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3D Printed Cast Is more Accurate than Conventional Stone Cast for Single Tooth Supported Fixed Prosthesis

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Abstract

Objective: Studying the clinical adaptation of the crown in relation to the finished line of the prepared abutment and assessing the fit and precision of single unit fixed dental prosthesis made on digitally printed positive replica casts that created by printers depending on digital intra oral scanning by using filament material of resin material were the goals of this in vitro investigation. **Materials and Methods**: After acquiring digital virtual casts through intraoral scanning of the prepared teeth using a 3Shape trios 4 intraoral scanners, ten digitally printed positive replica casts were created using a3D printers depending on digital intra oral scanning. The master model was created from filament material of resin material. Ten Conventional type 3Stone were used to from conventional stone cast (CS), final impression was made from dual viscosity impressions material. Every fixed dental prosthesis (FDP) was made using a Dentium 5-axis milling machine. A two-way ANOVA was conducted to characterize the whether the deference between groups was significant or not, 3D analysis software was used to superimpose the milled FDPs' intaglio surface and master model. Also post hoc analysis, and Tukey honestly significant difference test was employed. **Results**: The internal and marginal root mean square (RMS) values of the two groups (three dimensional printed and conventional stone cast) were significantly differed, according to a two-way ANOVA.

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Introduction

Accurate prosthesis fabrication requires precise castings. Other kinds of casts could be considered as substitutes for conventional type 3 stone cast if dental clinics regularly used digital images acquired with an intraoral scanner. The 3D-printed cast is one such option [1]. The fitness of the margin and internal portion of a dental restoration specially fixed dental prosthesis determines its quality. To provide a precise fit, accurate reproduction is necessary. Therefore, accuracy is crucial for creating impressions and copies [2,3]. Intra oral scan of the teeth and associated intra oral structure by using an intraoral scanner or the traditional technique of (elastomeric impression) can be used to create definitive dental master casts [4]. For many years, stone casts have been utilized for prosthetics, diagnosis, and treatment. They are vulnerable to damage and fracture and furthermore, because they are heavy, they are challenging to store. These issues can be avoided with digitally printed positive replica casts that are acquired from a digital scan to the intra oral structure. They can be sent digitally and are stored in a digital format [5,6].

After taking an imprint (intra orally), there is no need to create a definitive cast because the data are taken straight from the intra oral cavity by digital scan [7,8]. Definitive dental casts are still necessary for certain prosthetic treatments [9,10] but by using subtractive or additive manufacturing, 3D digital virtual casts can be used to create definitive and accurate dental casts. The technique of fabricating prostheses has been made simpler and more accurate by subtractive manufacturing (3D printing dental cast) [11,12]. However, due to the milling machine's restricted axes, it is challenging to replicate complicated geometries and undercuts with this manufacturing method [13]. Additionally, due of the milling bur's diameter, this approach produces a lot of waste and may result in inaccuracy (known as drill compensation) [14,15]. Additive manufacturing, also referred to as 3D printing, on the other hand, develops the intended shapes layer by layer after converting the planned CAD files into slice data [16,17]. Features like undercuts and intricate interior forms can be produced with little material waste [17,18].

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Additionally, multiple goods can be produced at the same time. Due to these benefits, 3D printers are becoming more and more popular in the prosthodontic field. Furthermore, 3D printers are now less expensive because the original patent for the concept has expired [19].
The photopolymerization process is used in digital printing. On the whole platform, the 3D printer printing a single image as a layer concurrently. Because all layers are exposed simultaneously, DLP can thereby shorten printing times [20]. Using high quality three diamantine printer affects accuracy of parenting [21]. Furthermore, it has been noted that the DLP technique produces diagnosis casts with greater accuracy than other 3D printer kinds [22]. Currently, the primary applications of 3D printers are the creation of surgical guides and orthodontic casts for dental implant procedures. They are anticipated to be utilized more frequently, nevertheless, to produce definitive castings for prosthodontics as well as prosthetics. The precision of 3D-printed orthodontic diagnostic castings has been assessed in studies. Nevertheless, there aren't many studies on digitally printed positive replica casts were created using a3D printers depending on digital intra oral scanning (FDP). Thus, the objective of this in vitro investigation was to assess the accuracy of 3D-printed casts in comparison to a traditional stone cast (CS) and the marginal and internal fit of FDPs made on a 3DP.

