Original Article

Microcomputed tomography a noninvasive method to evaluate the fit of a restoration as compared to conventional replica technique

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Abstract

Aim: The aim of the study was to compare the assessment methods used to evaluate the fit of Ni-Cr metal copings.

Settings and Design: Comparative- *Invitro* study design.

Materials and Methods: A stainless steel die simulating a prepared first maxillary premolar was used as a master die. Wax pattern copings were fabricated by the conventional dipping wax technique ($n = 20$) on the master die and were cast in Ni-Cr alloy. The finished copings were fitted on the master die and scanned by the micro-computed tomography (CT) scanner. Multiple projections of the sample were reconstructed to evaluate the marginal and internal fit at 5 predetermined locations. The same copings were used for the replica technique and were evaluated under a stereomicroscope in the same locations.

Statistical Analysis Used: Shapiro–Wilk's test and Unpaired *t*-test

Results: The marginal fit values observed were 127.71 and 95.06 μm, chamfer area fit values were 151.97 and 132.7 μm, axial area fit values were 62.36 and 46.14 μm, axio-occlusal area fit values were 139.52 and 123.6 μm, occlusal area fit values were slightly higher with 217.91 and 193.1 μm, respectively, in replica and micro-CT technique. There was no statistically significant difference observed in the fit between the two assessment methods ($\alpha > 0.05$).

Conclusions: There was no difference observed in the marginal and internal fit of Ni-Cr metal copings with the two methods of assessment. However, the micro-CT technique proved to be simpler, noninvasive, and time-saving assessment method.

Keywords: Conventional wax patterns, marginal and internal fit, micro-computed tomography technique, Ni-Cr alloy, replica technique

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INTRODUCTION

The success of a fixed prosthesis depends on the accurate fit of the restoration.[1] A marginal gap causes dissolution of the luting cement and ingress of fluids, microflora leading to secondary decay and plaque accumulation.[2,3] The internal fit provides adequate and uniform space for the luting cement.[4,5]

There are various techniques in literature such as the direct view measurement technique,[6-8] the silicone replica technique, and the cross-sectioning method used to assess the fit of a restoration.[4,8] The micro-computed tomography (CT), a relatively newer technique, brings about the scanning and three-dimensional (3D) reconstruction of the sample in the three planes which was compared in the study with replica technique.[9]

MATERIALS AND METHODS

The method was divided into the following steps:

Fabrication of stainless steel master model

Stainless steel master die was fabricated with VHF-CNC Milling Machine (VICTOR-VT PLUS 15, Dhanlaxmi Engineers, India) from a stainless steel block. The master die simulated a prepared maxillary first premolar to receive a metal-ceramic restoration with 4.5 mm height, 6° taper, and 120° chamfer[10] and consisted of a 1-mm antirotational groove positioned axio-occlusally[11] [Figure 1].

Fabrication of Ni-Cr metal copings

Dipping wax conventional method was planned for the fabrication of wax patterns. Two layers of red die: master (Renfert, Germany) spacer (15 µm in thickness) were applied in a unidirectional manner to give a uniform spacer thickness of about 30 µm, 1 mm away from the margins for cement thickness.[4,12] This master die was dipped in an electrically controlled wax bath at a recommended temperature of 60°–110°C.[13] The wax pattern was modified using an electric wax shaping instrument and GEO medium hard Crowax (Renfert, Germany) to get 0.5 mm thickness of the wax pattern coping which was confirmed using a wax gauge[5,14,15] [Figure 2]. Twenty wax pattern copings were fabricated and all were invested immediately to avoid any distortion. The manufacturer's guidelines were followed for the investing procedure.[16] The ringless casting technique was followed. The investment was allowed to bench set for 30 min and then placed in a burnout furnace at 900° for 45 min.[17] The patterns were cast in Ni-Cr alloy (Dentsply, USA)[18] using an electronic induction casting machine (Fornax, Bego, USA). The copings were retrieved following bench cooling and were finished with carborundum discs and carbide burs. The copings were inspected for any irregularities in the internal structure and were discarded in case of any defects. New copings were fabricated to get a total of 20 copings which were numbered as A1 to A20 for identification purpose [Figure 3].

