Comparative Evaluation Of Three-Dimensional Accuracy And Time Efficiency Of Conventional Versus Digital Impression Technique For Complete Arch Implant Level Impression: An In Vitro Study

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ABSTRACT

OBJECTIVE: The objective of this in vitro study was to evaluate and compare the trueness and time efficiency of conventional open-tray impressions and digital impression for complete arch implant level impression.

METHODS: A total number of 33 impressions were made using a fabricated master model with five implant replicas in the interforaminal region. The samples were divided into three groups with 11 samples in each group. Group 1: open tray splinted polyvinyl siloxane impression, Group 2: open tray splinted polyether impression and Group 3: digital impression. Conventional impressions were made using a custom tray and respective impression materials, while digital impressions were obtained using an intraoral scanner and implant scan body. A computerized coordinate-measuring machine was used to assess the three-dimensional accuracy. Time efficiency was analyzed by recording total treatment time, including preparation and working time, as well as the number of retakes/rescans. One-way ANOVA and Post Hoc tests were used for data analysis ($\alpha = 0.05$).

RESULTS: No statistically significant difference was found between open tray splinted polyvinyl siloxane impression, open tray splinted polyether impression and digital impression groups for linear and angular displacement ($p>0.05$). However, statistical significant difference was found in time efficiency for the group tested ($p<0.05$).

CONCLUSION: The accuracy of digital implant impression was comparable to the conventional open tray splinted polyvinyl siloxane, open tray splinted polyether impression. However, digital impression technique had improved time efficient compared to conventional implant impression open tray splinted impression, open tray splinted polyether impression and digital impression technique.

Introduction

Recent years have seen significant progress in the rehabilitation of edentulous patients, with dental implants showing the most promise. The creation of precisely fitting implant-retained prostheses and, ultimately, the long-term clinical success of these restorations depend heavily on the accuracy of impressions and casts.

.[1] Implant impressions, in contrast to tooth impressions, are subject to inherent component displacements when impression copings are attached to implants or replicas. Imprints of several implants may accrue more mistakes than impressions of a single implant due to the intrinsic displacements brought about by component connections.

It is widely acknowledged that optimal fit of an implant-fixed complete dental prosthesis is beneficial for its long-term success. Thus, construction of an accurately fitting restoration is of significant importance. To ensure a passive fit, the implant replicas must be precisely positioned in the master cast. A restoration is considered to have a passive fit when it does not introduce static forces into the prosthetic components or the surrounding bone structure. [3] Passive fit of implant-fixed complete dental prosthesis depends on the accuracy of the implant cast, which is directly dependent on the accuracy of the impression technique.[4]

The accuracy of the impression in terms of dimensional accuracy is essential, as even minor variations can lead to complications during the fabrication and delivery of the restoration. Both the technique used for obtaining the impression and the material employed have been subjects of extensive research concerning the dimensional accuracy of implant impressions. Polyether is considered a suitable choice owing to its natural rigidity and hydrophilicity. However, it does have drawbacks, such as inadequate tear strength, the potential for allergic reactions, and a limited working time. Additionally, it becomes rigid upon setting, which can complicate the removal of the impression from the patient's mouth. On the other hand, Polyvinyl siloxane (PVS) is favored in situations involving deep bony undercuts due to its enhanced flexibility, superior dimensional accuracy, and favorable flow characteristics. Nevertheless, it also presents challenges, including low strength, difficulty in pouring, and poor wettability.

Digital implant impressions taken using intraoral scanners have developed rapidly over the past decade. For digital implant impression, the scan body is connected to implants and the latter are scanned to indicate their position. The virtual models are then converted to stereolithography (STL) files and imported into software so that restorations can be designed. Unlike conventional implant impressions, digital dental implant impressions Remove the need for tray selection, dispensing, and preparation of impression materials, as well as the disinfection and shipping of impressions to the laboratory, while also potentially enhancing patient comfort. [9]

Although there have been many studies documented in literature regarding various impression techniques for implant level impression, conflicting evidence exists regarding the accuracy of both digital and conventional impression methods. Therefore, the objective of the study was to evaluate the three-dimensional accuracy and time efficiency of conventional and digital impression technique for complete arch implant level impression.

