DOI: 10.24938/kutfd.1836746 Kırıkkale Üniversitesi Tıp Fakültesi Dergisi 2026;28(2):220-226
Original Article Özgün Araştırma

IN VITRO EVALUATION OF ACCURACY OF DIGITAL IMPRESSIONS VERSUS CONVENTIONAL IMPRESSIONS AT VARYING IMPLANT DEPTHS FOR SINGLE CROWNS

Tek Kronlar İçin Farklı İmplant Derinliklerinde Dijital ve Konvansiyonel Ölçülerin Doğruluğunun İn Vitro Değerlendirilmesi

Vildan HAMURCU[1] Nihal ÖZCAN[2] Elif YİĞİT İREN[2] Buse ÖZDEMİR ÖNAL[2]

[1] *Kırıkkale Oral and Dental Health Center, KIRIKKALE, TÜRKİYE*

[2] *Department of Prosthetic Dentistry, Faculty of Dentistry, Kırıkkale University, KIRIKKALE, TÜRKİYE*

ABSTRACT

Objective: This *in vitro* study aimed to evaluate the effect of implant vertical positioning on the accuracy of digital and conventional impressions for single implants using three-dimensional superimposition analysis.

Material and Methods: A master model with a single implant analog (Biohorizons, 5.7 mm) was prepared at three different gingival depths (2 mm, 4 mm, and 6 mm) in the mandibular first molar region. Digital impressions were obtained using two intraoral scanners (Trios 3Shape and Cerec Omnicam), while conventional impressions were taken using polyvinylsiloxane (PVS) and condensation silicone (Type C silicone). In total, 96 test models (n=8 per group) were generated. All models were digitized and compared to the reference STL model using reverse-engineering software (Rapidform) for 3D deviation analysis. Statistical analysis was performed using the Kruskal-Wallis and Mann-Whitney U tests (α=0.05).

Results: No statistically significant differences were observed between the digital impression groups ($p>0.05$). Among conventional techniques, the group using C-silicone showed significantly higher deviations than the PVS group ($p<0.05$). Increasing gingival depth resulted in significantly greater deviation values in all axes, especially in the y- and z-axes at 6 mm depth ($p<0.05$).

Conclusion: The vertical gingival depth has a significant influence on impression accuracy. Digital techniques maintain higher accuracy across varying depths, whereas conventional techniques, particularly those using C-silicone, exhibit reduced performance at deeper levels.

Keywords: *Digital impression, conventional impression, implant depth, accuracy, in vitro study*

ÖZ

Amaç: Bu *in vitro* çalışmanın amacı, tek implantlı restorasyonlarda implantın dikey konumunun dijital ve konvansiyonel ölçü tekniklerinin doğruluğu üzerindeki etkisini üç boyutlu süperimpozisyon analizleri kullanarak değerlendirmektir.

Gereç ve Yöntemler: Mandibular birinci molar bölgesinde yer alan bir implant analogu, üç farklı gingival derinlikte (2 mm, 4 mm, 6 mm) olacak şekilde ana modele yerleştirildi. Dijital ölçüler *Trios 3Shape* ve *Cerec Omnicam* tarayıcılarıyla, konvansiyonel ölçüler ise polivinilsiloksan (PVS) ve kondenzasyon tipi silikon (C-silikon) ile alındı. Toplam 96 test modeli (her grup için n=8) oluşturuldu. Tüm modeller dijitalize edilerek referans STL modeliyle karşılaştırıldı ve 3D sapma analizleri *Rapidform* yazılımı ile gerçekleştirildi. İstatistiksel değerlendirmede *Kruskal-Wallis* ve *Mann-Whitney U* testleri kullanıldı (α=0,05).

Bulgular: Dijital ölçü grupları arasında anlamlı bir fark saptanmadı ($p>0,05$). Konvansiyonel yöntemlerde C-silikonla alınan ölçüler, PVS grubuna kıyasla anlamlı derecede daha yüksek sapma gösterdi ($p<0,05$). Gingival derinlik arttıkça tüm eksenlerde, özellikle 6 mm derinlikte y- ve z-ekseni sapmalarında belirgin artış gözlendi ($p<0,05$).

