NEU PRESS
Diş Hekimliği DERGİSİ
Vol: 6 No: 2 Year: 2024 Research Article e-ISSN: 2687-5535
https://doi.org/10.51122/neudentj.2024.96

Effect of Scanbody Material and Mucosa Modification Technique on The Accuracy of Digital Impressions of Edentulous Arches with Multiple Implants

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Article Info

Article History

Received: 10.08.2023
Accepted: 27.05.2024
Published: 30.08.2024

Keywords:
Prosthesis,
Implant Supported Prosthesis,
Scan body,
Digital Impression.

ABSTRACT

Aim: The aim of current research is to evaluate the effect of scanbody material and additional reference markers in the form of artificial landmarks on the accuracy of digital impressions of edentulous arches with multiple implants.
Material and Methods: A model of an edentulous maxilla with six implants (BLT, RC, Institut Straumann, AG) was used as master model. PEEK and PMMA scanbodies were screwed on the implants and digital impressions were obtained with an intraoral scanner (TRIOS4, 3Shape). Reference markers made of flowable composite (C), gingival barrier material (GB), scannable silicone (S) were placed on the edentulous spaces and impressions were obtained. The master model was digitalized with an extraoral high-resolution reference scanner. Deviations of the predetermined points and inter-implant distances were calculated by using superimpositining technique.
Results: Inter-implant distance measurements showed that PEEK scanbodies demonstrated better precision than PMMA scanbodies, (p<.001). In the subgroups, also PEEK groups were more accurate than PMMA groups (p<.001). Kruskal-Wallis test also showed statistical difference in deviations of the predetermined points among the groups in precision (p<.001). Addition of markers did not influence the precision and trueness in PEEK groups but in PMMA groups both in distance measurements and predetermined point deviations.
Conclusion: Addition of reference markers does not make any significance in the accuracy of digital impressions when PEEK scanbodies are used. PMMA seems not to be an alternative material as scanbody material, addition of markers is needed.

Dijital Tarama Parçası Materyalinin ve Mukoza Modifikasyon Tekniğinin Çoklu İmplantlarla Dişsiz Arkların Dijital Ölçülerinin Doğruluğuna Etkisi

Makale Bilgisi

Makale Geçmişi

Geliş Tarihi: 10.08.2023
Kabul Tarihi: 27.05.2024
Yayın Tarihi: 30.08.2024

Anahtar Kelimeler:
Protez,
İmplant üstü Protez,
Tarama Parçası,
Dijital Ölçü.

ÖZET

Amaç: Dental implantların dijital ölçüleri yaygın olarak kullanılmaktadır ve dişsiz çenelerin tam ark taramaları için tek ve kısmi dişsiz boşluklara göre daha düşük doğruluk sonuçları vermektedir. Mevcut araştırmanın amacı, çoklu implantlı dişsiz arkların dijital ölçülerinin doğruluğu üzerinde, tarama gövdesi malzemesinin ve ek referans alanlarının etkisini değerlendirmektir.
Gereç ve Yöntem: Ana model olarak altı implantlı (BLT, RC, Institut Straumann, AG) dişsiz bir maksilla modeli kullanılmıştır. PEEK ve PMMA tarama gövdeleri implantlara yerleştirilmiş ve bir ağız içi tarayıcı (TRIOS4, 3Shape) ile dijital ölçüler alınmıştır. Dişsiz boşluklara akışkan kompozit (C), dişeti bariyer materyali (GB), taranabilir silikondan (S) yapılmış referans işaretleyiciler yerleştirilmiş ve ölçüler alınmıştır. Ana model, yüksek çözünürlüklü bir referans tarayıcı ile dijitalleştirilmiştir. Önceden belirlenen noktaların sapmaları ve implantlar arası mesafeler çakıştırma tekniği kullanılarak hesaplanmıştır. Çoklu karşılaştırmaları belirlemek için Mann Whitney U ve Kruskal Wallis-H testi yapılmıştır.
Bulgular: İmplantlar arası mesafe ölçümleri, PEEK tarama gövdelerinin PMMA tarama gövdelerinden daha iyi hassasiyet gösterdiğini göstermiştir (Ortalama sapmalar; PEEK: 40±4 mμ, PMMA: 127±6 mμ, p<,001). Alt gruplarda da PEEK grupları PMMA gruplarına göre daha doğru sonuçlar vermiştir (p<,001). Kruskal-Wallis testi de kesinlikte gruplar arasında önceden belirlenmiş noktaların sapmalarında istatistiksel olarak farklılık göstermiştir (p<,001). Ek referans alanlarının eklenmesi, PEEK gruplarında ölçünün kesinliği ve doğruluğu etkilememiştir.
Sonuç: PEEK tarama gövdeleri kullanıldığında, referans işaretçilerin eklenmesi dijital ölçülerin doğruluğunda herhangi bir anlam ifade etmemektedir. PMMA, tarama gövdesi malzemesi olarak alternatif bir malzeme gibi görünmüyor, ek referans alanlarının eklenmesi gerekmektedir. Ancak farklı tarama teknolojileri ile daha ileri çalışmalar yapılmalıdır.

