Radiographic Evaluation of Marginal Accuracy of Metal Coping in Sectioned and Unsectioned 3D Printed Models and Gypsum Models

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ABSTRACT

Aim and objective: The aim of the study is to radiographically evaluate the marginal accuracy of metal coping in sectioned and unsectioned three-dimensional (3D) printed models and gypsum models.

Materials and methods: A cross-over, double-blinded randomized control trial was performed on 20 patients. The patients were given metal copings fabricated by conventional (control group) and digital impression techniques (experimental group). Sectioned and unsectioned 3D printed models were obtained from the digital impressions. Marginal accuracy of the copings was evaluated using radiographs.

Results: The marginal discrepancy was maximum in the copings fabricated by conventional impression (0.143 ± 0.24 mm), followed by 3D printed die-sectioned models (0.125 ± 0.16 mm), and the least marginal discrepancy was seen in the 3D printed under-sectioned models (0.095 ± 0.15).

Conclusion: It would be prudent to conclude that the digital impression technique producing 3D printed under-sectioned models demonstrated the highest dimensional and marginal accuracy. However, in the clinical scenario, both the conventional and digital impression techniques demonstrate variations within clinically acceptable limits.

Keywords: Conventional impression, Digital impression, Marginal accuracy.

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INTRODUCTION

Accuracy of the fit of the restoration has always remained as one of the primary factors in determining success of the restoration.1-3 A well-fitting restoration needs to be accurate both along its margins and internal surface.4,5 The marginal fit or accuracy of a restoration can be defined as the “misfit” or the gap measured at various points between the restoration and the tooth.6 Marginal accuracy is of great importance because acceptable fit at the margins is essential in maintaining gingival health and protecting the tooth from physical, chemical, bacterial, and thermal injuries.7-9 Open marginal configurations encourage bacteria and bacteria by-products to encroach the dentition which cause severe effects on the health of pulpal tissues.10-12 The most commonly used technique was taking an impression and fabricating conventional three-dimensional (3D) crowns on gypsum models.13 The accuracy of the impression was much dependent on the material,14-17 impression tray type,18-20 and impression technique.21-23 This introduced a lot of potential human and material errors.24-26 Hence, a newer method of 3D printing using CAD CAM was introduced which skipped taking impressions and directly fabricated copings by scanning the teeth directly in patients’ mouths.27-29

The enormous progress of digital dentistry over the last decade, especially with the advent of CAD CAM imaging and milling systems has created a new modality in digital dentistry.29 The most recent wave of technological development in digital dentistry revolves around the field of 3D printing.30 Three-dimensional printing is an emerging technology capable of readily producing accurate die and undie models. It is a process for the manufacture of tooling and functional prototype parts directly from computer models. Due to rapid expansion in 3D printing, newer materials and technologies continue to abruptly appear in the market and scientific literature.31,32 Three-dimensional printing methods can be classified under four categories: (1) Extrusion printing, (2) inkjet printing, (3) laser melting/sintering, and (4) lithography printing. In brief, in extrusion printing is a 3D printing process in which the inkjet technique functions by the deposition of powdered material in layers and the selective binding of the powder by printing of a binder material.33,34 The enormous progress of digital dentistry over the last decade, especially with the advent of CAD CAM imaging and milling systems has created a new modality in digital dentistry.29 The most recent wave of technological development in digital dentistry revolves around the field of 3D printing.30 Three-dimensional printing is an emerging technology capable of readily producing accurate die and undie models. It is a process for the manufacture of tooling and functional prototype parts directly from computer models. Due to rapid expansion in 3D printing, newer materials and technologies continue to abruptly appear in the market and
from direct exposition of the polymer to light as the vat or sample holder moves up or down. 30

Several reports have demonstrated the potential for accurate and precise restorations using CAD/CAM technology. 38–40 Several studies have been published on the accuracy of digital impressions, testing single-unit restorations, 41–44 several teeth in a row, 45–47 quadrants, 48 and full arch scans. 49,50 However, none of these studies have made any comparison with die-sectioned 3D printed models, neither have these studies shown the clinical representation. A recent report by Lee and Gallucci 51 compared the operator’s preference of digital vs conventional implant impression techniques. In this in vitro study, the overall perception of the inexperienced students was that they preferred the digital impression technique.

It is important to know which impression technique and which type of copings gives the least possible discrepancy in order to achieve a successful outcome. 52 Hence, this study aims to compare the marginal accuracy of metal coping in sectioned and unsectioned 3D printed models and gypsum models.