Sonuç: İmplantın dikey gingival derinliği ölçü doğruluğunu anlamlı düzeyde etkilemektedir. Dijital ölçü teknikleri farklı derinliklerde yüksek doğruluğu korurken, konvansiyonel yöntemler-özellikle C-silikon-daha derin implant konumlarında belirgin doğruluk kaybı göstermektedir.

Anahtar Kelimeler: *Dijital ölçü, konvansiyonel ölçü, implant derinliği, doğruluk, in vitro çalışma*

Correspondence/Yazışma Adresi: **Dr. Nihal ÖZCAN**
Department of Prosthetic Dentistry, Faculty of Dentistry, Kırıkkale University, KIRIKKALE, TÜRKİYE
Phone/Tel: +905444665700 **E-mail**/E-posta: nihal.zcan@gmail.com
Received/Geliş Tarihi: 10.12.2025 **Accepted**/Kabul Tarihi: 02.02.2026

KÜ Tıp Fak Derg 2026;28(2):220-226
Doi: 10.24938/kutfd.1836746

INTRODUCTION

The long-term clinical success of implant-supported prostheses largely depends on the passive fit of the superstructure. Passive fit refers to the complete and tension-free adaptation of the prosthesis when not under occlusal load.[1] This is particularly critical because, unlike natural teeth, osseointegrated implants lack a periodontal ligament and, therefore, cannot compensate for misfits through physiological movement.[2,3]

Achieving a passive fit begins with an accurate reproduction of the intraoral implant position through impression procedures.[4,5] Several factors influence the accuracy of implant impressions, including the impression material, technique, implant position, and angulation.[6]

Obtaining accurate and repeatable impressions remains a clinical challenge. Numerous studies have compared digital and conventional impression techniques, particularly in complex cases involving multiple and angled implants.[7-10] While some findings favor digital impressions, others report better outcomes with conventional techniques or find both to be clinically acceptable.[11-13]

A limited number of studies have investigated the effect of vertical positioning of implants on impression accuracy. In clinical scenarios where implants are placed subgingivally due to esthetic, anatomical, or prosthetic requirements-impression copings may be located below the gingival margin.[14] This subgingival placement can compromise the stability of the coping within the impression material and negatively impact the accuracy of conventional impressions.[14,15]

Previous studies have reported inconsistent findings regarding the effect of implant depth on impression accuracy. While most investigations found no significant influence of equigingival or shallow subgingival placement, others emphasized reduced scan body visibility at greater depths and reported increased positional and angular deviations, indicating the absence of a clear consensus in the literature.[16,17]

Evaluation of the amount of linear displacement is the most commonly used method to assess the accuracy of implant impressions. Different methods are used to measure the amount of linear distortion. Some of these methods include measuring the linear distance (in a single plane) between implant or abutment centers with reference to each other, measuring the amount of displacement of implant or abutment centers in 3 dimensions (Dx, Dy, Dz), and measuring the total amount of change in linear distance (Dr, $Dr^2 = Dx^2 + Dy^2 + Dz^2$) of implant or abutment centers. Implant or abutment displacement is a crucial factor in evaluating the accuracy of an implant impression. Therefore, evaluating the amount of displacement of each implant or abutment midpoint in the x, y and z axes seems to be the most logical evaluation method to quantify the amount of linear distortion. Therefore, many studies have also evaluated the total amount of 3D displacement (Dr) to determine which measurement technique is more accurate.[5]

This study aimed to examine the impact of gingival depth on impression accuracy, independent of implant angulation and number, by evaluating a single parallel implant at different gingival depths. The null hypothesis was that implant depth and impression technique would have no significant influence on impression accuracy.

MATERIALS AND METHODS

Master Model Preparation

A straight implant analog (Wide Neck Bone Level Implant Analog, diameter 5.7 mm; Biohorizons, Birmingham, USA) was placed in the right mandibular first molar region (tooth 46) of dentate mandibular arch models (Frasaco GmbH, Germany) at three different gingival depths (2, 4, and 6 mm). Three master models were fabricated. A modified dental surveyor (Bredent BF1, bredent GmbH & Co. KG, Germany) was used to standardize vertical implant placement by ensuring parallel alignment of the implant-healing cap complex to the reference plane.