To cite this article: Göksoy F., Çağıl Ayvalıoğlu D., Gökçen-Röhlıg B. Effect of Scanbody Material and Mucosa Modification Technique on The Accuracy of Digital Impressions of Edentulous Arches with Multiple Implants. NEU Dent J, 2024;6:131-41. https://doi.org/10.51122/neudentj.2024.96

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INTRODUCTION

One of the critical criteria for the success of implant-supported prosthesis applications is the fabrication of prostheses with passive fit. To achieve prostheses with passive fit, it is crucial to accurately transfer the angles and positions of implants placed within the jawbone onto the working model, necessitating precise impressions of the implant superstructures.[1] Traditional and digital impression methods are used to obtain measurements for implant-supported prostheses. In recent years, digital impressions have gained popularity compared to conventional methods due to their clarity of data and ease of use, with intraoral scanners becoming widely used in clinical practice.

During digital impression-taking, it is vital to ensure that the scan bodies' surfaces are fully visible. Once adequate imaging is achieved, the scan bodies' images are matched with the digital libraries of implant manufacturers, facilitating accurate determination of implant analog positions. Today, major manufacturers produce scan bodies made from different materials, such as polyether ether ketone (PEEK), aluminum alloys, titanium alloys, and resins.[2-5] The impact of using scan bodies made from different materials on impression accuracy remains to be debated, with insufficient data currently available.[1]

The digital impression technique is highly sensitive when taking impressions in edentulous patients due to the absence of anatomical reference points like teeth. It has been noted that deviations during scanning increase with the rising number of implants placed in edentulous arches.[6] Therefore, the lack of sufficient anatomical structures that could serve as references complicates achieving accurate measurements in fully edentulous arches. Establishing additional reference points during imaging to prevent deviations in the images and ensure uninterrupted continuity of measurements during scanning is believed to contribute to measurement accuracy.[6]

Since natural teeth are absent in complete edentulism, discrepancies are also observed during the merging of obtained images within the software and during obtaining a virtual model. This study is designed based on the assumption that having reference points during scanning facilitates the alignment of scanned areas, thereby enhancing measurement accuracy. In addition to investigating the effect of added reference points in edentulous regions, the study aims to explore how differences in digital scanning materials and body design impact the digital measurement of multiple implants in fully edentulous arches. This study tests two hypotheses:

1. PEEK scan bodies provide more precise measurements than PMMA scan bodies.
2. The use of additional reference areas increases measurement accuracy.

MATERIALS AND METHODS

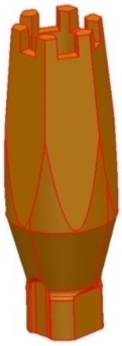
In this study, an upper jaw model mimicking complete edentulism was used as the primary model. The main model was produced using a 3D printer (Uniz NBEE 3d, 9400 Activity Rd Ste L San Diego, CA 92126, US) with pink-colored resin to mimic gum tissue color (Figure 1).

Figure 1: Master Resin Model

Six implants (bone level 4.1-10mm, BLT, RC, Institut Straumann, AG, Basel, Switzerland) were placed parallel to each other on the obtained model using a parallelometer. The implants were positioned in the regions of teeth numbered 16, 14, 12, 22, 24, and 26.