Evaluation of marginal and internal fit

Micro-computed tomography technique

The marginal and internal fit of the Ni-Cr metal copings were assessed using the micro-CT technique in high resolution [Figure 4]. Being a noninvasive procedure, this technique was conducted prior to the replica technique. The Ni-Cr metal coping was seated on the master die, and this assembly was positioned in the X-ray Phoenix v|tome|x Micro-CT scanner, GE, India, with the following parameters: Voltage – 205 kV, Maximum output – 320W, Current – 210 mA, Magnification – 4.7X, Voxel size (resolution) – <2 µm (3D), Nano-CT® configuration for voxel resolution <1 µm (3D), and Scan time – approximately 45 min [Figure 5].

Figure 1: Master die

Figure 2: Wax pattern on master die

Multiple projections of the sample were reconstructed in the 3D-sagittal plane, coronal plane, and transaxial plane using the Phoenix datos/×2.0 Acquisition (General Electrics, India) software producing around 1000 slices of the internal structure which was measured quantitatively[19] [Figure 6].

The marginal and internal fit was evaluated at five predetermined locations – marginal area, chamfer area, axial area, axio-occlusal transition area on both sides, and occlusal area [Figure 7]. All the copings were successively scanned following the same procedure and locations for evaluation.

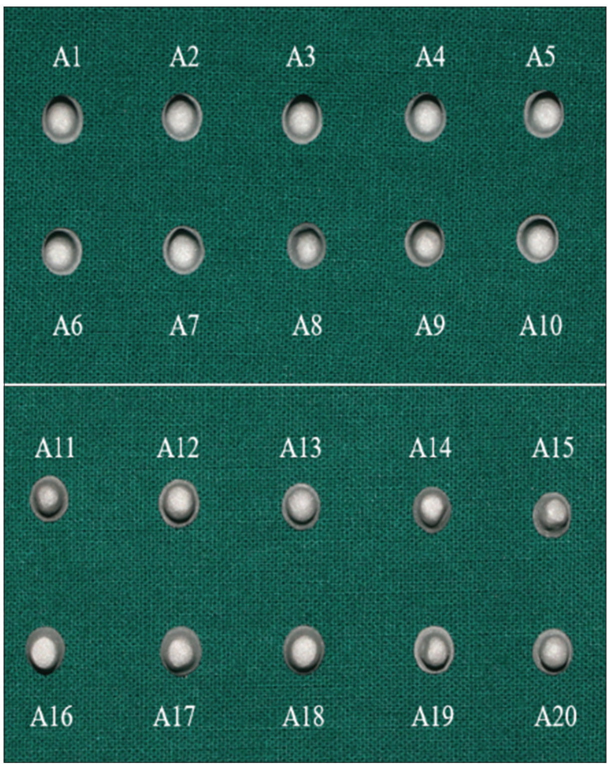


Figure 3: Ni-Cr metal copings

Replica technique

Once the micro-CT scanning was completed, the marginal and internal fit of all Ni-Cr metal copings was assessed using the replica technique. In this technique, Vinyl Polysiloxane Impression Material-Light body (Express™ XT 3M ESPE, Germany) was used as the cement analog. The impression material was injected by Automix Cartridge Dispensor [Garant™, 3M ESPE, Germany) into the inner portion of all Ni-Cr metal copings. These copings were successively then placed on the master die.[17,20] A load of 20 N was applied to the occlusal surface of Ni-Cr metal copings for 5 min with the Instron Testing Machine (USA)[21] [Figure 8]. The Ni-Cr metal copings containing the light body was removed [Figure 9] from the master die and the space occupied by the master die was filled with Type IV gypsum following standardized procedure [Figure 10]. A disc filing system (DFS) Diamond Disc was used to cut the Ni-Cr metal copings in the occlusal–gingival direction into two equal parts. Care was taken to produce least vibrations while sectioning. The mid-point of the buccal and lingual surfaces of the copings was marked to standardize the sectioning. These sections were stabilized and read under