The implant analogs were positioned 2, 4, and 6 mm deeper than the cervical level of the adjacent teeth. Standardization of the buccolingual, mesiodistal, and cervico-occlusal positions was verified using a coordinate measuring machine (CMM, Eastman Machine Company Ltd, Derbyshire, UK). The implant analogs were fixed to the master model with cold self-cured acrylic resin (Procryla, President, Germany) using an appropriate spacer.

An ideal soft tissue thickness of 3 mm was assumed and considered as the bone level. To obtain standardized gingival contours, a cylindrical healing cap (radius 4 mm, height 10 mm) was fabricated by layering composite resin onto a standard healing cap, and dimensions were verified using a digital caliper (Digimatic CD15DCX Mitutoyo, Americana Ltd.) with composite resin (Filtek™ Z250, 3M ESPE, USA). Gingival modeling of tooth 46 was performed using baseplate wax around the healing cap screwed to the implant analog. A VPS index was fabricated according to the gingival contour dimensions, including adjacent teeth (Elite HD+, Zhermack SpA, Italy). The gingival areas of all master models were shaped using this index. The inner surface of the index was coated with petroleum jelly, and gingival silicone (Gingifast Elastic, Zhermack SpA, Italy) was applied to obtain standardized soft tissue contours. The silicone was allowed to set for 10 minutes in accordance with the manufacturer’s recommendations.

Digital impressions were performed using 2 different intraoral scanners, Trios 3 (3Shape, Copenhagen, Denmark) and cerec Omnicam (Sirona, Bensheim, Germany); conventional impressions were performed using 2 different impression materials: PVS (Elite HD, Heavy body and Light Body Zhermack SpA, Italy) and C-silicone (Zetaplus, Heavy body and Light Body Zhermack, Italy). A total of 96 test models were obtained with 4 types of impressions from 3 master models (n = 8 each). Groups were distributed as follows: group A: digital impressions were made by Trios 3Shape, group B: digital impressions were made by cerec Omnicam, group C: conventional impression with PVS, group D: conventional impression with type C-silicone.

Conventional Impression Phase

For conventional impressions, custom trays were fabricated from light-polymerized acrylic resin with tissue stops (Procryla, President, Germany). The trays were allowed to polymerize for 24 hours prior to impression making to minimize polymerization shrinkage. Before impression procedures, the impression coping was screwed onto the implant analog. All conventional impressions were obtained using the putty-wash technique at room temperature by a single operator. Residual impression material was removed from the master models between consecutive impressions.

The implant analog and impression coping were repositioned within the impression. Before the application of the gingival silicone, metal plates were used to isolate the implant area from adjacent teeth. A gingival separator (Gingifast Separator, Zhermack SpA, Italy) was applied around the impression post to prevent bonding between the impression and gingival silicones, followed by application of gingival silicone to simulate peri-implant soft tissue in the stone model. Type IV dental stone (Elite Rock, Zhermack SpA, Badia Polesine, Italy) was mixed under vacuum according to the manufacturer's recommended powder-to-water ratio (20 mL/100 g) using a vacuum mixer (Smart-Mix, Amann Girrbach) and poured carefully. A total of 48 stone casts obtained from conventional impressions were digitized using an industrial reference scanner (smartScan, Breuckmann, Meersburg, Germany). The 48 digital impressions acquired from intraoral scanners were also transferred to the computer. All standard tessellation language (STL) datasets obtained from intraoral scanners and digitized stone models were imported into reverse-engineering software (Rapidform XOR3, INUS Technology, Seoul, Korea) for three-dimensional comparison.

Digitalization of Conventional Impressions

An extraoral high-resolution industrial reference scanner (SmartScan, Breuckmann, Meersburg, Germany) was used to digitize the master models and the stone casts obtained from conventional impressions. The SmartScan system is a white-light 3D scanner with a resolution of 45 µm, suitable for reverse engineering and three-dimensional modeling applications. Scanning was performed under standardized light, temperature, and humidity conditions, and the data were recorded using the Optocat scanning software (Optocat 2015R2, AICON 3D Systems GmbH, Braunschweig, Germany). The manufacturer-recommended implant acquisition protocol was followed, and all datasets were exported in standard tessellation language (STL) format.