The design of the polymethyl methacrylate (PMMA) digital impression post was created using Powershape software (Autodesk 2021). Additional reference areas were incorporated into the design to enhance measurement accuracy and reduce deviation. Production was carried out using a 3D printer (Uniz NBEE 3d, 9400 Activity Rd Ste L San Diego, CA 92126, US) with PMMA resin (Uniz Z Dental Model, 9400 Activity Rd Ste L San Diego, CA 92126, US) (Figure 2).

Figure 2: CAD design of PMMA digital impression scan body



The study comprises 8 groups. Prior to the study, power analysis was conducted using SPSS software to determine the sample size of the research groups. Based on an effect size of 0.5 and a significance level of 0.05, it was determined that measurements should be taken from 40 points in each group.

During the placement of modification materials, soft tissue and palatal mucosa areas between implants were selected to create additional reference areas. The exact number and locations of modifications—gingival barriers, composite, and scannable silicone—were applied in all study groups (Figure 3). Polymerizations of reference materials were performed according to manufacturers' instructions, and measurements were taken after polymerization was completed. Details of materials used in group formations and modifications are provided in Table 1.

Figure 3: a) PEEK b) PEEK + GB c) PEEK + C d) PEEK + S

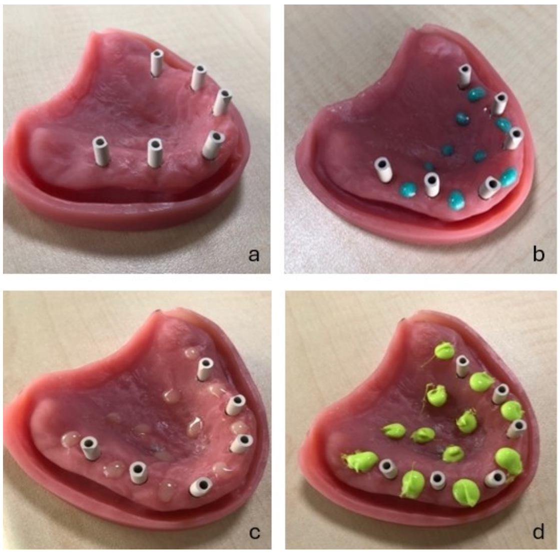


Table 1: The material list

Group	Modification	Firm
PEEK	----------	Institut Straumann, AG, Basel, Switzerland
PEEK+GB	Gingival Barrier(GB)	Scan Body: Institut Straumann, AG, Basel, Switzerland OpalDam Green Light Cured Gingival Barrier, Ultradent Products, Inc,USA
PEEK+C	Composite (C)	Scan Body: Institut Straumann, AG, Basel, Switzerland 3M ESPE Filtek Ultimate Flowable Restorative A2 Shade
PEEK+S	Scannable Silicone (S)	Scan Body: Institut Straumann, AG, Basel, Switzerland Aqium 3D Light Scannable, Müller Omicron Dental, Germany
PMMA	-----------	----------
PMMA+GB	Gingival Barrier (GB)	OpalDam Green Light Cured Gingival Barrier, Ultradent Products, Inc,USA
PMMA+C	Composite (C)	3M ESPE Filtek Ultimate Flowable Restorative A2 Shade
PMMA+S	Scannable Silicone (S)	Aqium 3D Light Scannable, Müller Omicron Dental, Germany

In a prospective and double-blind study design, all digital measurements were taken by an assisting researcher (GG). An experienced CAD specialist at Mayıs Design conducted overlaps. Other researchers (BGR and DA) analyzed overlap results using coded data for group names. Following evaluations and statistical analyses, the researcher who performed the scans replaced these codes with actual group names.

The researcher who took digital measurements has worked with digital measurements for approximately 2 years as a clinician. However, to ensure standards, the researcher calibrated the study model by scanning it five times under the supervision of an expert familiar with the system before scans. Digital group measurements were obtained using an intraoral scanner (TRIOS4, 3Shape, Denmark). Five scans were conducted from each group, and data in STL format were saved. After each scan, the scan body was removed, replaced, and manually removed to eliminate errors due to improper seating. In PMMA groups, only the scan body was designed and produced, and the system's original screw was used to attach the measurement post to the implant.

