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*Research Article*

# IMPACT OF REUSE OF DENTAL IMPLANT ANALOGS ON IMPRESSION ACCURACY

Sergen DENİZ[1], Mustafa ZORTUK[1], Taha Yaşar MANAV[1]*

[1] Department of Prosthodontics, Faculty of Dentistry, Mustafa Kemal University, Antakya, Hatay, Turkey

*Correspondence: tahamanav@gmail.com

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## ABSTRACT

**Objective:** This study aimed to examine the impact of repeated use of different implant impression analogs on the accuracy of the resulting impressions.

**Materials and Methods:** Implant bodies from three brands (Group SA: Straumann, Switzerland; Group DA: Dio Implant, South Korea; and Group MA: Mode Implant, Turkey) were used to create master models. Five reference casts were then fabricated for each brand (n=5) from these master models. Ten impressions were taken from each reference cast using the same analogs, which were sterilized between each impression. Both the reference and working casts were digitized using a three-dimensional scanner. The working casts were aligned with their respective reference casts using software (Geomagic, USA). One-way ANOVA was used to compare the groups, while repeated-measures ANOVA was used to compare the impressions within each group. Multiple comparisons were performed using the Bonferroni, Tukey's HSD, and Tamhane's T2 tests, with significance set at $p<0.05$.

**Results:** The RMS value for Group SA was 0.002 mm for the first impression, while the first impression RMS values for the other two groups were 0.04 mm and 0.03 mm, respectively. By the tenth impression, the RMS value for Group SA had increased to 0.08 mm, while the tenth impression RMS values for Groups DA and MA had reached 0.14 mm. Group SA demonstrated statistically significant differences after the third impression, whereas Groups DA and MA exhibited significant differences after the first impression.

**Conclusion:** The results of this in vitro study demonstrated that repeated use of the same implant impression analog had a negative impact on impression accuracy.

**Keywords:** Dental implants, Dental prosthesis, Impression technic

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## INTRODUCTION

Dental implant prosthetics represent one of the most rapidly expanding fields of dentistry with a notable impact on patient satisfaction. By expanding the range of possible treatments, these prosthetics have enabled the application of fixed implant-supported restorations in a variety of cases, thereby meeting patients' functional and aesthetic expectations more effectively (1).

When implant-supported fixed restorations are seated on abutments and do not create static loads within the prosthetic system or surrounding bone tissue, this condition is referred to as passive fit. A passive fit represents the optimal compatibility between the implant and prosthetic components. The attainment of passive fit is contingent on the implementation of a meticulous impression procedure (2).

Impressions in implant prosthetics can be obtained using a variety of techniques, which are broadly classified as conventional or digital. Impressions of conventional implants may be performed using either open-tray or closed-tray techniques. Impressions from implants differ from those from natural teeth in that they involve the use of impression copings and analogs, which vary depending on the chosen method and are screwed onto the implants. Impression copings, analogs, and screws connecting these components are critical elements that must be used with precision as they are essential for ensuring the accuracy of conventional implant impressions. The analog serves to replicate the implant embedded within the alveolar bone within the working cast, and remains a constituent part of the cast throughout the prosthetic fabrication process (3).
A multitude of variables can affect impression accuracy. In conventional techniques, several factors can influence the accuracy of the impression, including the selected method of impression, modifications to the impression copings, manner of connection of the copings to the analogs, dimensional stability of the gypsum used for cast fabrication, number of implants, angulation of the implants, and depth of the implants (4,5).

Manufacturers recommend that impression copings and analogs be used only once (6). However, owing to concerns regarding the cost and environmental impacts, these components are frequently reused. In light of these considerations, it is imperative to establish evidence-based guidelines for the reuse of impression components rather than relying on clinician preference.

The existing literature contains several studies on the reuse of implant components (7,8). Although studies have been conducted on the impact of reusing impression copings on impression accuracy, research on the effect of reusing impression analogs remains limited (8,9). The primary aim of this study was to evaluate the effect of the repeated use of impression analogs from three different implant brands on impression accuracy and surface changes, both within and between brands. The null hypothesis of this study was that the repeated use of impression analogs has no effect on impression accuracy.

## MATERIALS AND METHODS

The objective of this study was to assess the influence of the repeated use of implant analogs on the accuracy of impressions. The present study was approved by the Hatay Mustafa Kemal University Non-Interventional Clinical Research Ethics Committee (Approval date: April 14, 2022; decision number: 34).