Digital impression

Scan bodies (Snap Scanbody Ø 5.7 mm, height 15 mm, PEEK; Biohorizons, Birmingham) were attached to the implant analogs using finger pressure. After scanning, virtual models were generated. Digital impressions obtained with Omnicam and Trios 3 were exported as STL files and imported into reverse-engineering software (Rapidform XOR3, INUS Technology Inc., Seoul, South Korea). The datasets were superimposed with the corresponding master models to evaluate three-dimensional deviations. Deviations were calculated and recorded along the x- (buccolingual), y- (mesiodistal), and z- (vertical) axes for each sample.

Accuracy and precision

Linear displacement values along the x-, y-, and z-axes were recorded in millimeters. Test scans were aligned to the reference scans using a best-fit algorithm, and deviation values were calculated. Geometric features corresponding to the cylindrical surface and top plane of the scan body were identified to define a reference intersection point, which was matched to the corresponding point in the test scan. Overall positional deviation and axis-specific deviations were measured by calculating the displacement of the implant analog midpoint relative to the master model.

Statistical analysis

Sample size determination was based on previous studies evaluating variables such as implant angulation, which reported group sizes ranging from 5 to 12 scans.[18,19] Statistical analyses were performed using IBM SPSS Statistics 23 (IBM Corp., Armonk, NY, USA). Data distribution was assessed with the Kolmogorov-Smirnov test and found to be non-normally distributed. Descriptive statistics were calculated for all variables. Comparisons among multiple groups were conducted using the Kruskal-Wallis test, followed by pairwise comparisons with the Mann-Whitney U test and Bonferroni correction. Statistical significance was set at $p<0.05$.

RESULTS

A statistically significant difference was found between the impression accuracies of different gingival depths. The values for different impression groups across gingival depths are shown in Table 1.

KÜ Tıp Fak Derg 2026;28(2):220-226
Doi: 10.24938/kutfd.1836746

Table 1: Comparison results of impression methods in models with different gingival depths

		6 mm gingiva				4 mm gingiva				2 mm gingiva			
		Median (P25-P75)	**Min-Max**		**p**	**Median (P25-P75)**	**Min-Max**		**p**	**Median (P25-P75)**	**Min-Max**		**p**
X	Trios 3	0.01 (0.009-0.014)	0.008-0.022	b	0.135	0.005 (0.004-0.006)	0.003-0.006	b	**0.014**	0.001 (0-0.002)	0-0.003	b	**<0.001**
	Omnicam	0.009 (0.008-0.019)	0.007-0.05	b		0.005 (0.003-0.006)	0.003-0.007	b		0.002 (0-0.003)	0-0.003	b	
	PVS	0.011 (0.009-0.022)	0.005-0.041	b		0.006 (0.005-0.007)	0.004-0.008	b		0.002 (0.001-0.003)	0-0.003	b	
	Type C silicone	0.036 (0.017-0.068)	0.005-0.12	b		0.01 (0.008-0.01)	0.001-0.012	a		0.006 (0.006-0.009)	0.003-0.015	a	
Y	Trios 3	0.011 (0.01-0.011)	0.008-0.013	b	**0.002**	0.006 (0.004-0.008)	0.003-0.263	b	**0.006**	0.001 (0.001-0.002)	0-0.002	b	**0.001**
	Omnicam	0.01 (0.009-0.013)	0.007-0.022	b		0.004 (0.003-0.006)	0.002-0.007	b		0.001 (0-0.002)	0-0.003	b	
	PVS	0.011 (0.009-0.013)	0.009-0.044	b		0.006 (0.005-0.007)	0.004-0.647	b		0 (0-0.002)	0-0.004	b	
	Type C silicone	0.061 (0.02-0.165)	0.012-0.288	a		0.021 (0.009-0.069)	0.006-0.276	a		0.008 (0.005-0.019)	0.003-0.027	a	
Z	Trios 3	0.008 (0.006-0.01)	0.003-0.026	b	**<0.001**	0.005 (0.003-0.006)	0.003-0.007	b	**<0.001**	0.001 (0-0.001)	0-0.002	b	**<0.001**
	Omnicam	0.009 (0.007-0.012)	0.006-0.024	b		0.004 (0.003-0.006)	0.003-0.007	b		0 (0-0.001)	0-0.002	b	
	PVS	0.016 (0.01-0.025)	0.008-0.035	b		0.005 (0.004-0.006)	0.003-0.008	b		0.001 (0.001-0.002)	0.001-0.002	b	
	Type C silicone	0.04 (0.036-0.057)	0.033-0.107	a		0.093 (0.044-0.144)	0.024-0.78	a		0.019 (0.012-0.106)	0.006-0.156	a	