After completing scans for one group, a 10-minute break was taken to rest the device and the clinician; no more than two groups were scanned daily. Scans were performed at room temperature and under daylight.

The digital master model was created by scanning the resin model using an industrial scanner (SOLUTIONIX, MEDIT Corp., 23 Goryeodae-ro 22 gil, Seongbuk-gu, Seoul, Korea). Scanning data from intraoral scanners for group scans and industrial scanners for reference model scans were saved as STL files and imported into Geomagic Control X (3D Systems, Rock Hill, SC, USA) software. Reference model data (digital master model) were loaded into the program for image alignment. Data for comparison areas on the program, soft tissue areas, and distances between implants were processed. Eight points were identified in soft tissue when selecting points, the implant distances were evaluated using seven different measurements, and the images were merged (Figure 5). Seven different measurements were taken to assess the distances between implants, and images were overlaid. During measurements, implants were numbered from 1 to 6, and the measurements were conducted as follows: (1-2), (2-3), (3-4), (4-5), (5-6), (1-6), and (2-5) (Figure 6).

Figure 4: a) PMMA b) PMMA+GB c) PMMA + C d) PMMA+ S

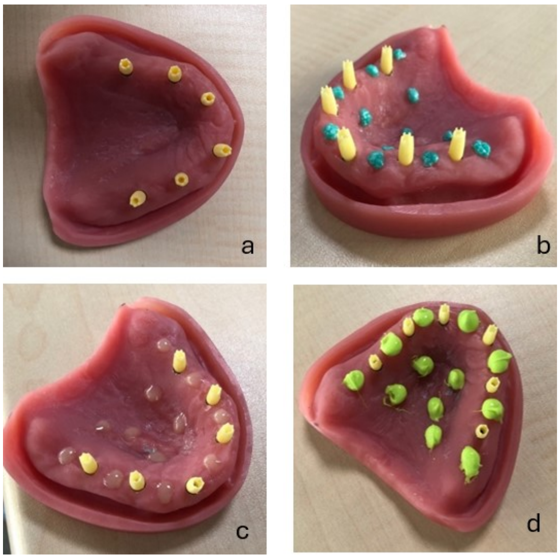


Figure 5: Calculation of soft tissue deviations

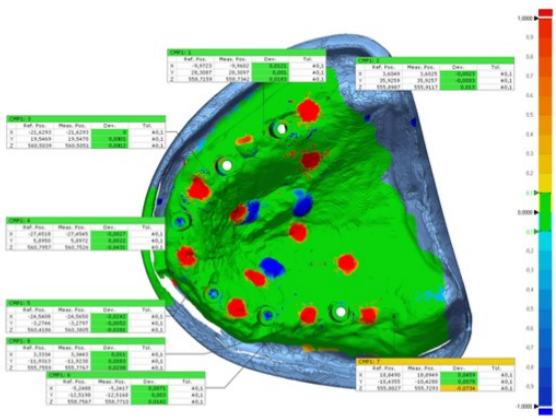
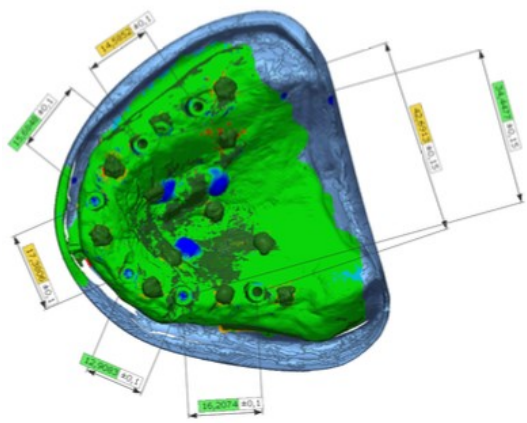


Figure 6: Measuring distances between implants



The data obtained in this study were analyzed using IBM SPSS 28 (MAC OS). Descriptive statistical methods such as mean, standard deviation, median, frequency, ratio, minimum, and maximum were employed to evaluate the study data. The normality of variables was assessed using histogram graphs and the Kolmogorov-Smirnov test. For variables that did not exhibit normal distribution, analyses were performed using the Kruskal-Wallis and Mann-Whitney U tests. Cases where the p-value was less than 0.05 were considered statistically significant.

