dental Centre, Delhi and cobalt chromium copings were manufactured at DentCare Dental Lab Pvt.Ltd, Kerala.

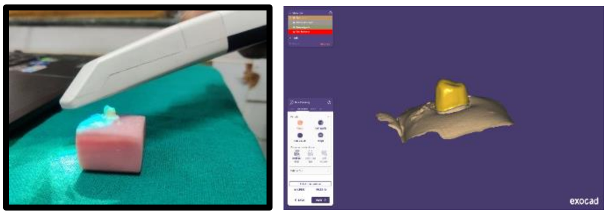

FIGURE 1: Scanning & designing of copings

Once the 3-D image was captured through a computer surface digitization technique, 3-D image processing was done and the digitized data was entered in the computer. The prosthesis was designed using the Exocad software (Fig. 1) and the command was sent to the computer-aided manufacturing (CAM) unit for fabricating the restoration. In this stage, the milling was done with computerized electrically driven diamond disks or burs which cut the restoration from blanks. This process is commonly known as the "subtractive method". FABRICATION OF COPINGS- The data sets of group 1 from the CAD software were converted into milling sequence and loaded into the 4-axis milling machine (VHF K4, Germany) to mill a part out of the zirconia blank using subtractive manufacturing. All copings were designed with a thickness of 0.7 mm; the cement space was set to 40 µm with no space at 0.5 µm from the margin. The CAD/CAM milled zirconia copings in the pre-sintered state were carefully retrieved from the zirconia blank. The excess powder on the milled copings was cleaned by brush. The dried copings were placed on the ceramic beads in the sintering unit (TAEBO1/M/ZIRKON-100, USA) at 1500°C for 12 hrs (overnight).

The milling process for the cobalt-chromium copings involved placing the pre-sintered hard Co-Cr blocks (CORITEC Co-Cr disc; imes-icore GmbH, Germany) in the 5 axis CAD/milling system (CORITEC 450i, imes-icore GmbH Im Leibolzgraben, Germany) (Fig. 2). Since the milled copings were in the final densely-sintered stage, no sintering process was necessary. All copings were designed with a thickness of 0.7 mm; the cement space was set to 40 µm with no space at 0.5 µm from the margin.

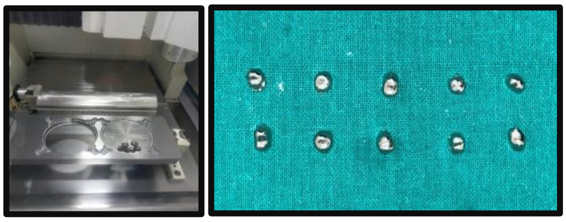

FIGURE 2: a- Milling of cobalt-chromium blank, b- Cobalt-chromium copings

LUTING OF COPINGS- Resin-modified cement, Prevest fusion ultra dc (India) was used to lute both groups of copings to their respective prepared teeth (Fig. 3). The cement was dispensed into the internal surface of the coping and the coping was luted on the prepared tooth. The luted copings were left undisturbed overnight.

EVALUATION USING SCANNING ELECTRON MICROSCOPY- Samples for SEM were prepared to withstand the vacuum conditions and high energy beam of electrons of SEM, and have to be of a size that will fit on the specimen stage. The sectioned sample was mounted on stubs to be fixed for the preparation of the sample to be sputter coated by palladium particles in 8 cycles in the presence of Argon gas (Fig. 4).

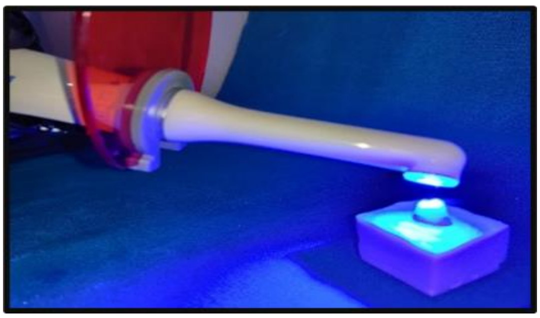

FIGURE 3: Luting zirconia copings

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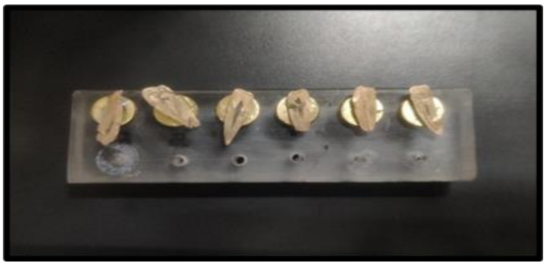

FIGURE 4: Gold sputtered zirconia copings mounted

Then the samples were subjected to Scanning Electron Microscopy. The images obtained were utilized for measuring the specific sites in each specimen. (Figs. 5,6).

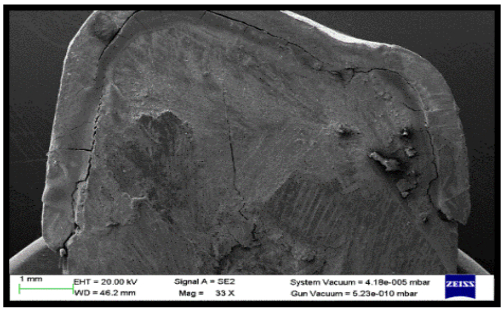

FIGURE 5: SEM Image of Zirconia Coping

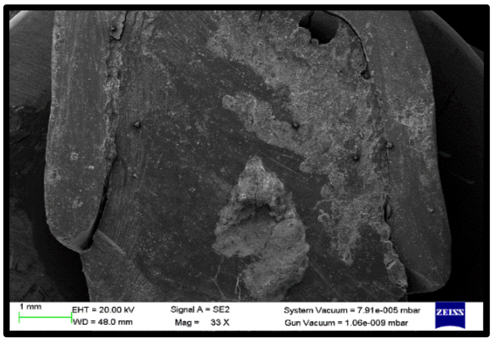

FIGURE 6: SEM image of cobalt-chromium coping

3. Results

The Shapiro-Wilk test was done to assess normality. Since the marginal fit data was not normally distributed, the Mann-Whitney U test was done. Since the internal fit data was normally distributed, the independent t-test was carried out. The results indicated that there was no significant difference between the marginal fit of the zirconia copings and cobalt chromium copings.