Figure 4: Micro-computed tomography scanner

Figure 5: Master die placed in the micro-computed tomography scanner

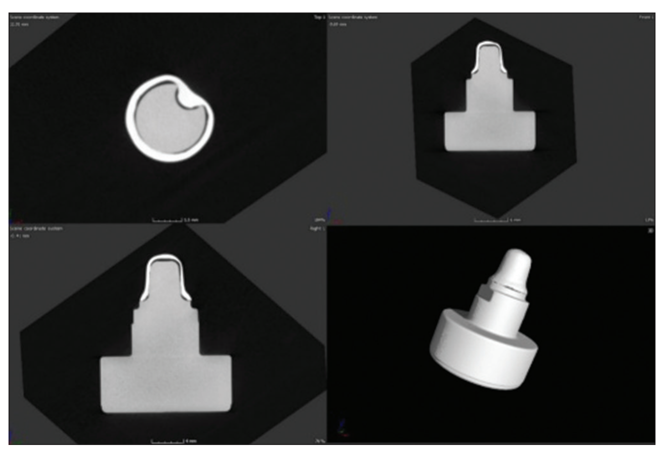


Figure 6: Three-dimensional reconstruction

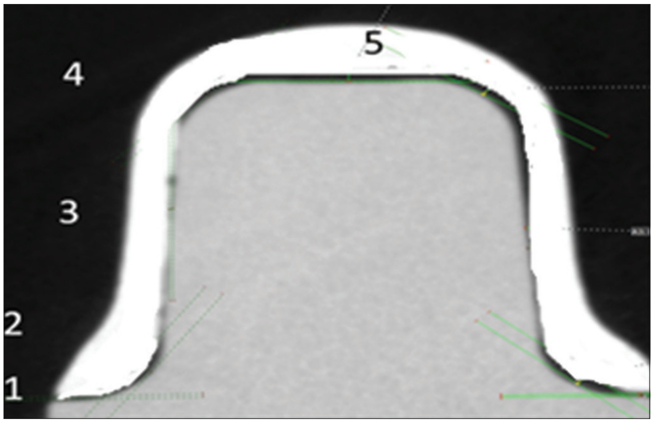


Figure 7: Micro-computed tomography measurement

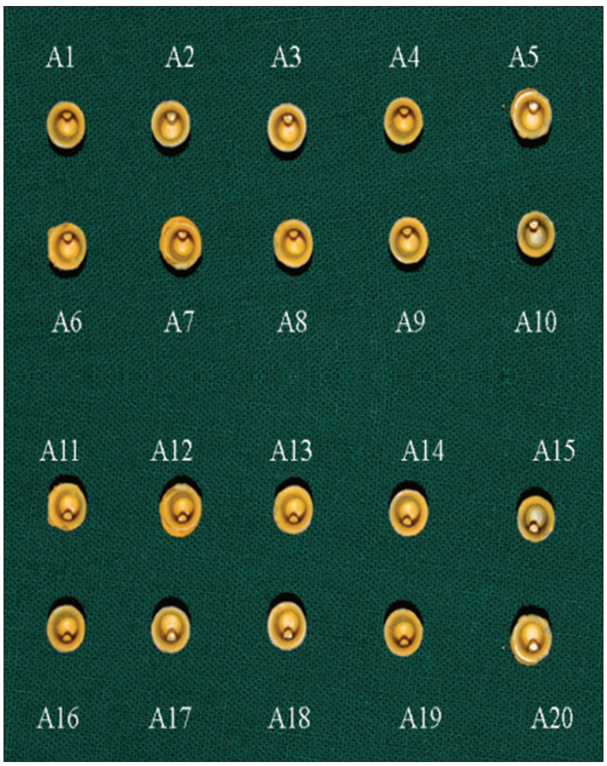


Figure 9: Impression material in copings

a stereomicroscope and photographed.[22] (Wuzhou New Found Instrument Co. Ltd, China, Model: XTL 3400E, Magnification-×15]. The images were evaluated using ImageJ software (Chroma Systems Pvt. Ltd., India Model: MVIG 2005), and the cement analog thickness was measured in the five predetermined regions[23,24] [Figure 11]. The study was kept standardized by measuring the marginal and internal fit in the same five locations as the micro-CT technique.