RESULTS

In this study, a complete edentulous jaw model produced using a 3D printer was used to place 6 implants, aiming to investigate the in vitro impact of digital scanning material and modifications added to edentulous areas on the accuracy of digital measurements of multiple implants. During hypothesis testing, deviations at pre-defined points in soft tissue areas and deviations observed in the measurement of distances between implants were evaluated separately.

1) Evaluation of Inter-Implant Distance Measurements

The impact of added modifications on measurement accuracy was assessed by comparing distances between implants. It was observed that modifications significantly affected measurement accuracy at a statistically significant level ($p < 0.05$) (Table 2, Figure 7). The mean deviation values for groups were calculated as follows: 0.40 ± 0.35 mm for PEEK group, 0.51 ± 0.47 mm for PEEK + GB group, 0.51 ± 0.43 mm for PEEK + C group, 0.43 ± 0.38 mm for PEEK + S group, 0.12 ± 0.61 mm for PMMA group, 0.97 ± 0.64 mm for PMMA + GB group, 0.70 ± 0.49 mm for PMMA + C group, and 0.83 ± 0.52 mm for PMMA + S group.

Figure 7: Graphical comparison of group means

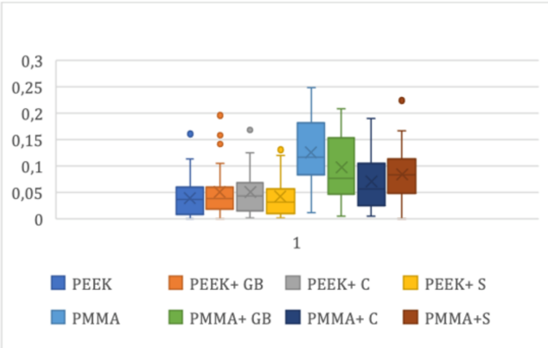


Table 2: Analysis of the Effect of Modification Addition on the Distance Between Implants

	Mean (mm)	SD	Median	Minimum	Maximum	Range	Test Statistics[a]	
PEEK	0.04	0.03	0.03	0.0006	0.16	0.16	Kruskal-Wallis H	65.604
PEEK-GB	0.05	0.04	0.03	0.0005	0.19	0.19		
PEEK-C	0.05	0.04	0.04	0.0017	0.17	0.16	df	7
PEEK-S	0.04	0.03	0.03	0.0030	0.13	0.13		
PMMA	0.12	0.06	0.11	0.01	0.24	0.23		
PMMA-GB	0.09	0.06	0.07	0.006	0.20	0.20	Asymp.Sig	<0.001
PMMA-C	0.07	0.04	0.05	0.005	0.18	0.18		
PMMA-S	0.08	0.05	0.08	0.001	0.22	0.22		

a: Kruskal Wallis Test, p< 0.05

The Mann-Whitney U test revealed statistically significant differences ($p < 0.001$) between several groups: PEEK-PMMA+S, PEEK-PMMA+GB, PEEK-PMMA, PEEK+S-PMMA+S, PEEK+S-PMMA+GB, PEEK+S-PMMA, PEEK+GB-PMMA+GB, PEEK+GB-PMMA, PEEK+C-PMMA, and PMMA+C-PMMA (Table 3).