The tests showed that the marginal fit was more accurate in Group I zirconia copings (37.18±18.21 µm) than in Group II cobalt-chromium copings (46.11±34.63) (Table 1).

Material	N	Median	Interquartile (IQR) range	25% (Q1)	75% (Q3)
Zirconia copings	20	37.18	18.21	18.80	57.68
Cobalt chromium copings	20	46.11	34.53	19.09	53.22

TABLE 1: Comparison of marginal fit across two study groups.

Independent t-tests (internal fit) show that the null hypothesis is true at a p-value of 0.466 indicating no significant difference in internal fit between zirconia and cobalt chromium copings. The internal fit was also more accurate for Group I zirconia copings (88.58±34.61um) than Group II cobalt-chromium copings (95.33±22.04 um) (Table 2).

Material	Number of samples, n (N=40)	Mean	Standard. Deviation	Mean difference	P value
Zirconia copings	20	88.5809	34.61458	6.75	0.466
Cobalt chromium copings	20	95.332	22.04103		

TABLE 2: Comparison of the internal fit in the two study groups

4. Discussion

The integration of digitization in prosthodontics is now a fundamental aspect of contemporary dental care. With CAD/CAM technology, restorations and dental prostheses can be designed and manufactured with maximum accuracy. The use of CAD/CAM in prosthodontics, from acquiring digital impressions to fabricating different prosthesis designs has become routine practice. [6]

The CAD/CAM technology used for designing the final prosthesis allows the clinician to evaluate undercuts in the tooth preparation. The margins of the restoration can

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be assessed even before the milling procedure thus ensuring better precision of the margins of the restoration. These tasks can be completed within hours, allowing for same-day cementation of the final restoration and eliminating the need for provisional restorations. Moreover, digitization removes potential errors arising from dimensional changes in dental materials and impression techniques. [7-9]

Cobalt-chromium alloys were introduced into dentistry during the early 20th century, primarily for removable partial denture frameworks. The use of Co-Cr in dentistry became more widespread because of its favourable properties, such as excellent mechanical strength, corrosion resistance, and biocompatibility. Co-Cr alloys have high wear resistance and can withstand significant masticatory forces making these restorations highly durable. The combination of these properties and the continuous advancement in dental materials and technology made Co-Cr alloys a popular choice for fixed prosthetic restorations. [10-12]

Ongoing research into aesthetic restorations has highlighted zirconia as a prevalent material in restorative dentistry due to its advanced properties and effectiveness. It yields very favourable mechanical properties and excellent aesthetics as a result of which they can closely mimic natural teeth. [3, 13-14] Because of its superior mechanical strength, zirconia is indicated for use in posterior restorations, long-span bridges, and in patients with bruxism.

The longevity of a restoration depends on the marginal fit and internal fit. Holmes et al introduced a classification for marginal gap in 1989. According to their classification, the perpendicular measurement from the internal surface of the casting to the axial wall of the preparation is called the internal gap and the same measurement at the margin is called the marginal gap. [15-17]

McLean and Von Fraunhofer proposed a marginal gap and cement thickness of less than 120µm for successful restorations after evaluating more than 1000 crowns following 5 years of study. More recent studies conducted by Hassan et al states that adjusting cement space to 90 and 110 µm may be considered to improve the crown margin adaptation without critically influencing the crown retention. It can be estimated that increasing the cement-space thickness parameter can improve the marginal adaptation. [18-21]

The main factors affecting the marginal fit of restoration are impression making, master cast fabrication, die spacer application, and cementation of the restoration. [22-24] Zarauz et al and Syrek et al conducted in vivo studies to evaluate the marginal fit of crowns based on conventional impression techniques and digital impressions. Results were more accurate for the digital system in both studies. [25-26]

In addition, the method of fabrication can affect the marginal fit and internal fit of a restoration.[27] Dixit et al (2016) compared the marginal fit of zirconia crowns fabricated using CAD/CAM technology, Co-Cr crowns fabricated using SMLS, pressable LD crowns and Ni-Cr copings that were cast. They found that the marginal fit of CAD/CAM zirconia crowns was most accurate, followed by SMLS Co-Cr, pressable lithium disilicate and lastly Ni-Cr copings.[28]

Although sample sectioning and SEM evaluation, as is done in our research, have been used for years to evaluate the marginal and internal fit of restorations, it is worth noticing that those approaches are destructive methods and sectioning inevitably involves the loss of some information. Other techniques to evaluate marginal fit that is present in the literature include direct-view technique with a stereomicroscope or optical microscope, the 3-dimensional laser scanner, the cross-sectioning technique, the weight technique the impression replica technique, and computerized x-ray microtomography.

5. Conclusion

While CAD/CAM-fabricated copings of both zirconia and cobalt-chromium offer advantages over traditional methods, this study indicated that CAD/CAM zirconia copings provide a better marginal and internal fit. This can lead to more successful and predictable restorations in fixed prosthodontics, impacting both the clinical longevity of the prosthesis and the overall satisfaction of the patient.

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