**Materials and Methods**

**Study Design**

This study is a cross-over, double-blinded randomized controlled clinical trial. The study was performed in the Department of Prosthodontics, Saveetha Dental College. A total of 20 samples were fabricated for each of the three groups. A cross-over trial was performed by evaluating the three groups on the same patient to eliminate operator bias.

**Sample Size Estimation**

The sample size was estimated to be 6 in each group using G power with inputs fed from a pilot study by Kocaagaoglu et al. 53 However, the sample size was increased to 20 patients to increase the level of significance.

**Patient Selection**

Patients were recruited from the ones who repeated to the OPD of Saveetha Dental College based on the inclusion and exclusion criteria.

**Inclusion Criteria**

Healthy subjects with no history of systemic diseases, both genders, age limit 20–60 years, patients requiring fixed partial dentures, and patients not willing for implants.

**Exclusion Criteria**

Patients with systemic disease, patients who are allergic to local anesthetic solutions, patients with limited mouth opening, patients indicated for implant placement, and patients not willing for the treatment.

The study was conducted in the Department of Prosthodontics, Saveetha Dental College, after the approval by the research and ethics committee. Twenty patients were included in this study that were to undergo tooth preparation of two or more teeth. An informed consent was taken from each patient for agreeing to be a part of the study.

**Group**

Group I—Copings fabricated from conventional impressions.

Group II—Copings fabricated on 3D printed undie-sectioned models

Group III—Copings fabricated on 3D printed die-sectioned models

**Blinding**

The patients were chosen by computerized random number allocation, based on the inclusion and exclusion criteria. The double-blinded cross-over clinical trial employed independent radiographic evaluators to avoid bias. The preparation of copings, burnout, casting, and finishing was performed by a single laboratory technician for each sample. The designing of the digital models was performed by two different operators on random allocation to avoid any form of bias. The radiographic evaluation was also performed by three different operators and an average of the three values was taken. The operator was unaware which coping was fabricated on which model during the evaluation.

**Conventional Master Models**

A double cord light body impression was made of the whole arch to be used as the master model. This is addition silicon type of elastomer. A putty impression was made following which undercuts were relieved and light body impression was taken. Then, the set impression tray was removed from the master cast by pulling slowly to break the seal, then snapped out along the long axis of the teeth. The impression was disinfected with 2% glutaraldehyde. The cast was prepared by pouring die stone into the impression. The same procedure was used for all the patients.

**Digital Impression Technique**

The digital impressions were taken using the TRIOS impression machine. The scanning was started with the occlusal surfaces followed by the buccal, lingual, and proximal surfaces. While scanning the occlusal surfaces, the scanner head was kept at 0 to 5 mm from the tooth. For the scanning of the buccal and lingual surfaces, the scanner tip was rolled at 45°–90° to the buccal and lingual sides, respectively. The scan was viewed as a 3D model on multiple axes to confirm that the preparations are satisfactory. After the scanning was completed, an open-formatted STL scan from TRIOS was imported into the Dental Manager (3 Shape) CAD software.

**Preparation of the Metal Copings**

Wax pattern was fabricated and two layers of die spacers were applied 1 mm away from the margins by using a brush. To normalize the contour and thickness of the wax patterns, the dipping wax technique was used to form the copings. Wax sprues were attached and the wax pattern was invested using phosphate-bonded investment material. Wax burnout procedure was carried out at 250–270°C and preheat procedure was carried out at 270–950°C in two stages and casting was performed using an induction casting machine. After being heated to 950°C for wax elimination, the specimens were cast with nickel–chromium alloy with the help of a casting machine.

**Method of Evaluating Dimensional Discrepancy Based on Radiographic Evaluation**

A radiographic assessment of the marginal discrepancy of the copings was performed with the help of intraoral periapical radiographs obtained by the long cone paralleling technique.
to minimize the distortion using the film holders. A customized occlusal bite jig was fabricated by attaching putty elastomeric material to a film holder and asking the patient to bite on it. This jig was used to standardize the film placement and cone angulation. The marginal discrepancy was measured on the mesial and distal aspect of the tooth as seen on the intraoral radiograph. The marginal discrepancy was measured using the Dental Imaging Software.

Statistical Analysis
All analyzes were conducted using SPSS 21 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics (mean, standard deviation, and standard error) were carried out for each model. A paired t-test was performed to compare variables across the study groups.

The independent variables in this study are the study groups. The dependent variable is the mean score of the radiographic marginal discrepancy (in mm).