At 2 mm and 4 mm gingival depths, significant differences were found among the impression groups in all three axes (x, y, and z) ($p<0.05$). Group D (conventional impressions with condensation silicone) exhibited significantly greater displacement in all axes compared with the other groups. No statistically significant differences were detected among groups A (Trios 3), B (Cerec Omnicam), and C (PVS).

At a gingival depth of 6 mm, no significant difference was observed among the groups along the x-axis; however, significant differences were observed along the y- and z-axes, with group D again demonstrating the highest deviation values ($p<0.05$) (Table 1).

Overall analysis using the Kruskal-Wallis test revealed a statistically significant difference among impression methods across all gingival depths ($p<0.05$). Group D consistently showed the highest deviation values, whereas no significant differences were found among groups A, B, and C (Table 2). Axis-specific analysis confirmed significantly greater deviations for group D in all three axes (Table 2).

Table 2: Results of different measurement methods according to ($a^2=xa+y^2+z^2$)

		Median (P25-P75)	**Min-Max**		**p**
2mm	Trios 3	0.06 (0.05-0.068)	0.017-0.075	b	**<0.001**
	Omnicam	0.064 (0.037-0.069)	0.011-0.077	b	
	PVS	0.066 (0.053-0.075)	0.029-0.09	b	
	Type C silicone	0.173 (0.161-0.363)	0.16-0.435	a	
4mm	Trios 3	0.124 (0.116-0.14)	0.105-0.519	b	**0.001**
	Omnicam	0.116 (0.111-0.12)	0.107-0.133	b	
	PVS	0.131 (0.119-0.139)	0.113-0.813	b	
	Type C silicone	0.326 (0.253-0.471)	0.247-1.032	a	
6mm	Trios 3	0.168 (0.16-0.192)	0.15-0.23	b	**<0.001**
	Omnicam	0.195 (0.175-0.204)	0.152-0.25	b	
	PVS	0.228 (0.172-0.259)	0.162-0.262	b	
	Type C silicone	0.397 (0.365-0.533)	0.246-0.596	a	
Total	Trios 3	0.124 (0.068-0.162)	0.017-0.519	b	**<0.001**
	Omnicam	0.116 (0.069-0.175)	0.011-0.25	b	
	PVS	0.131 (0.075-0.188)	0.029-0.813	b	
	Type C silicone	0.356 (0.246-0.436)	0.16-1.032	a	

Significant differences were observed among the 2 mm, 4 mm, and 6 mm gingival depths for all three axes (x, y, and z) ($p<0.001$) (Table 3). Total displacement analysis demonstrated that deviation values increased with increasing gingival depth across all impression methods. The Omnicam group showed the lowest overall deviation values. At 4 mm gingival depth, deviations across all axes were statistically similar, whereas at 2 mm depth lower deviation was observed in the z-axis and at 6 mm depth lower deviation was observed in the y-axis (Table 3).

KÜ Tıp Fak Derg 2026;28(2):220-226
Doi: 10.24938/kutfd.1836746

Table 3: Examination of differences between methods by groups

			Median (P25-P75)	Min-Max		p
Total	X	2mm	0.002 (0.001-0.003)	0.000-0.015	c	**<0.001**
		4mm	0.006 (0.004-0.007)	0.001-0.012	b	
		6mm	0.012 (0.009-0.023)	0.005-0.120	a	
	Y	2mm	0.002 (0.000-0.003)	0.000-0.027	c	**<0.001**
		4mm	0.006 (0.004-0.009)	0.002-0.647	b	
		6mm	0.011 (0.010-0.019)	0.007-0.288	a	
	Z	2mm	0.001 (0.000-0.004)	0.000-0.156	c	**<0.001**
		4mm	0.006 (0.004-0.016)	0.003-0.780	b	
		6mm	0.012 (0.008-0.034)	0.003-0.107	a	

a, b, c: different lowercase letters indicate significant differences between the medians of the groups (a = highest median).