RESULTS

The marginal and internal fit were evaluated at these five predetermined locations for all the 20 Ni-Cr metal

Figure 8: Load application

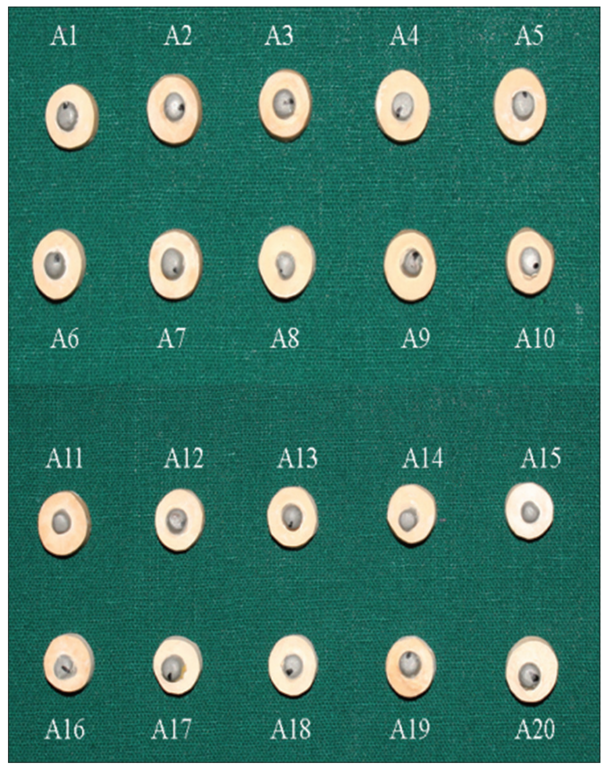


Figure 10: Type IV gypsum filled

copings and a mean was generated for both the methods of assessment [Table 1].

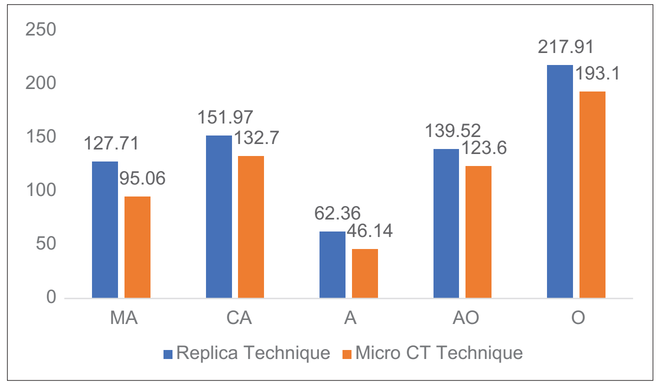
The data were compiled using Microsoft Excel Spreadsheet and subjected to statistical analysis using Statistical Package for the Social Sciences version 20 (IBM, India). Shapiro–Wilk's test was done to determined normality of the data. Data were found to be normally distributed, thus parametric tests were done. Unpaired *t*-test was done to determine whether there was any statistically significant difference in the mean measurements when calculated using replica technique or by micro-CT technique. $P < 0.05$ was

Figure 11: Stereomicroscope image

Table 1: Marginal and internal of Ni-Cr metal copings assessed by replica and microcomputed tomography technique (μm)

Locations	Replica/micro-CT	*n*	Mean (SD)	*P*
Marginal area	Replica technique	20	127.71 (85.3299928)	0.267
	Micro-CT technique	20	95.06 (28.7324903)	
Chamfer area	Replica technique	20	151.97 (72.4767557)	0.430
	Micro-CT technique	20	132.7 (15.1953940)	
Axial area	Replica technique	20	62.36 (28.4891090)	0.124
	Micro-CT technique	20	46.14 (12.4372380)	
Axio-occlusal area	Replica technique	20	139.52 (38.3645322)	0.270
	Micro-CT technique	20	123.6 (21.3083187)	
Occlusal area	Replica technique	20	217.91 (40.1059278)	0.356
	Micro-CT technique	20	193.1 (71.8106306)	