Materials and Methods

A single unit FDP was abutted by the maxillary right first molars utilizing a filament resin typodont (AG-3 ZPVK; Frasaco GmbH). The standard abutment preparation type was full crown preparation (360 degree, 1mm with margins of chamfer type). The created printed cast as a master model made of filament epoxy resin duplicated ither from intra oral scan or by scan to the conventional cast made by conventional impression by using an optical scanner (3Shape TRIOS4 4 advance wireless intraoral scanner) with a 6-mm accuracy.
Metal rim look stock tray (Mendcy, Italy) were used with heavy body silicon (Zemach, Germany) for primary impression making, after the study cast fabrication, it was layered by 1 mm baseplate wax as spacer and acrylic non perforated special tray was fabricated, finished and painted with adhesive material to provide mechanical attachment to the impression material. dual viscosity impressions were used (10 minutes according to the manufacturer's instruction to ensure for full polymerization) the tray impression was moved with the snap out removed to fabricate ten master model by purring the final impression and cast creating according to the manufacturer's specifications [22], it was then stored in an incubator for 8 hours at 23°C to control water evaporation and prevent dimensional changes. Type III dental stone (Fuji Rock; GC) was poured into the tray, and the stone cast separated from the impression after 45 minutes to ensure full polymerization. Following a 8-hour storage period, the stone castings were digitalized using a reference scanner and saved as a standard tessellation language (STL) file (CS group).
A trained clinician created ten three dimensional printed casts (3DP group) by scanning the master model with an intraoral scanner. Using the pertinent exported STL files (digital virtual casts), three dimensional printed casts were produced using a three-dimensional dental model printer (3Dent; EnvisionTEC GmbH). In around three hours, the 3D printer created ten castings at a 50 mm resolution. These cast then scanned using the digital intra oral scanner, and the analytic software (STL file) was stored. The single-unit FDPs were built using CAD-CAM software (Dentium milling) throe an STL file, the crowns were fabricated to the collected data include the scanning of the conventional cast data and intra oral scan. Using a 5-axis milling machine (DWX-50; Roland DG Corp), the single-unit FDPs were produced from a polyurethane block (innoBlanc model; innoBlanc GmbH). Following milling, the intaglio of the finished single-unit FDPs was captured by a reference scanner and stored as an STL file. Using 3D analysis tools, all STL files were reduced to the region of interest, eliminating defects and artifacts for precise superimposition (Geomagic Verify 2015; Geomagic GmbH). The single unit FDPs intaglio scan data and the master model data were automatically aligned before being overlaid. For precise alignment, the best-fit alignment the acceptance varieties were then strongminded in this way: the maximum value/the minimum value (±10 mm); and the overall deviation was computed using standards from a dye chart. Root mean squares (RMSs) were used to quantify the dimensional differences between the digitalized single unit FDPs' intaglio surface data and the master model [23]. RMSs were computed using the subsequent formula:

$$RMS = \sqrt{\frac{1}{n}\sum_{i} x_i^2}$$

Root mean squares (RMSs) where xi is the measurement argument of the master model and n is the quantity of the measured points. In this study, an exact 3D match was indicated by a low RMS score. To measure the 3D data, the castings were also separated into the mesial and distal sides using a line that split each abutment's mesiodistal region in half, and between the marginal and interior sections using a line that curved sharply towards the axial wall (Figures 1 and 2).
The statistical analysis was carried out using statistical software (IBM SPSS Statistics, v22.0; IBM Corp.). To find out if the kind of group and side, as well as how they interacted, affected the RMS values, a 2-way ANOVA was employed. To find significant differences between the groups, the post hoc Tukey HSD honestly significant difference (HSD) test (a=.05) was used.

Results

The mean RMS and standard deviation values for internal and marginal disagreement are displayed in Table 1. The internal (entire) RMS values in CS and 3DP were 25.55 mm and 53.77 mm, respectively, whereas the marginal (entire) RMS values were 34.88 mm and 43.56 mm. Furthermore, it was shown that the side accuracy between 3DP type and cast group had a significant interaction (P=0.009).
Significant differences were found between groups (P<0.001) and between side (P=0.007) internal RMS values, as shown in Table 2.
Nevertheless, the interaction effect between the groups and sides type (P=0.571) and the marginal RMS values between on the sides (P=0.762) were not significant. As seen in Table 3, the marginal and internal RMS values for 3PD were significantly higher than those for CS (P<0.001) according to the post hoc Tukey HSD test.
Color difference maps (figure 3) showed the variations between the FDPs' intaglio surface and the master model. The inside part of 3DP is shown in light blue on the vertical slopes (negative discrepancies) and dark yellow on the occlusal surfaces (positive discrepancies).