DISCUSSION

The null hypothesis was rejected, as impression accuracy was significantly influenced by both implant vertical placement depth and impression technique. Accurate implant-level impressions are essential for achieving passive fit and minimizing mechanical and biological complications associated with implant-supported restorations.

Previous studies comparing digital and conventional impression techniques in single- or short-span restorations have reported inconsistent findings, although a general tendency toward higher precision with digital impressions has been described, particularly under challenging conditions.[20,21] Conventional impressions, however, remain a well-established method and may still be advantageous in selected clinical situations.[22] In the present study, both techniques were applied under standardized conditions, allowing direct comparison and highlighting differences related to subgingival implant positioning.

Vertical implant depth represents a critical clinical variable, as increased subgingival placement may reduce the visibility and stability of impression copings or scan bodies, thereby compromising impression accuracy.[23] While several studies have focused on implants placed at or above the gingival level and evaluated factors such as impression technique and implant number, the influence of vertical implant depth has been less extensively investigated.[24,25] The present findings contribute to this limited evidence by demonstrating that increased gingival depth adversely affects impression accuracy even for a single, parallel implant.

Impression accuracy is also dependent on the evaluation method used. Although various measurement techniques have been employed in previous studies, differences in application protocols may account for variability in reported outcomes. Three-dimensional superimposition allows for more comprehensive assessment of positional deviations, although it requires a reliable reference framework and may be influenced by subsequent manufacturing steps.[26] For this reason, a three-dimensional evaluation approach was adopted in the present study.

The literature reports conflicting results regarding the accuracy of digital versus conventional impressions. Some studies have shown superior accuracy of conventional impressions, particularly in angled implant configurations, whereas others have found no significant differences between techniques.[11,12,27] In full-arch impressions, digital and conventional methods have been reported to demonstrate comparable accuracy.[28] Assunçao et al. reported that condensation silicone produced the least accurate results among elastomeric materials in angled implant models, a finding consistent with the present study, in which condensation silicone exhibited the greatest deviations.[29] Differences among studies may be attributed to variations in experimental design, implant positioning, and measurement protocols.[30]

Several investigations have reported higher accuracy for digital impressions compared with conventional techniques in full-arch or multi-implant scenarios.[9,11] In contrast, Ribeiro et al. found comparable accuracy between digital and conventional impressions using three-dimensional superimposition.[12] The discrepancies between these findings and the present results may be related to the combined effects of vertical implant depth and scan body visibility on data acquisition.

In the present study, Trios 3 and Omnicam demonstrated linear deviations below the clinically acceptable threshold of 150 µm, consistent with previous reports.[31] PVS impressions also remained within this threshold, whereas condensation silicone exceeded it. Reduced scan body exposure in deeper subgingival positions has been reported to negatively affect digital impression accuracy.[32] Studies evaluating implant depth have reported increased positional and angular deviations with greater subgingival placement, although others found no significant influence of depth and recommended longer scan bodies to improve accuracy.[22,17,33] The present findings support the observation that increasing gingival depth leads to greater deviations across impression methods.

KÜ Tıp Fak Derg 2026;28(2):220-226
Doi: 10.24938/kutfd.1836746

Omnicam demonstrated the lowest deviation values at all gingival depths, which may be attributed to its ability to efficiently capture and align three-dimensional data under reduced scan body exposure. PVS impressions showed greater dimensional stability than condensation silicone, particularly at 2 mm and 4 mm depths, consistent with previous reports indicating that implant depth does not significantly affect PVS accuracy.[7]

Overall, the present study demonstrated that exact transfer of implant position was not achieved across all impression techniques. Digital impression systems, particularly Omnicam, showed higher precision than conventional methods, whereas condensation silicone exhibited the greatest deviations. Implant vertical depth significantly influenced impression accuracy, underscoring the importance of selecting an appropriate impression technique and properly positioning implants in subgingival clinical situations.