The null hypothesis was that there is no difference in the three-dimensional accuracy and time efficiency of conventional and digital impression technique for complete arch implant level impression.

MATERIALS AND METHODS

This study was conducted in the Department of Prosthodontics and Crown & Bridge, to evaluate and compare three-dimensional accuracy and time efficiency of conventional and digital complete arch implant level impressions. The test for accuracy were performed at KIET Group of Institution, Ghaziabad.

A total number of 33 impressions was made for an edentulous mandibular model and divided into 3 groups, comprising of 11 samples in each group. Group 1: (n=11) Open tray splinted polyvinyl siloxane impression. Group 2: (n=11) Open tray splinted polyether impression. Group 3: (n=11) Digital Impression.

A diagnostic cast of a mandibular edentulous patient was chosen to produce a master model (control). A tungsten carbide bur will be utilized to create five holes in the interforaminal regions of the mandibular cast. An implant replica was placed into each hole and secured with Type IV dental stone. A pickup impression coping will be attached to each implant replica. An open-tray impression was taken using low viscosity silicone impression material along with high viscosity silicone impression material in a prefabricated plastic tray. Once the impression material has fully polymerized, the guide pins will be loosened, and the impression tray will be removed from the cast. An implant replica was connected to each impression coping, and the impression was poured for the fabrication of the master model.

A pickup impression coping will be attached to each implant replica of the master model, and the copings were secured using a pattern resin. A custom tray will be created utilizing auto polymerized acrylic resin, and this same tray will be employed for impression making in both group 1 and group 2. Tray adhesive will be applied before the impression is made, and the definitive impression will be taken using the custom tray along with polyvinyl siloxane impression material for group 1 and polyether impression material for group 2. After a duration of 10 minutes, the definitive complete-arch impression was retrieved from the master model, and the implant replicas were connected to the copings. Type IV dental stone, mixed according to the manufacturer's guidelines, will be poured into the impression to create the definitive cast. A total of 11 definitive casts will be produced using the conventional open tray splinted polyvinyl siloxane impression technique for group 1, while another 11 definitive casts will be created using the open tray splinted polyether impression technique for group 2.

For group 3, an intraoral scanner along with scan bodies was utilized to create 11 digital models. The digital scan process was conducted in accordance with the manufacturer's guidelines. To enable measurement, the scan images were stored in a standard tessellation language (STL) file format. These procedures will be carried out 11 times to produce 11 digital models..

A computerized coordinate-measuring machine was employed to assess and calculate the three-dimensional position of implant replicas within the master model and the three groups. The degree of linear displacement was indicated by the centroid coordinate differences in absolute values (Δx, Δy, and Δz). Angular displacement was determined by analyzing the long-axis angles of the implant replicas. The long axes will be projected onto the XY and ZX planes, with the projection angles denoted as θXY and θZX. The effectiveness of both impression techniques was assessed by recording the total treatment duration and the number of retakes or rescans. The total treatment duration was recorded in minutes and seconds, encompassing both preparation time and working time. Preparation time for the conventional open tray impression includes the selection of the tray, application of adhesives, placement and removal of the implant impression coping, and the assembly of the impression coping with the implant analog into the impression. Working time encompasses the process of making the impression and the number of retakes. For the digital impression, preparation time includes creating the lab prescription and the placement and removal of the scan body. Working time involves scanning the scan body and adjacent teeth, scanning the opposing teeth, bite registration, and the number of rescans.

Figure 1: Intaglio surface of Open tray splinted Polyvinyl impression (Group I)

Figure 2: Intaglio surface Open tray splinted Polyether Impression (Group II)

Figure 3: Digital Implant level Impression (Group III)