Discussion

Since disparities in the marginal and internal fits between the sides (mesial side and distal side) and groups (CS and 3DP) were found, the study's findings supported the rejection of the null hypothesis. One significant development for dental offices is the use of intraoral scanners. Stone cast alternatives, including 3D-printed casts, will be needed as this technique gains traction. In this work, FDPs created on stone casts and FDPs made on 3D-printed castings were compared for internal and marginal fit.
The entire digital process—from getting the scan to making the prosthesis—was contrasted with the conventional process in this study. Since the precision of the casts was compared in earlier studies, mistakes in the prosthesis fabrication process were eliminated [8,11,23]. As a result, the complete

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fabrication process was not evaluated. Because the current investigation was carried out in a standardized environment, the overall number of manufacturing errors at every stage of the workflow was reduced.

Both 2D and 3D approaches can be used to measure the prosthesis' internal and marginal fit. The replica, direct view, and cross-sectioning techniques are all part of the 2D measurement strategy. One These techniques quantify the amount of variation in pictures captured with a stereomicroscope or similar instruments. The incapacity of 2D measures to assess discrepancy at multiple sites is their primary drawback. In contrast, the 3D analysis measures the thickness of the inside and outside of virtual space numerous times.

Its use of a color map to visually represent the entire discrepancy is advantageous, as no information is lost that might arise from measuring just one area [24]. The temperature differential between the oral cavity and the surrounding air causes thermal contraction in silicone impression materials [24]. Because the imprint was created at ambient temperature, these errors were not replicated in our investigation. Consequently, a clinical impression was less accurate than a standard impression control. According to Mously et al., the internal gap increased as the spacer thickness setting increased. Additionally, several studies have demonstrated that the spacer thickness setting affects how well the prosthesis fits [2,3,25].

To get an exact RMS result in the current experiment, the spacer thickness was set to 0. Both the internal and marginal fits are influenced by the prosthesis's material [25]. In this investigation, a polyurethane block was utilized as the prosthetic material. Because this block is machined to the same size as the desired form, it has the advantage of reducing the issue of expansion and shrinkage during milling [18,25]. Furthermore, because it does not reflect light like metal, zirconia, or ceramic do, it is perfect for scanning and appropriate for 3D evaluation. A prosthesis made using CAD-CAM technology has had its marginal accuracy assessed [4,26]. The range of marginal discrepancies that are clinically important is unknown, and there are differences in the ranges of marginal fit that are clinically acceptable. In a 5-year clinical study involving 1000 restorations, McLean and von Fraunhofer determined that the maximum permissible marginal gap was 120 mm. Furthermore, the definition of clinically adequate internal fit values, which have been reported using a range of techniques, is still up for debate [25,26].

The present study also revealed that the RMS value of 3DP (53.77 mm) was higher than that of CS (25.55 mm) in the interior (entire) area, as indicated in Table 1 and depicted in Figure 3. According to Anadioti et al., a prosthesis built using the 3D printing method of stereolithography (SLA) die had a substantially better internal fit than one made using a stone die. These numerical values and results are comparable to those of the current investigation, even though the prosthesis material, measurement techniques, and 3D printing technology utilized to create the cast varied. Table 1 indicates that the current study found that in the marginal (entire) area, the RMS value of 3DP was greater than that of CS. This is consistent with Anadioti et al.'s findings [19,26], who concluded that a prosthesis manufactured on a stone die had a somewhat better fit than one manufactured on a SLA die. Numerous factors, such as postprocessing, materials, manufacturer setting parameters, and 3D printing procedures, affect the resolution and accuracy of 3D printers. For example, the SLA process is affected by horizontal resolution, which is determined by the diameter of the laser beam, and vertical resolution, which is dependent on layer thickness [27]. Moreover, changing the setup parameters leads to varying machining accuracy and build timeframes, which may result in residual internal tension during the post-curing phase and perhaps distort the prosthesis. When compared to the CS group, the 3DP group's greater RMS values in the internal and marginal areas are caused by the 3D printer's formative processes. In a 3D printer, materials are deposited toward the axis layer by layer. This layer-by-layer technique creates a stair-step impression on the object's surface [27,28]. As a result, the product may have dimensional errors or uneven surfaces [28]. Furthermore, because the DLP technique utilized in this study is based on a bottom-up projection in which the build platform moves higher, a polymerized layer is sandwiched between the resin vat and the layer that came before. When the build platform is removed from the vat during the construction process, the coagulated material may attach firmly to the resin and deform the item. [29]. The current study evaluated cast discrepancies by splitting the internal and marginal fit into mesial and distal sides in order to separate the data and appropriately measure the castings. The mesial and distal side RMS values in the marginal and internal areas were not statistically different, except for the 3DP group's internal RMS values (Figure 4).