This study has certain limitations. Its *in vitro* design cannot fully replicate clinical conditions such as saliva, soft tissue variability, and patient movement. In addition, only a single, parallel implant configuration was evaluated, which may limit the generalizability of the findings.

Conflict of interest: The authors have no conflicts of interest to declare.

Researchers' Contribution Rate Statement: Concept/Design: NÖ, VH; Analysis/Interpretation: NÖ,VH; Data Collection: NÖ,VH; Writer:NÖ, EYİ, BÖÖ. Critical Review: EYİ, BÖÖ; Approver: NÖ, VH, EYİ, BÖÖ.

Support and Acknowledgement: This study was supported by the Scientific Research Projects Coordination Unit of Kırıkkale University (Project number: 2019/152).

*Ethical Approval/Informed Consent***:** This study was conducted in vitro and did not involve human or animal subjects. Therefore, ethical approval and informed consent were not required.

REFERENCES

1. Karl M, Rosch S, Graef F, Taylor TD, Heckmann SM. Static implant loading caused by as-cast metal and ceramic-veneered superstructures. *J Prosthet Dent.* 2005;93(4):324-330.
2. Del'Acqua MA, Chávez AM, Compagnoni MA, Molo F de A. Accuracy of impression techniques for an implant-supported prosthesis. *Int J Oral Maxillofac Implants.* 2010;25(4):715-721.
3. Kim Y, Oh TJ, Misch CE, Wang HL. Occlusal considerations in implant therapy: Clinical guidelines with biomechanical rationale. *Clin Oral Implants Res.* 2005;16(1):26-35.
4. Papaspyridakos P, Chen CJ, Gallucci G, Doukoudakis A, Weber HP, Chronopoulos V. Accuracy of implant impressions for partially and completely edentulous patients: A systematic review. *Int J Oral Maxillofac Implants.* 2014;29(4):836-845.
5. Kim JH, Kim KR, Kim S. Critical appraisal of implant impression accuracies: A systematic review. *J Prosthet Dent*. 2015;114(2):185-192.
6. Wee AG. Comparison of impression materials for direct multi-implant impressions. *J Prosthet Dent.* 2000; 83(3):323-331.
7. Lee SJ, Betensky RA, Gianneschi GE, Gallucci GO. Accuracy of digital versus conventional implant impressions. *Clin Oral Implants Res.* 2015; 26(6):715-719.
8. Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng IJ, Ercoli C. Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis. *J Prosthet Dent.* 2016;116(2):184-190.
9. Amin S, Weber HP, Finkelman M, El Rafie K, Kudara Y, Papaspyridakos P. Digital vs. conventional full-arch implant impressions: a comparative study. *Clin Oral Implants Res.* 2017;28(11):1360-1367.
10. Seelbach P, Brueckel C, Wöstmann B. Accuracy of digital and conventional impression techniques and workflow. *Clin Oral Investig.* 2013;17(7):1759-1764.
11. Roig E, Garza LC, Álvarez-Maldonado N, et al. *In vitro* comparison of the accuracy of four intraoral scanners and three conventional impression methods for two neighboring implants. *PLoS One.* 2020;15(2):e0228266.
12. Ribeiro P, Herrero-Climent M, Díaz-Castro C, et al. Accuracy of implant casts generated with conventional and digital impressions: An *in vitro* study. *Int J Environ Res Public Health.* 2018;15(8):1599.
13. Alikhasi M, Alsharbaty MHM, Moharrami M. Digital implant impression technique accuracy: A systematic review. *Implant Dent.* 2017;26(6):929-935.
14. Linkevicius T, Svediene O, Vindasiute E, Puisys A, Linkeviciene L. The influence of implant placement depth and impression material on the stability of an open tray impression coping. *J Prosthet Dent.* 2012;108(4):238-243.
15. Lee H, Ercoli C, Funkenbusch PD, Feng C. Effect of subgingival depth of implant placement on the dimensional accuracy of the implant impression: An *in vitro* study. *J Prosthet Dent.* 2008;99(2):107-113.
16. Flügge T, van der Meer WJ, Gonzalez BG, Vach K, Wismeijer D, Wang P. The accuracy of different dental impression techniques for implant-supported dental prostheses: A systematic review and meta-analysis. *Clin Oral Implants Res.* 2018;29(1):374-392.
17. Sequeira V, Harper MT, Lilly CL, Bryington MS. Accuracy of digital impressions at varying implant depths: An *in vitro* study. *J Prosthodont.* 2023;32(1):54-61.
18. Choi YD, Lee KE, Mai HN, Lee DH. Effects of scan body exposure and operator on the accuracy of image matching of implant impressions with scan bodies. *J Prosthet Dent.* 2020;124(3):379:e1-e6.
19. Park SW, Choi Y Do, Lee DH. The effect of the improperly scanned scan body images on the accuracy of virtual implant positioning in computer-aided design software. *J Adv Prosthodont.* 2020;12(3):107-113.
20. Abduo J, Palamara JEA. Accuracy of digital impressions versus conventional impressions for 2 implants: An *in vitro* study evaluating the effect of implant angulation. *Int J Implant Dent.* 2021;7(1):75.
21. Awad EM, ElSheikh MM, El-Segai AA, et al. Effect of soft tissue thickness on accuracy of conventional and digital implant impression techniques. *BMC Oral Health.* 2024;24(1):1318.