Three master models were prepared for the three different implant brands to simulate an intraoral scenario with a missing maxillary first molar (tooth #16). To this end, tooth #16 regions were removed from the maxillary models (Frasaco Study Model ANA 4; Frasaco GmbH, Germany). Implant bodies from three different brands (Straumann 4.1 mm Bone Level, Dio UFII 4.5 mm Bone Level, Mode 4.5 mm Bone Level) were placed in the respective models with the aid of a parallelometer to ensure accurate positioning (Table 1). The implants were positioned within the sockets of tooth #16 until the implant neck was reached and then stabilized with cold acrylic resin (Integra, United Dental Group, Turkey). This process resulted in the creation of three maxillary models, which were divided into three groups. The resulting groups were designated as Group SA, Group DA, and Group MA.

**Table 1.** Details of dental implant analogs

| Groups | Product | Reference Number | Material | Brand |
|---|---|---|---|---|
| Group SA | RC Bone Level Implant Analog | 025.4101 | Titanium Alloy (Ti-6Al-7Nb) | Straumann, Straumann Group |
| Group DA | UFII Fixture Analog Regular | SSFA4012 | Titanium | Dio Implant, Dio Implant Co. |
| Group MA | Analog RP | 08.00.00.35 | Stainless steel-Cobalt alloy | Mode Implant, Mode Medikal |

For each group, five reference casts were produced using a conventional impression technique with A-type silicone material (Zhermack Hydrorise, Italy). The reference casts

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were digitized using an intraoral digital scanner (YouJoy Pioneering Park C, China) and saved in STL format for subsequent analysis.

Subsequently, repeated impressions were obtained from each reference cast until 10 working casts were obtained for each reference cast. Similarly, impressions were obtained using an A-type silicone material (Zhermack Hydrorise, Italy). To ensure accurate implant analog connections, a gingival simulator (Gingifast Rigid; Zhermack, Italy) was applied to the implant-level impressions to create a precise replica of the gingival margin. Subsequently, the impressions were poured with Type 4 gypsum (Elite Rock, Zhermack, Italy) to fabricate the working casts, which were then digitized and exported in the STL format.

For reuse, the implant analogs were meticulously extracted from the gypsum casts using a mechanical breaking device (GERATECH Landmaschinen GmbH, Thuringia, Germany). The analogs were manually cleaned for a period of two minutes using a soft nylon brush. Subsequently, the implant analogs were sterilized in an autoclave (Sumer Inc., Turkey) at 134°C for ten minutes, followed by a fifteen-minute drying process. The same implant analogs were utilized for subsequent impressions, although new impression copings and screws were used. This procedure was repeated ten times for each reference cast, resulting in a total of 50 working casts per group.

Digital working and reference casts were analyzed using Geomagic Control X software (Geomagic, USA). Prior to undertaking three-dimensional analyses, the reference casts for each group were aligned with their corresponding working casts using the "best fit alignment" feature of the software. The color-mapping feature of the software was employed to visualize the deviations between the aligned casts, with variations represented by a defined scale. Green areas indicated minimal deviations, while blue and red areas represented positive and negative deviations, respectively. Positive deviations (blue areas) indicated that the working cast was larger than the reference cast, whereas negative deviations (red areas) indicated narrower regions. These deviations were comparable to the expansion and shrinkage observed in conventional impressions.

Deviation thresholds were defined in accordance with the standards set forth by the American Dental Association (ADA) for elastomeric impression materials (Standard No. 19) (10). Green areas were regarded as acceptable, with deviations of ±20 μm, whereas blue and red areas were classified as deviations of ±100 μm. The software automatically calculated the three-dimensional displacements between scanned points using the Root Mean Square (RMS) value, which represents the square root of the mean squared deviation (Figure 1).

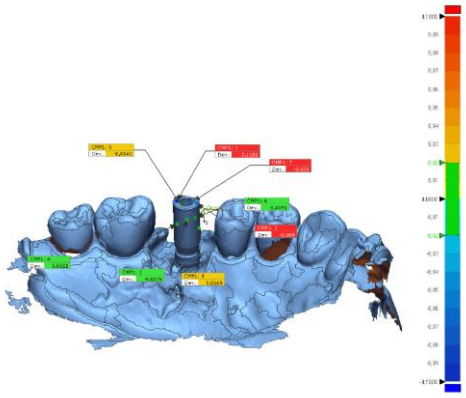

**Figure 1.** Calculation of RMS value by comparing 3D discrepancies between analogs in two casts by using software.

Statistical analyses were conducted using SPSS software (SPSS v23, IBM, USA). Comparison of RMS values based on impression order was performed using repeated-measures analysis of variance (ANOVA), while one-way analysis of variance (ANOVA) was used for comparisons of RMS values between groups. Post-hoc comparisons were performed using Bonferroni, Tukey's HSD, and Tamhane's T2 tests. Statistical significance was set at $p<0.05$.