This result appears to be due to the qualities of the material used in the 3D printer. A photopolymerization approach is required for resin, one of the materials used in the DLP process. Photopolymerization-induced material shrinkage can result in residual tension, skewing, or distortion in the final product. The RMS values on the distal side appear to be higher because the strain is directed toward the mesial side (Figure 4). According to an analysis of study results, prostheses made from stone casts fit better than those made from 3D-printed castings. The difference was barely noticeable as all findings fell below the clinically acceptable range (<120 mm) [30]. These findings strengthen the case for using 3D-printed casts for long-term prosthesis. However, because various factors in the mouth cavity influence the digitalization and impression processes, clinical trials should be conducted to assess 3D printing.

Conclusion

The following deductions were made considering the results of this in vitro investigation:

1) The 3DP group's internal and marginal RMS values were noticeably greater than the CS groups.

2) Nonetheless, the internal and marginal f values for both groups were within the clinically acceptable range (<120 mm).

3D printer accuracy needs to be further improved.

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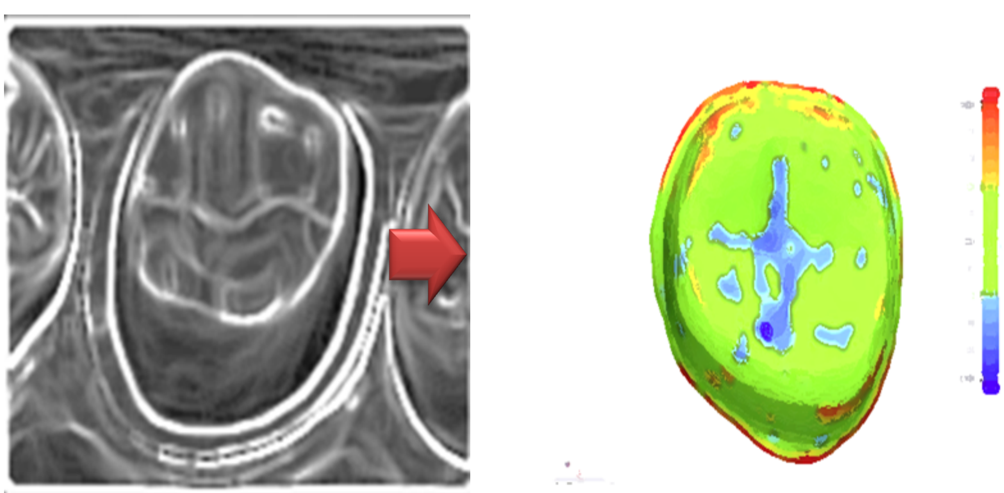
Figure 1. Scanning image analysis for single unit fixed dental prosthesis.

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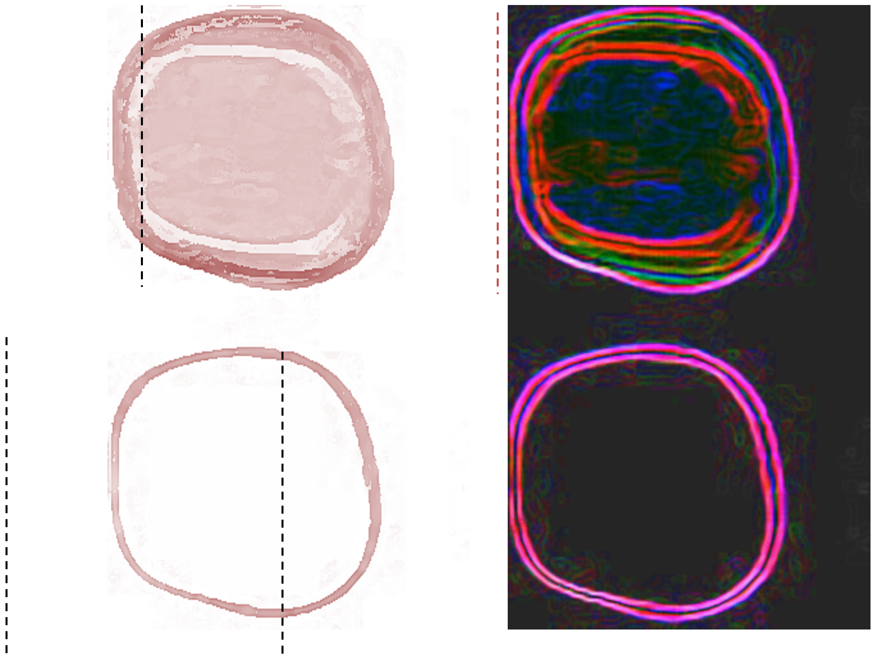