Table 3: Intergroup analysis of the difference in the distance between implants

Pairwise Comparisons					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test St.	Sig.	Adj. Sig.[a]
(PEEK)-(PEEK+S)	-5.686	19.356	-0.294	0.769	1.000
(PEEK)-(PEEK+GB)	-16.343	19.356	-0.844	0.398	1.000
(PEEK)-(PEEK+C)	-21.157	19.356	-1.093	0.274	1.000
(PEEK)- (PMMA+C)	-51.129	19.356	-2.641	0.008	0.231
(PEEK)- (PMMA+S)	-70.186	19.356	-3.626	<0.001	0.008
(PEEK)- (PMMA+GB)	-81.071	19.356	-4.188	<0.001	0.001
(PEEK)-(PMMA)	-118.200	19.356	-6.107	<0.001	0.000
(PEEK+S)- (PEEK+GB)	10.657	19.356	0.551	0.582	1.000
(PEEK+S)- (PEEK+C)	15.471	19.356	0.799	0.424	1.000
(PEEK+S)- (PMMA+C)	-45.443	19.356	-2.348	0.019	0.529
(PEEK+S)- (PMMA+S)	-64.500	19.356	-3.332	<0.001	0.024
(PEEK+S)- (PMMA+GB)	-75.386	19.356	-3.895	<0.001	0.003
(PEEK+S)-(PMMA)	-112.514	19.356	-5.813	<0.001	0.000
(PEEK+GB)- (PEEK+C)	-4.814	19.356	-0.249	0.804	1.000
(PEEK+GB)-(PMMA+C)	-34.786	19.356	-1.797	0.072	1.000
(PEEK+GB)- (PMMA+S)	-53.843	19.356	-2.782	0.005	0.151
(PEEK+GB)-(PMMA+GB)	-64.729	19.356	-3.344	<0.001	0.023
(PEEK+GB)-(PMMA)	-101.857	19.356	-5.262	<0.001	0.000
(PEEK+C)-(PMMA+C)	-29.971	19.356	-1.548	0.122	1.000
(PEEK+C)-(PMMA+S)	-49.029	19.356	-2.533	0.011	0.317
(PEEK+C)- (PMMA+GB)	-59.914	19.356	-3.095	0.002	0.055
(PEEK+C)-(PMMA)	-97.043	19.356	-5.014	<0.001	0.000
(PMMA+C)-(PMMA+S)	-19.057	19.356	-0.985	0.325	1.000
(PMMA+C)-(PMMA+GB)	29.943	19.356	1.547	0.122	1.000
(PMMA+C)-(PMMA)	67.071	19.356	3.465	<0.001	0.015
(PMMA+S)-(PMMA+GB)	10.886	19.356	0.562	0.574	1.000
(PMMA+S)-(PMMA)	48.014	19.356	2.481	0.013	0.367
(PMMA+GB)-(PMMA)	37.129	19.356	1.918	0.055	1.000

The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Statistical analysis showed that the PEEK group exhibited less deviation compared to both PMMA and PMMA with modifications ($p < 0.05$).

When evaluating the intra-group differences in inter-implant distance measurements within PMMA and PEEK groups, no significant difference was found within PEEK groups ($p > 0.05$) (Figure 8). However, within PMMA groups, statistically significant differences were observed among groups ($p < 0.05$) (Figure 9 Table 4). Further analysis indicated that the significant difference within PMMA groups was primarily driven by the PMMA + C - PMMA comparison, where the difference was statistically significant at $p < 0.001$ (Table 4).

Table 4: Analysis of the difference in inter-implant distance measurements in PMMA groups

Pairwise Comparisons of PMMA Groups					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
(PMMA+C)- (PMMA+S)	-9.47	9.695	-0.97	0.329	1.000
(PMMA+C)- (PMMA+GB)	15.47	9.695	1.59	0.111	0.663
(PMMA+C)- PMMA	36.82	9.695	3.79	<0.001	0.001
(PMMA+S) -(PMMA+GB)	6.00	9.695	0.61	0.536	1.000
(PMMA+S) - PMMA	27.35	9.695	2.82	0.005	0.029
(PMMA+GB)- PMMA	21.35	9.695	2.20	0.028	0.166

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 5: Intergroup analysis of soft tissue deviations

	Descriptive Statistics				Test Statistics[a]	
	N	Minimum	Maximum	Mean ± SD		
PEEK	40	0.001	0.22	0.09± 0.05	Kruskal-Wallis H	3.94
PEEK-C	40	0.015	0.24	0.10± 0.06	df	7
PEEK-S	40	0.005	1.86	0.29 ± 0.58		
PMMA	40	0.0001	0.22	0.08± 0.05		
PMMA-GB	40	0.004	0.85	0.12 ± 0.16	Asymp.Sig	0.78
PMMA-C	40	0.008	0.28	0.10 ± 0.06		
PMMA-S	40	0.004	1.85	0.28 ± 0.50		
PEEK-GB	40	0.005	0.28	0.09 ± 0.06		

Figures 8: Intragroup evaluations of deviations in the distance between implants PEEK group