## RESULTS

In each group, five root mean square (RMS) values were obtained for each impression order. The mean RMS values in millimeters for each group are presented in Table 2. Statistical analysis was conducted to examine the differences in RMS values across impression orders and between the groups. Comparisons between impression orders are presented in Table 2, and comparisons between groups are presented in Table 3. Additionally, the calculated RMS values are visually represented in Figure 2.

For Group SA, there was a statistically significant difference in the mean root-mean-square (RMS) values across impression order ($p<0.001$). The first three impressions showed significant differences when compared with the 8th, 9th, and 10th impressions.

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For Group DA, the mean RMS values showed a significant difference across impression order ($p<0.001$). In particular, the first impression showed a statistically significant difference from all subsequent impressions, and a similar pattern was observed for the second impression. The third impression exhibited similarities to the fifth impression only. Moreover, while the fourth impression exhibited similarities to the fifth impression, it demonstrated significant differences from all other impressions.

**Table 2.** Comparison of calculated mean RMS (mm) values according to the impression order.

| Imp Order | Group SA | Group DA | Group MA |
|---|---|---|---|
| Imp1 | 0.002±0.001$^{cd}$ | 0.043±0.016$^{g}$ | 0.033±0.017$^{f}$ |
| Imp2 | 0.003±0.001$^{cd}$ | 0.054±0.015$^{f}$ | 0.055±0.017$^{e}$ |
| Imp3 | 0.008±0.002$^{cd}$ | 0.064±0.015$^{e}$ | 0.065±0.016$^{d}$ |
| Imp4 | 0.033±0.016$^{d}$ | 0.076±0.017$^{d}$ | 0.074±0.016$^{c}$ |
| Imp5 | 0.045±0.016$^{c}$ | 0.088±0.023$^{cde}$ | 0.082±0.015$^{c}$ |
| Imp6 | 0.044±0.016$^{c}$ | 0.105±0.015$^{c}$ | 0.104±0.035$^{abcdef}$ |
| Imp7 | 0.055±0.017$^{bc}$ | 0.115±0.016$^{bc}$ | 0.106±0.046$^{abcdef}$ |
| Imp8 | 0.064±0.015$^{b}$ | 0.124±0.016$^{b}$ | 0.124±0.016$^{b}$ |
| Imp9 | 0.074±0.017$^{a}$ | 0.134±0.013$^{ab}$ | 0.133±0.015$^{b}$ |
| Imp10 | 0.084±0.015$^{a}$ | 0.141±0.015$^{a}$ | 0.145±0.014$^{a}$ |
| Test Statistics* | 81.646 | 519.591 | 3.155 |
| p | <0.001 | <0.001 | 0.007 |

Imp: Impression; a-f: No statistical difference between measurements with the same letter within each group; *Repeated Measures ANOVA

For Group MA, the mean root-mean-square (RMS) values showed significant differences across impression order ($p<0.001$). However, no significant differences were observed between the fourth and fifth impressions, sixth and seventh impressions, or eighth and ninth impressions.

A comparison of the groups showed that Group SA consistently exhibited more accurate results, with lower deviations than the other two groups for all repeated impressions, except for the sixth impression. No statistically significant differences were observed between the Groups DA and MA.

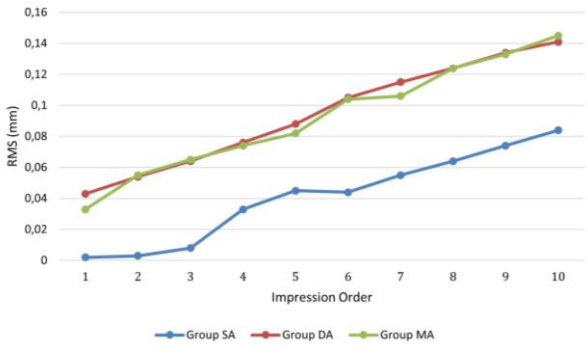
Upon examination of the data regarding the repeated use of analogs, Group SA demonstrated no statistically significant differences in the root-mean-square (RMS) values during the initial three impressions. However, a notable increase in RMS values was observed from the fourth impression onwards, and this increase was statistically significant. In contrast, both Groups DA and MA exhibited a significant increase in RMS values from the first impression, with this increase remaining statistically significant throughout the impression order.