RESULTS
The mean values of the marginal discrepancy on radiographic examination were 0.143 ± 0.24 mm, 0.095 ± 0.15, and 0.125 ± 0.16 mm for copings fabricated from conventional, undie-sectioned, and die-sectioned groups, respectively (Table 1 and Fig. 1). Paired t-test was used to perform an intergroup comparison. A statistically significant difference was noted in the marginal accuracy of the copings fabricated on the undie-sectioned models in comparison with the conventional and die-sectioned groups (Fig. 2).

Table 1: Means, standard deviation, standard errors, and p values of the marginal discrepancies in conventional, 3D printed die-sectioned, and 3D printed undie-sectioned copings.

| Pairs                        | Mean  | Standard deviation | p value |
|------------------------------|-------|--------------------|---------|
| Conventional                 | 0.1425| 0.23522            | 0.145   |
| 3D printed die sectioned     | 0.1250| 0.16132            |         |
| Conventional                 | 0.1425| 0.23522            | 0.054   |
| 3D printed undie-sectioned   | 0.0950| 0.14491            |         |
| 3D printed die-sectioned     | 0.1250| 0.16132            | 0.001   |
| 3D printed undie-sectioned   | 0.0950| 0.14491            |         |

DISCUSSION
Marginal fit of the restoration is one of the most important criteria to be taken into consideration because failure to achieve an optimum fit can promote plaque formation and leaching out of the luting cement, which causes secondary caries leading to pulpal and periodontal failure which ultimately leads to failure of the restoration. Ideally, the margins of the prosthesis should meet the margins of the prepared tooth in a non-detectable junction. But, in clinical practice, it is very difficult to achieve this in all the cases. Hence, some amount of marginal discrepancy is clinically acceptable. The terms marginal fit and internal fit are similar but not same. Holmes et al. who established several gap definitions according to contour difference between the crown and tooth margin, state that “the perpendicular measurement from inner surface of casting to the axial wall of preparation is called internal gap, and the same measurement at the margin is called marginal gap.”

In this study, the marginal discrepancy was evaluated through radiographic assessment. The results of this study showed a statistical significant difference between the conventional and digital impression techniques. Conventional models showed greater dimensions compared to the digital models; however, the difference was not statistically significant (p < 0.5). Some of the previous studies by Lee and Gallucci who reported that a digital impression proved to be a more efficient technique and Yuzbasioglu et al. who reported that digital impression was a more time efficient technique and preferred by patients as compared to the conventional technique also showed similar results, which was also confirmed by Fleming et al. in his systematic review, who reported that digital models offer a high degree of validity when compared to direct measurement on plaster models. These results were in contrast to the study reported by Basaki et al. who reported that models obtained from digital impressions were less accurate than the conventional casts. The increase in dimensions of the conventional model poured with type IV stone can be explained by the setting expansion of the gypsum products.
The marginal accuracy was the highest in the digital model group with undie section. There was a statistical difference seen while comparing to other groups. Some of the previous studies have reported no statistically significant differences between the models produced by conventional methods and digital methods. Most of these studies had taken conventional impressions, followed by making the copings digitally. This has proven to reduce the accuracy of the models. In this study, the radiographs were taken using paralleling cone technique using a position indicating device to standardize the angulation of X-ray. The average value of marginal discrepancy can range from 95 to 150 μm with the average of 120 μm. The values obtained in this study are within the range of acceptable marginal discrepancy.

The accuracy of the impression was much dependent on the material, impression tray type and impression technique, bulk of the material, and other factors. Also, in conventional impressions, the accuracy of the impression can be hampered by bleeding, saliva, gingival crevicular fluid, etc., which can cause a distortion in recording a margin. Excessive bleeding and pooling of saliva will inhibit the flow of the material in the sulcus area. In contrast to the conventional impressions, the accuracy of digital impressions depends on the true to the optical scan. In our study, we used a TRIOS scanner which is reported to have one of the best combinations of speed, trueness, accuracy, and precision. In this study, 3D printed models were used as literature has reported higher accuracy of printed models when compared to milled models.

Although the results of the study demonstrated the digital impression technique is better than the conventional impression technique, there are certain limitations in the study. The evaluation of marginal discrepancy which was carried out using radiographic evaluation, recorded the discrepancy only in the mesial and distal regions due to its limitation in displaying the image only in two dimensions. With the recent advances in technology, it would have been more prudent to use a cone beam computed tomography (CBCT), a cone beam volumetric tomography (CBVT), or a micro CT to evaluate the volumetric changes in the marginal gap.

**Conclusion**

Digital dentistry is an emerging branch of dentistry which has shown promising results. Digital impression technique with 3D printed undie-sectioned models demonstrated the most accurate results. The variations between the groups are within acceptable limits. Hence, we can conclude that both conventional and digital impression techniques will result in acceptable crowns, and can be used in clinical scenarios.

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