SD: Standard deviation, Micro-CT: Micro-computed tomography



Graph 1: Graph depicting the marginal and internal of Ni-Cr metal copings assessed by replica and micro-computed tomography technique

considered statistically significant. There was no statistically significant difference in the values of marginal and internal fit of the Ni-Cr metal copings observed between the two assessment methods [Graph 1].

DISCUSSION

The marginal and internal fit plays an important role in the ultimate success of a restoration. A marginal and internal fit within the acceptable range aids in longevity of the restoration. There is no concord regarding the acceptable marginal fit in literature. A few authors believe a marginal gap of 100–150 μm is certified clinically acceptable.[3,7] Moldovan, in his study, stated a marginal fit of 100 μm is good and 200–300 μm is acceptable.[25] A marginal misfit results in exposure of the cement layer to the oral fluids leading to dissolution of the luting cement, causing accumulation of bacteria, plaque, food debris eventually leading to secondary caries, inflammation of the periodontium, and ultimate failure of the restoration.

There are various techniques in literature to assess the marginal and internal fit of a restoration.[26] The direct view measurement technique is one of the most common, inexpensive, and straightforward techniques. It is an *in vitro* technique that allows only measurement of the marginal fit after cementation of the copings and viewed under a stereomicroscope,[6] light microscope, or digital microscopy.[7] The silicone replica technique consists of injecting a light body silicone material into the internal structure of the coping and seating of this coping on the master die simulating the clinical cementation technique. Once the silicone material sets, the coping is removed from the die and a heavy body material is injected or Type IV gypsum is poured to stabilize and support the light body layer. This assembly is sectioned and marginal and internal fit is measured at various locations. The cross-sectioning method allows for direct measurement of the cement thickness and marginal gap in both horizontal as well as vertical directions.[4,8] The micro-CT is a newer technique to evaluate the fit by processing the slices of the samples scanned, reconstructing the assembly by the software and measuring the gap.

A study conducted by Vojdani *et al*., suggested that the conventional dipping wax method of wax pattern fabrication produced metal copings with better marginal as well as internal fit over the computer-aided design (CAD)/computer-aided manufacturing (CAM) technique.[4] Hence, in this study, the wax patterns were fabricated by the popular conventional dipping wax method. To avoid any discrepancy, a single operator conducted the study. Following the fabrication of the Ni-Cr metal copings, the marginal and internal fit was assessed by the micro-CT technique as it is a noninvasive technique as compared to the replica technique, wherein the copings were sacrificed to evaluate the marginal and internal fit. The copings were seated on the master die in a single position due to the presence of an antirotational groove that avoided any unreliable movements of the metal copings on the master die. This master die with the coping assembly was placed in the scanning unit for the scanning and 3D reconstruction of the master die, the metal coping, and the space between the two.[18,27] This space was quantitively measured using the Phoenix datos/×2.0 Acquisition software at five predetermined locations for all the copings.

The replica technique for the assessment of the fit of the same set of copings was conducted after the assessment by the micro-CT technique. Light body was used as cement analog and injected into the internal surface of the copings followed by uniform force application for a fixed period of 5 min. The copings were retrieved from the master die and the space occupied by the master die was replaced using Type IV gypsum following the standard protocol as instructed by manufacturers. These samples were sectioned using a clean sharp DFS disc for each sample to avoid any unreliable movements of the disc while cutting and to get a straight incision. The samples were sectioned in two equal halves buccolingually. The antirotational groove was avoided during the sectioning procedure. This assembly of all the copings was viewed under a stereomicroscope to study the marginal and internal fit at five predetermined locations similar to the micro-CT technique to avoid any discrepancy.[23,24]