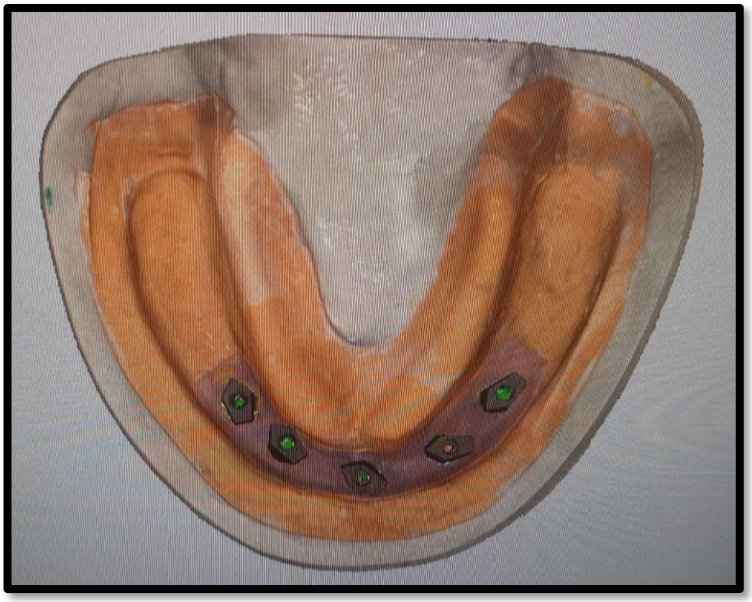

Figure 4: Evaluation of linear and angular displacement under CMM machine for PVS impression.

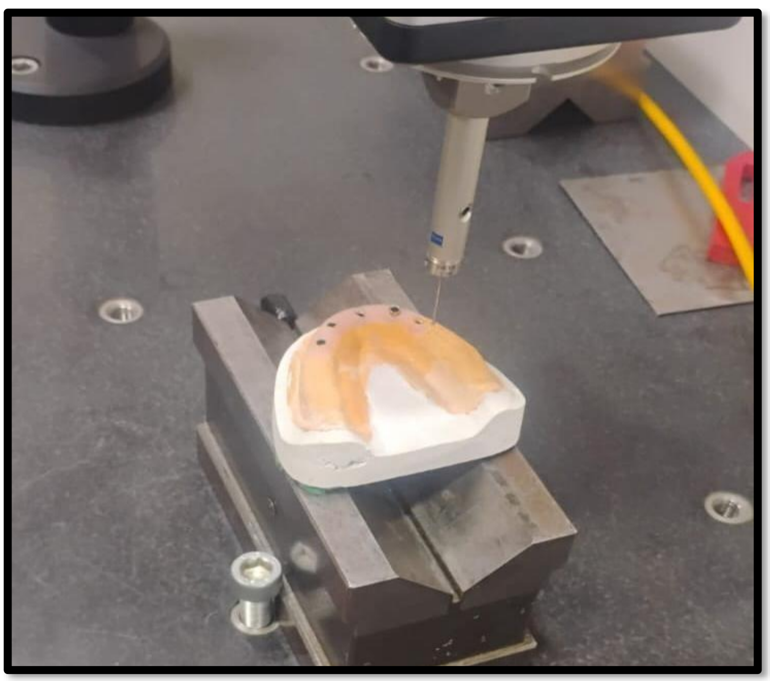

Figure 5: Evaluation of linear and angular displacement under CMM machine for polyether impression material.