**Table 3.** Calculated mean RMS (mm) values comparison between groups.

| Imp Order | Group SA | Group DA | Group MA | Test Statistics* | p |
|---|---|---|---|---|---|
| Imp1 | 0.002 ±0.001$^{a}$ | 0.043 ±0.016$^{b}$ | 0.033 ±0.017$^{b}$ | 12.380 | 0.001 |
| Imp2 | 0.003 ±0.001$^{a}$ | 0.054 ±0.015$^{b}$ | 0.055 ±0.017$^{b}$ | 24.107 | <0.001 |
| Imp3 | 0.008 ±0.002$^{a}$ | 0.064 ±0.015$^{b}$ | 0.065 ±0.016$^{b}$ | 52.427 | <0.001 |
| Imp4 | 0.033 ±0.016$^{a}$ | 0.076 ±0.017$^{b}$ | 0.074 ±0.016$^{b}$ | 10.238 | 0.003 |
| Imp5 | 0.045 ±0.016$^{a}$ | 0.088 ±0.023$^{b}$ | 0.082 ±0.015$^{b}$ | 8.168 | 0.006 |
| Imp6 | 0.044 ±0.016$^{a}$ | 0.105 ±0.015$^{b}$ | 0.104 ±0.035$^{b}$ | 10.359 | 0.002 |
| Imp7 | 0.055 ±0.017$^{a}$ | 0.115 ±0.016$^{a}$ | 0.106 ±0.046$^{a}$ | 3.194 | 0.077 |
| Imp8 | 0.064 ±0.015$^{a}$ | 0.124 ±0.016$^{b}$ | 0.124 ±0.016$^{b}$ | 22.586 | <0.001 |
| Imp9 | 0.074 ±0.017$^{a}$ | 0.134 ±0.013$^{b}$ | 0.133 ±0.015$^{b}$ | 24.622 | <0.001 |
| Imp10 | 0.084 ±0.015$^{a}$ | 0.141 ±0.015$^{b}$ | 0.145 ±0.014$^{b}$ | 26.632 | <0.001 |

Imp: Impression; a-b: No statistical difference between measurements with the same letter. *One-way ANOVA

**Figure 2.** Graphical representation of mean RMS values




## DISCUSSION

The findings revealed statistically significant differences among repeated impressions for all three groups ($p<0.05$). These findings indicate that repeated use of implant analogs affects impression accuracy and therefore leads to rejection of the null hypothesis.

Coordinate measuring machines (CMMs) are among the most used methods in the literature for mechanical evaluation; however, they have certain disadvantages. These include challenges associated with calibration and difficulties in consistently measuring the same point

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across repeated evaluations (10,11). Accordingly, research indicates that virtual measurements may offer greater reliability than their mechanical counterparts (10,11). In this study, digital measurement methods were employed to obtain more precise and repeatable results. Additionally, studies employing digital measurement methods can be found in the literature (12).

The results revealed significant differences in RMS values for Group SA after the third impression, whereas significant differences were observed starting from the first impression for the remaining two groups. It was found that repeated impression-taking, cast fabrication, and sterilization procedures affect the accuracy of implant impressions. Cleaning and sterilization processes have the potential to induce thermal and chemical stress on materials, which may result in changes in their surface morphology (13). Several studies have examined the impact of sterilization on reusable medical devices, with some indicating that morphological changes resulting from sterilization processes may affect clinical outcomes (14,15). For example, Yang et al. (15) determined that intra-aortic balloons could not be reused because of structural surface changes resulting from cleaning and sterilization processes. Furthermore, the reuse of balloon catheters has been linked to a decline in their mechanical properties (14). Conversely, other studies indicated that sterilization does not affect the clinical performance of specific medical devices. Gorokhovsky et al. (16) discovered that sterilization had no adverse effects on the clinical efficacy of stainless steel curettes. Similarly, Pernier et al. (17) reported that although autoclave sterilization caused a slight increase in surface roughness of orthodontic wires, it did not compromise their mechanical properties or clinical performance. Moreover, a study examining the influence of sterilization on the accuracy of impression copings and analogs revealed that sterilization did not affect impression accuracy (18). However, the findings of our study are not consistent with this conclusion, as it was determined that repeated impression-taking and sterilization stages exerted an influence on impression accuracy. The factors that may be responsible for this include damage incurred during the removal of the analog from the gypsum cast or deformation caused by repeated loosening and tightening of the screws.