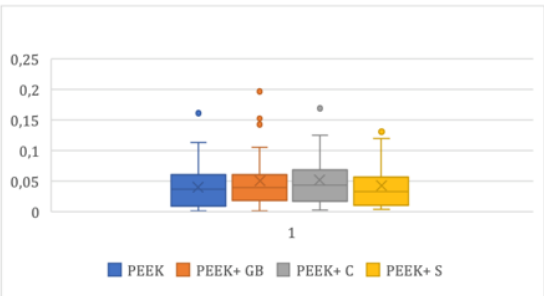
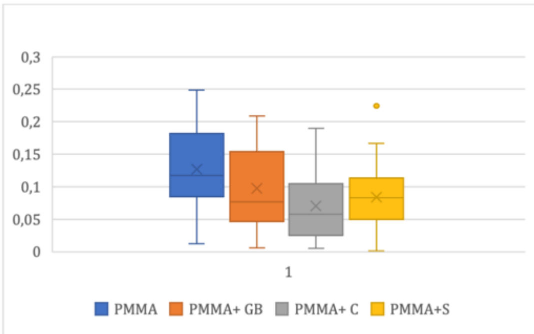


Figure 9: Intragroup evaluations of deviations in the distance between implants, PMMA group



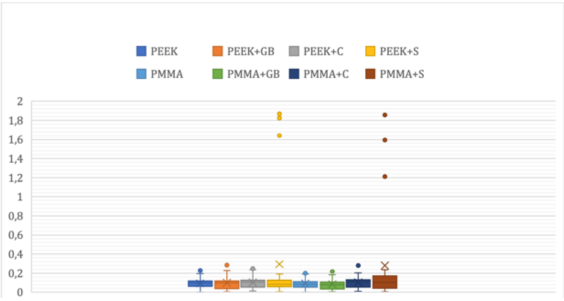
2) Analysis of Deviations in Soft Tissue

When analyzing deviations in soft tissue, there is no statistically significant difference between groups (Table 5, Figure 10). Similarly, intra-group analyses within the PMMA and PEEK groups did not yield statistically significant results (Table 6).

Table 6: Intragroup analysis of PEEK and PMMA groups

Test Statistics		
	PEEK	PMMA
Kruskal-Wallis H	1.120	2.702
df	3	3
Asymp. Sig.	0.772	0.44

Figure 10: Graphical examination of Soft Tissue deviation



DISCUSSION

This in vitro study aimed to investigate and compare the effects of different materials used in digital scan bodies and the design of digital scan bodies on the accuracy of measurements in edentulous areas and between implants, along with the potential impact of additional reference points. When evaluating the results of the study, the first null hypothesis that "PEEK scanning components provide clearer measurements compared to PMMA scanning components" was accepted, while the second null hypothesis that "the use of additional reference points improves measurement accuracy" was partially accepted. PEEK scanning components yielded significantly better results compared to PMMA scanning components. The use of additional reference points significantly improved measurement accuracy in the PMMA groups, while it did not affect the measurement accuracy in the PEEK groups.

In this study, different scan bodies and additional reference points were evaluated. Statistically, significant differences were found between the PEEK and PMMA groups regarding implant-to-implant distance measurements, with the PEEK group showing less deviation than the PMMA group. In the subgroups where additional reference points were added, generally, less deviation was observed in PEEK groups compared to subgroups consisting of PMMA modifications. PEEK and PMMA groups showed deviations in soft tissue and implant-to-implant distances within clinically acceptable levels. While implant-to-implant distance measurements varied between 0.46 ± 0.42 mm in the PEEK group and 0.94 ± 0.60 mm in the PMMA group, soft tissue deviations ranged from 0.14 ± 0.30 mm in the PEEK group to 0.15 ± 0.27 mm in the PMMA group. Deviations in digital measurements of multiple implants in partial edentulism averaged 11 µm, whereas deviations in complete edentulous arches were higher. Previous studies have reported distance deviation values ranging from 47-226 µm, consistent with findings in this study and current clinical practices.[1,7,8]