Figure 2. Single unit FDPs intaglio scan data subdivisions.

Table 1. RMS values for fixed partial dentures' internal (complete) gap and marginal (complete) discrepancy (mm).

The area	groups	N	(RMS) (micro m) Mean /Standard Deviation	p-value
discrepancy of the Marginal	CS	10	34.88/3.4	
	3DP	10	43.56/2.6	
Inferior gap	CS	10	25.55/2.1	
	3DP	10	53.77/2.5	0.001

Table 2. Mean and ±SD between groups and between sides (2-way ANOVA).

groups	N	Mesial Mean and Standard Deviation	Distal Mean and Standard Deviation	p-value
Conventional cast	10	27.66/2.4	28.77/2.4	
Three D printed	10	52.67/4.3	57.88/4.5	0.001

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Table 3. Mean and ±SD between groups and between sides (post-hoc Tukey HSD test).

groups	N	Mesial Mean and Standard Deviation	Distal Mean and Standard Deviation	p-value
Conventional cast	10	39.66/2.4	39.77/2.4	
Three D printed	10	54.67/4.3	54.88/4.5	0.001

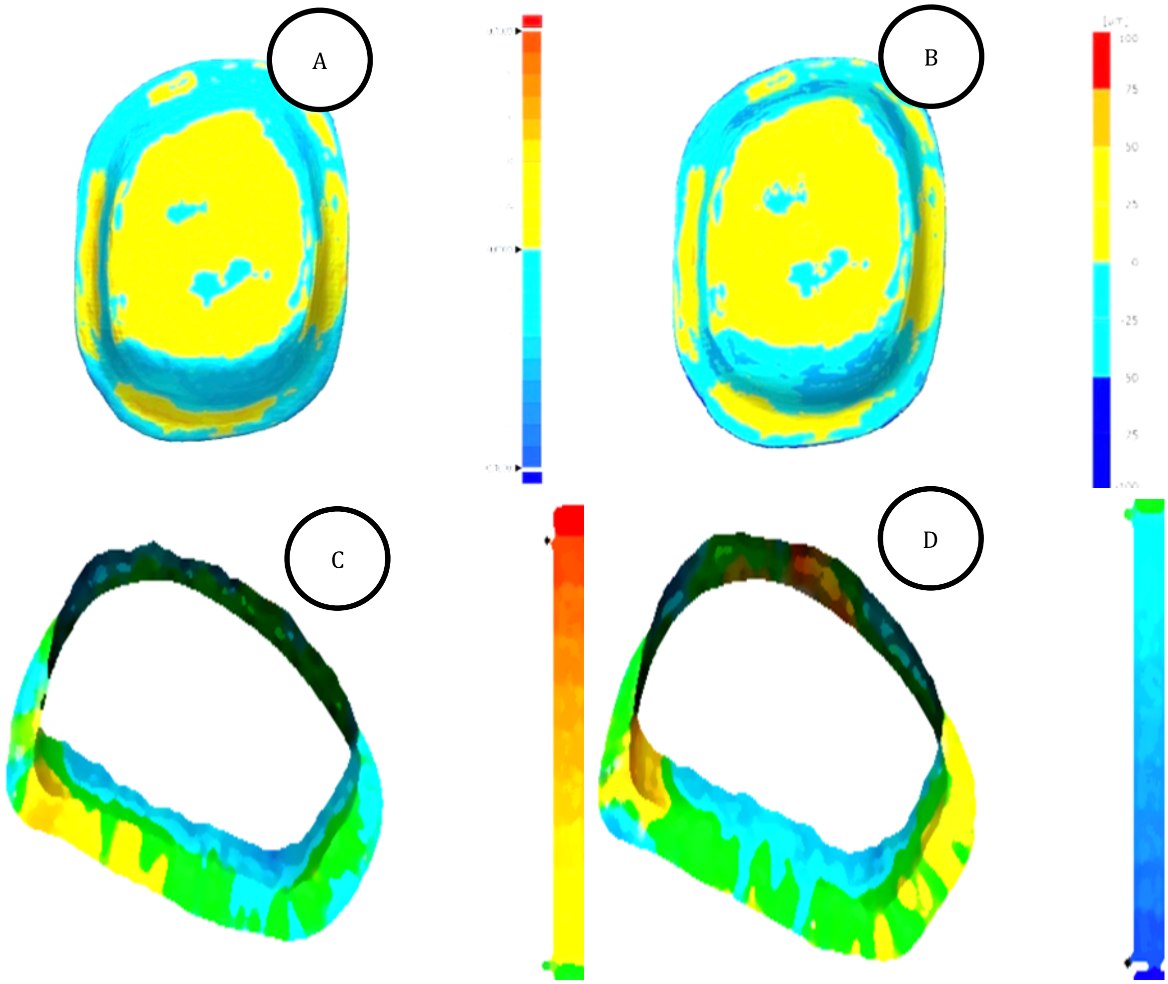

Figure 3. Maps showing differences in color. A, CS internal fit. B, 3DP's internal fit. C, CS's marginal fit. D, 3DP's marginal fit. 3DP stands for 3D-printed cast; CS stands for traditional stone cast.

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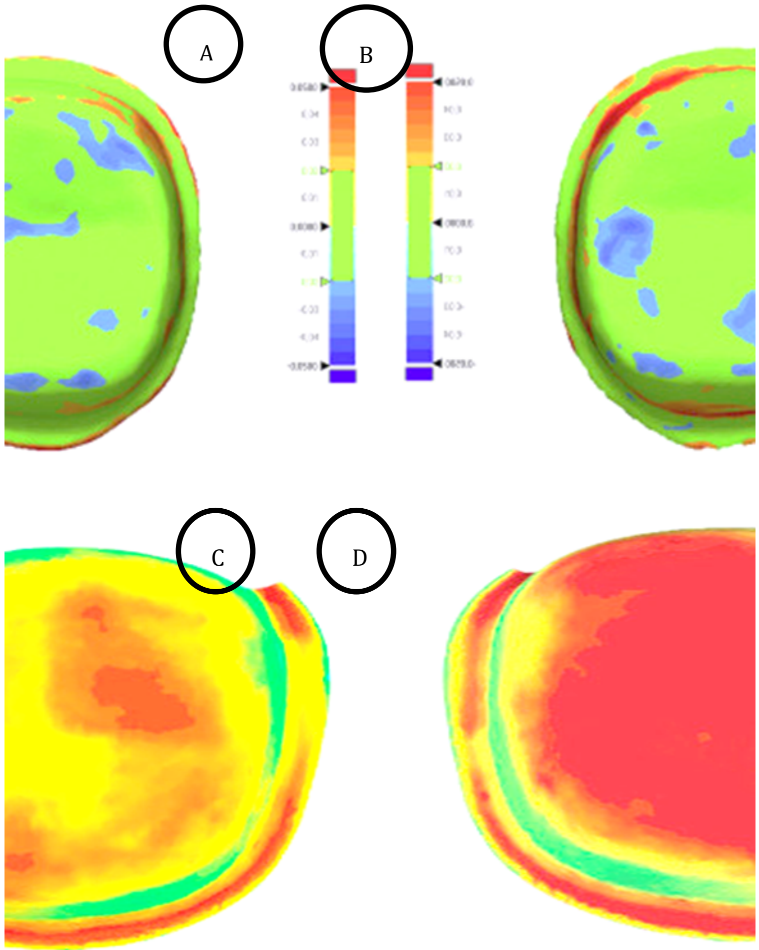

Figure 4. Color difference maps of inconsistencies. A: The mesial side of the CS's interior region. B: distal side in 3DP's interior area. C: mesial side in CS's interior area. D represents the distal side of the 3DP's internal area. 3DP stands for 3D-printed cast, while CS is for conventional stone cast.