It is possible that the screws used to secure impression copings to the analogs may have contributed to the observed deviations. It is possible that the increased deviations observed in this study may be attributed to deformation in the threads of the analog's screw receptacle, potentially resulting from repeated tightening. In a related study, Laskar et al. (19) examined the threads of implant analog screws made from different materials after repeated use and found significant wear, particularly in the screw threads. Yalavarthy et al. (7) advised that titanium implant analog screws should not be reused more than six times. In this study, new impression copings and screws were used for each impression. Nevertheless, analogous deformation may have occurred in the screw threads within the analogs. The occurrence of wear and damage at connection points represents a significant challenge for the accuracy of conventional impression techniques.

Another potential cause of analog non-reusability is damage incurred during the removal of the analog from the gypsum cast. When the connection region between the impression coping and the analog is damaged, it becomes impossible to accurately transfer the implant position to the impression. To ensure consistency, an industrial breaking device was employed in this study to remove the analogs, and all procedures were conducted by a single operator. Notwithstanding the implementation of standardization procedures and the utilization of automated devices, deviations were still discernible in the impressions. Given that in routine clinical workflows, the manual removal of analogs is standard practice and standardization is not maintained, the possibility of analog deformation increases.

Implant analogs are manufactured from various metal alloys, including stainless steel, aluminum, and titanium, depending on the implant system. The resistance of these alloys to changes during sterilization and reuse varies (20). In this study, Group SA analogs were composed of a titanium alloy (Ti-6Al-7Nb, TAN), Group DA analogs were made of titanium, and Group MA analogs were composed of a stainless steel-cobalt alloy. The discrepancies in accuracy observed among the groups may be attributed to variations in material composition. The TAN alloy exhibited superior corrosion resistance compared with grade 5 titanium and stainless steel (21). Additionally, the TAN alloy exhibited the lowest corrosion behavior among the titanium alloys and was therefore considered the most suitable for biomedical applications among the materials compared (22). This superior resistance may have resulted in less wear during the sterilization and removal processes, thereby explaining the higher accuracy and reduced deviations in repeated use observed for Group SA.

The literature contains an ongoing debate regarding the acceptability of deviations in impressions. Ma et al. (23) introduced the concept of "machining tolerance," which refers to the inherent inconsistency in implant impressions

due to the spatial relationships between metal components. The tolerances for these impressions ranged from 22 µm to 100 µm. Discrepancies in implant components may be attributed to the manufacturing process. Nevertheless, Assunçao et al. (24) proposed that deviations of up to 50 µm along any axis might be acceptable for well-made impressions. Some studies have utilized this threshold for the interpretation of their findings (25). In a review of 41 studies on impression accuracy, Lee et al.(5) reported that clinically acceptable deviations ranged from 0.6 to 136 µm. Consequently, there is no consensus in the literature regarding the definition of a clinically acceptable level of deviation. Even when the upper limit of 136 µm was used as a reference, only Group SA permitted up to 10 repeated impressions with the same analog. Given the limited literature on the reuse of analogs, further research is required.

A limitation of this study is the reliance on root-mean-square (RMS) values to evaluate the accuracy of impressions. While RMS provides a measure of overall three-dimensional accuracy, it does not offer detailed data on coronal, angular, or rotational deviations. Additionally, this study was conducted in vitro, and therefore factors such as the effects of saliva, temperature, and soft tissue on impression materials, as well as conditions specific to the oral cavity, were not simulated.

## CONCLUSION

Considering the limitations of this study, the following conclusions were drawn:
Statistically, Group SA analogs can be reused up to three times, whereas analogs from the other groups should ideally be used only once.
Given the lack of consensus in the literature on clinically acceptable deviation thresholds and the fact that the analogs were removed by breaking the casts, the reuse of impression analogs carries inherent risk.

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None

## Authorship contributions
Sergen Deniz contributed to the concept, design, data collection, analysis, literature search, and writing. Mustafa Zortuk contributed to the concept, design, and writing. Taha Yasar Manav contributed to the literature search and writing.

## Data availibity statement
The datasets analyzed during the current study are available from the corresponding author on reasonable request.

## Declaration of competing interest
The authors declare no conflict of interest related to this study.

## Ethics
This study was approved by the Hatay Mustafa Kemal University Non-Interventional Clinical Research Ethics Committee with the decision dated 14.04.2022 and numbered 04/34.

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