Traditional methods can achieve minimal error in measurements of multiple implants in complete edentulism. The open-tray impression technique, where implant impression copings are splinted to each other, is the most commonly used method and provides clinically acceptable results. However, achieving the desired accuracy in digital impressions of multiple implants in complete edentulism remains challenging, with controversial outcomes.[9,10] The low clarity observed in complete edentulism is attributed to the high number of overlaps performed by software algorithms for 3D image acquisition and the lack of fixed anatomical reference points. A systematic review examining impression techniques used in implant-supported prostheses recommended using the interconnection of scanner components to enhance measurement accuracy.[11]

Conversely, Mizumoto et al. demonstrated in their study that adding additional reference points did not significantly affect the accuracy of scanning data; in fact, using dental floss to create additional reference points adversely affected results, increasing deviations.[12] Canullo et al. also conducted another study where scan bodies were splinted together using intermediate components with numerous reference points, yielding results similar to those in the literature, indicating that splinting scan bodies did not affect scanning accuracy and even had a negative effect in the presence of angular deviations.[13] Arıkan et al. further noted that while splinting scanning components improved scanning clarity, conventional impressions obtained by splinting measurement components yielded more precise results.[14]

The characteristics of scan bodies significantly affect scanning accuracy.[15] A systematic review concluded that scan bodies' surface, geometry, and material influence implant measurements.[16] Previous studies have predominantly used PEEK or titanium with aluminum alloys as scan body materials, with slight inclusion of PMMA materials in studies. Therefore, there are no other studies against which we can compare the results obtained using PMMA scan bodies. In this study, the low impression accuracy observed with PMMA scan bodies is thought to be more related to geometry than the surface characteristics of the scan bodies. The scan body must have a solid structure for intraoral scanners to capture images. The PMMA scan body produced in this study did not differ in color or surface gloss from PEEK scan bodies. However, the PMMA scan body designed for use in this study was manufactured in a sharper-edged form to create additional reference points during scanning. Compared to PMMA scan bodies, PEEK scan bodies had simpler shapes. Our findings indicated that scan bodies with simpler designs are more suitable for scanning accuracy, a conclusion supported by similar findings in a study by Muizomata et al., where scan bodies with shorter and less complex structures resulted in fewer angular and distance deviations.[12] Another study investigating the relationship between the body, geometry, and shape of two different scan bodies found significant differences in 3D positioning and angular deviations between the two scan bodies.[17]

In the context of PMMA groups, another reason for the observed low accuracy is the absence of this new design in the scanner software library. Images obtained from the scanner are first transferred to software where the model is created. During model creation, aligning the image converted by the CAD software from the scanner part in STL format, which is present in the CAD software library, helps reduce errors in the model.[18] In our study, since a new design was attempted, which is not present in the CAD library.

Previous studies in this field indicate that factors such as the distance between scanning components, the depth of the implant, visibility of scanning components, position within the scan, and the experience of the operator can affect the accuracy of digital implant scans performed with multiple scanning components.[19,20] For the most precise scanning, additional reference points on scanning bodies, as recommended by implant manufacturers, can facilitate soft tissue scanning, thereby reducing deviations during measurement, albeit not statistically significant.

The current study has several limitations. Only one scanner was used for model scanning in the study. Different intraoral scanners with varying technologies may yield different results, which is an important factor to consider when translating study findings into clinical practice. Moreover, the study is an in vitro study, and the scanning environment differs from the oral cavity. Factors such as saliva and mobile mucosa movement were not considered. It should also be noted that a physical model made of material reflecting light differently was used for scans. The optimized scanning conditions raise the possibility that similar results may not be achieved under in vitro conditions.

CONCLUSION

In conclusion, the use of PEEK scan bodies in full-arch implant measurements results in low deviations. Additional modifications applied to edentulous areas do not affect measurement accuracy. Although PMMA material does not provide as high precision as PEEK, the study's findings are promising for its use. Evaluating the effect of material differences on scanning accuracy could be more objectively assessed by designing PMMA scan bodies to match the original geometry of manufacturers. Studies on this topic are quite limited. Therefore, more in-vitro and in-vivo research is needed.

Ethical Approval

This in-vitro study does not require ethics committee approval.

Financial Support

The authors declare that this study received no financial support.

Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: BGR, GG, DAŞ. Data collection or data entry: GG. Analysis and interpretation: BGR, GG, DAŞ. Literature search: GG, DAŞ. Writing: GG, BGR, DAŞ.

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