22. Giménez B, Özcan M, Martínez-Rus F, Pradíes G. Accuracy of a digital impression system based on active wavefront sampling technology for implants considering operator experience, implant angulation, and depth. *Clin Implant Dent Relat Res.* 2015;17(1):e54-e64.
23. Laohverapanich K, Luangchana P, Anunmana C, Pornprasertsuk-Damrongsri S. Different Implant subgingival depth affects the trueness and precision of the 3D dental implant position: A comparative *in vitro* study among five digital scanners and a conventional technique. *Int J Oral Maxillofac Implants.* 2021;36(6):1111-1120.
24. Balamurugan T, Manimaran P. Evaluation of accuracy of direct transfer snapon impression coping closed tray impression technique and direct transfer open tray impression technique: An *in vitro* study. *J Indian Prosthodont Soc.* 2013;13(3):226-232.
25. Sabouhi M, Bajoghli F, Dakhilalian M, Beygi A, Abolhasani M. Effects of impression coping design, impression technique, and dental undercuts on the accuracy of implant impressions assessed by 3-dimensional optical scanning: An *in vitro* study. *Implant Dent.* 2016;25(2):238-246.
26. Schmidt A, Wöstmann B, Schlenz MA. Accuracy of digital implant impressions in clinical studies: A systematic review. *Clin Oral Implants Res.* 2022;33(6):573-585.
27. Abdel-Azim T, Zandinejad A, Elathamna E, Lin W, Morton D. The influence of digital fabrication options on the accuracy of dental implant-based single units and complete-arch frameworks. *Int J Oral Maxillofac Implants.* 2014;29(6):1281-1288.
28. Berrendero S, Salido MP, Valverde A, Ferreiroa A, Pradíes G. Influence of conventional and digital intraoral impressions on the fit of CAD/CAM-fabricated all-ceramic crowns. *Clin Oral Investig.* 2016; 20(9):2403-2410.
29. Assuncao WG, Gennari Filho H, Zaniqueili O. Evaluation of transfer impressions for osseointegrated implants at various angulations. *Implant Dent.* 2004;13(4):358-366.
30. Akalin ZF, Ozkan YK, Ekerim A. Effects of implant angulation, impression material, and variation in arch curvature width on implant transfer model accuracy. *Int J Oral Maxillofac Implants.* 2013;28(1):149-157.
31. Wu HK, Chen G, Huang X, Deng F, Li Y. Accuracy of single-implant digital impression with various scanbody exposure levels at anterior and posterior regions. *J Dent.* 2023;138:104641.
32. Fluegge T, Att W, Metzger M, Nelson K. A Novel Method to evaluate precision of optical implant impressions with commercial scan bodies: An experimental approach. *J Prosthodont.* 2017;26(1):34-41.
33. Gimenez-Gonzalez B, Hassan B, Özcan M, Pradíes G. An *in vitro* study of factors influencing the performance of digital intraoral impressions operating on active wavefront sampling technology with multiple implants in the edentulous maxilla. *J Prosthodont.* 2017;26(8):650-655.