Figure 6: Evaluation of linear and angular displacement for digital impression

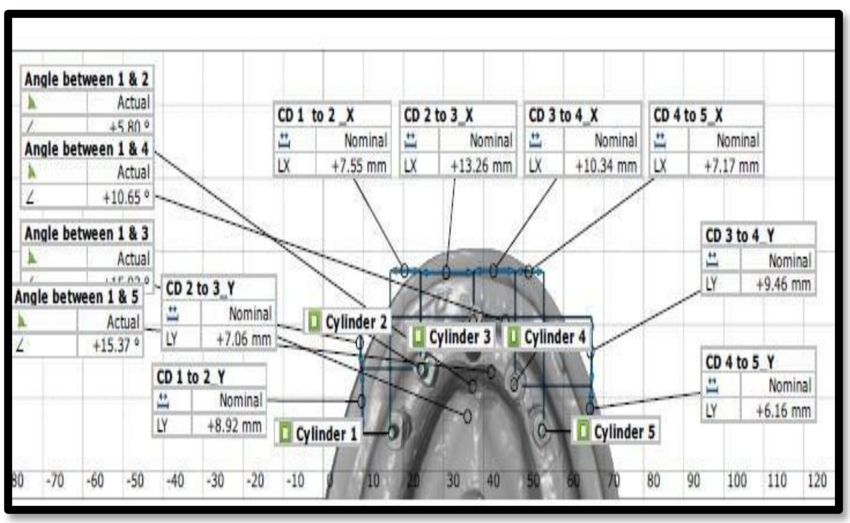

Table 1: Intergroup comparison of linear displacement among groups

Linear displacement	GROUP	GROUP	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LDX	1	2	0.8634	.9812	1.000	-3.351	1.625
		3	0.5347	.9812	1.000	-1.953	3.023
	2	1	0.8634	.9812	1.000	-1.625	3.351
		3	1.3981	.9812	.493	-1.090	3.886
	3	1	0.5347	.9812	1.000	-3.023	1.953
		2	1.3981	.9812	.493	-3.886	1.090
LDY	1	2	0.2027	.8182	1.000	-2.277	1.872
		3	0.4428	.8182	1.000	-2.518	1.632
	2	1	0.2027	.8182	1.000	-1.872	2.277
		3	0.2401	.8182	1.000	-2.315	1.835
	3	1	0.4428	.8182	1.000	-1.632	2.518
		2	0.2401	.8182	1.000	-1.835	2.315

LDZ	1	2	0.2527	.8182	1.000	-2.277	1.872
		3	0.4428	.8182	1.000	-2.518	1.632
	2	1	0.1127	.8182	1.000	-1.872	2.277
		3	0.2401	.8182	1.000	-2.315	1.835
	3	1	0.3428	.8182	1.000	-1.632	2.518
		2	0.2201	.8182	1.000	-1.835	2.315
Over all LD	1	2	0.53303	.29137	.232	-1.2719	.2058
		3	0.04596	.29137	1.000	-.6929	.7848
	2	1	0.53303	.29137	.232	-.2058	1.2719
		3	0.57899	.29137	.168	-.1599	1.3178
	3	1	0.04596	.29137	1.000	-.7848	.6929
		2	0.57899	.29137	.168	-1.3178	.1599

Table 1, shows intergroup comparison of Linear displacement between the groups tested with a non-significant difference among the groups.

Table 2: Intergroup comparison of angular displacement among groups

Dependent Variable	GROUP	GROUP	Mean Difference (I- J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
AD 1-2	1	2	.3918	1.1280	1.000	-3.252	2.469
		3	3.4918*	1.1280	.013	-6.352	-.631
	2	1	.3918	1.1280	1.000	-2.469	3.252
		3	3.0999*	1.1280	.030	-5.960	-.240
	3	1	3.4918*	1.1280	.013	.631	6.352
		2	3.0999*	1.1280	.030	.240	5.960
AD 1-3	1	2	.3776	.9920	1.000	-2.893	2.138
		3	1.8786	.9920	.204	-4.394	.637
	2	1	.3776	.9920	1.000	-2.138	2.893
		3	1.5010	.9920	.422	-4.016	1.015
	3	1	1.8786	.9920	.204	-.637	4.394
		2	1.5010	.9920	.422	-1.015	4.016
AD 1-4	1	2	.2921	.7455	1.000	-2.183	1.598
		3	1.1020	.7455	.449	-2.992	.788
	2	1	.2921	.7455	1.000	-1.598	2.183
		3	.8100	.7455	.858	-2.700	1.080
	3	1	1.1020	.7455	.449	-.788	2.992
		2	.8100	.7455	.858	-1.080	2.700
AD 1-5	1	2	.5943	.9221	1.000	-2.933	1.744
		3	1.6641	.9221	.244	-4.002	.674
	2	1	.5943	.9221	1.000	-1.744	2.933
		3	1.0698	.9221	.765	-3.408	1.269
	3	1	1.6641	.9221	.244	-.674	4.002
		2	1.0698	.9221	.765	-1.269	3.408
Overall AD	1	2	.41398	.59828	1.000	-1.9310	1.1031
		3	2.03413*	.59828	.006	-3.5512	-.5171
	2	1	.41398	.59828	1.000	-1.1031	1.9310
		3	1.62015*	.59828	.033	-3.1372	-.1031
	3	1	2.03413*	.59828	.006	.5171	3.5512
		2	1.62015*	.59828	.033	.1031	3.1372

Table 2, shows intergroup comparison of angular displacement between the groups tested with a non-significant difference among the groups.