In the current study, the marginal and internal fit of the Ni-Cr metal copings assessed by the micro-CT technique and replica technique showed no statistical significant difference. In a study conducted by Cunali *et al.*,[28] they compared the marginal and internal adaptation of zirconia crowns and evaluated the marginal and internal adaptation by two different assessment techniques. They conducted the study differently, wherein the Type IV gypsum used in our current study was replaced by the regular body polyvinyl siloxane material. They concluded that the micro-CT technique produced lesser values as compared to the silicone replica technique. Another study conducted by Rungruanganunt compared the silicone replica technique and the micro-CT technique, but the methodology to measure the gap in the silicone replica technique was by photometric technique. No studies have been conducted to assess the marginal and internal fit of Ni-Cr metal copings fabricated by conventional dipping wax method by the micro-CT technique. In a study conducted by Vojdani *et al.*,[4] the marginal and internal fit of metal copings was assessed using the popular technique of cross-sectional analysis. In another study performed by Fathi *et al.*[12] evaluated the marginal and internal fit of the copings fabricated by conventional and CAD/CAM wax patterns as well as studied the two evaluation methods to assess the fit. He concluded in his study that the silicone impression technique and conventional cementation technique produced similar results. He further added that cementation technique was more specific at marginal areas.

The replica technique has been a popular and reliable technique to measure the fit over years. The replica technique can be conducted by either of the two methods, wherein the light body injected can be supported by the regular body putty or Type IV gypsum. The limitations of the replica technique observed while conducting the study were improper and difficulty in seating of the metal coping on the master die with light body, difficulty of removing the metal coping from the master die after injecting the light body, and application of pressure. The polymerization of the silicone material leads to some discrepancy. The chances of tearing of the thin flexible light body layer in the marginal area on removal of the coping were high leading to repeating of the steps performed.[23] The sectioning of coping was difficult even after using high-end cutting discs; if the axis of the sectioning changed, it would give inconsistent results. The fit could be only assessed in limited points on the section.

The micro-CT technique is an innovative technique for assessing the fit of a restoration which was first introduced in the year 1980 by Jim Elliot. It was relatively simpler, reconstruction was uncomplicated, and no sample preparation was required as in the replica technique where the assembly had to be sectioned. This is the only method to reconstruct the master die and the suprastructure three-dimensionally. The marginal and internal fit could be assessed in all the positions in the three planes.[19,27] The assessment locations were restricted to five predetermined locations in the present study. The main highlight of this technique is that it was noninvasive, highly accurate with micrometer precision, and the measurements could be reproduced repeatedly at various sites.[9,20] However, this technique relies on a good radiographic contrast between the metal die and the restoration to measure the fit. Hence, this study was conducted without cementation of the coping on the master die which does not simulate the clinical situation.[22,29]

The present study compared the two assessment methods to evaluate the fit of the Ni-Cr metal copings. Both the techniques measured the fit within the acceptable normal ranges. The values of the internal fit in the occlusal area observed were slightly higher in both the assessment methods. The micro-CT technique could be used as useful analytical tool to measure the marginal and internal fit without sacrificing the sample.

The limitations of the study were that the marginal and internal fit was assessed on a stainless-steel master die which only simulated a natural tooth. Both the assessments were done in ideal situations and the clinical situations were not replicated. In the micro-CT technique, the copings were not cemented on the master die; therefore, the actual gap or discrepancy of the fit could be observed. Cementation of the copings may lead to misfit due to the film thickness of the luting cement and may hinder incomplete seating of the restoration. The clinical significance of the present study may serve as a useful guide in deciding which is a more reliable, reproducible, simpler, and accurate method of assessing marginal and internal fit of Ni-Cr metal copings. This study concluded that there was no difference observed in the values of marginal and internal fit between the two methods of assessment. However, the micro-CT technique produced more consistent, reliable, 3D, repeatable values, and was a time-saving technique. It could be used as a useful guide for the evaluation of the fit of a restoration prior to the cementation procedure to observe the discrepancy of the fit.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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