Table3: Intergroup comparison total treatment time for conventional and digital among groups

Dependent Variable	GROUP	GROUP	Mean Difference	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
TTC/ TTD	1	2	-.142625*	.042970	0.253	-1.298	7.474
		3	-.560250*	.062272	0.0257	-3.781	4.991
	2	1	-.034875	.008430	0.253	-7.474	1.298
		3	.142625*	.014242	0.0384	-6.869	1.903
	3	1	-.417625*	.042970	0.0257	-4.991	3.781
		2	.107750	.042970	0.0384	-1.903	6.869

Table 3, shows Group 3 has the lowest total treatment time followed by group 2 and least by Group 1. The treatment times for group 1 and group 2 was higher compared to total treatment time for digital across all groups. The overall means suggest a significant difference in treatment durations between groups.

Results

The present in vitro study was conducted in the department of Prosthodontics and crown & bridge. The data was statistically analyzed using Social Sciences software (SPSS 16 Inc, Chicago IL, USA). A parametric test, specifically One-way analysis of variance (ANOVA), was employed to evaluate the means across the groups, followed by a post hoc pairwise comparison test.

Linear deviation in x axis ranged from 10.661 to 12.059**,** with Group 2 having the highest deviation (12.059) followed by Group 1 (11.195) and least by Group 3 (10.661). For y axis, linear deviation was highest with Group 3 (10.733) showing the highest deviation (10.733**)** followed by group 2(10.492) and least by group 1 (10.290). For z axis, linear deviation was highest with group 2 (11.28) followed by group 1 (10.74) and least by group 3 (10.70). The data confirms that linear displacement does not significantly differ among groups**.** ($p>0.05$). Angular deviation in Group 3 was highest deviation followed by Group 2 and Group 1 has the lowest deviation, However, the results are non-significant among the groups.

Discussion

The main objective of implant impressions is to create a precise working cast that enhances the likelihood of producing a passively fitting implant prosthesis.

Achieving a passive fit is essential for the long-term success of the implant, which relies on various factors such as the recorded dental impression, the physical and mechanical characteristics of the impression material, the technique used for the impression, the choice of impression tray, and the angulation of implant placement.

The accuracy of the impression in terms of dimensional stability is vital, as even minor discrepancies can lead to challenges during the fabrication and delivery of the restoration.

It is widely recognized that achieving an optimal fit for an implant-fixed complete dental prosthesis is crucial for its long-term success. To ensure a passive fit, it is essential to accurately position the implant replicas within the master cast. A restoration can be deemed to have a passive fit if it does not impose static loads on the prosthetic system or the adjacent bone tissue. The passive fit of an implant-fixed complete dental prosthesis relies on the accuracy of the implant cast, which is directly influenced by the accuracy of the impression technique.

Based on the results of the present study, the null hypothesis was partially rejected as no statistically significant difference($p>0.05$) was found between three-dimensional accuracy of conventional and digital impression techniques for complete arch implant level impression. However, a significant difference ($p<0.05$) was observed between the time efficiency between conventional and digital impression techniques.

The results of the present study showed that the linear deviation for open tray splinted polyether impression material was highest followed by polyvinyl siloxane impression and least by digital impression technique with no significant difference between groups ($p>0.05$). These findings suggested that both conventional and digital impressions yield comparable three - dimensional accuracy. The results are in accordance to the study conducted by Reddy et al.18 who evaluated that dimensional accuracy of casts made from polyvinyl siloxane impression and polyether implant impression compared to digital implant impression technique and found that both the materials and impression techniques had similar dimensional accuracy for transfer procedures. Papaspyridakos et al. compared the accuracies of complete-arch implant impressions by using different impression techniques and found that the accuracy of intraoral digital scanning was comparable with that of the master model and the conventional open-tray impression technique.

However, the results are in contradiction with the study conducted by Garcia et al. who stated that the digital implant impression showed less deviation compared to conventional impression technique because the non-rigid impression tray used during conventional impression can flex during impression making or removal, causing distortion. Also, impression coping can move during impression removal which can result in positional errors and errors in placing the implant analog into the impression leading to deviation. When pouring the stone model, minor volumetric changes can affect the final accuracy. Whereas, optical and intraoral scanners have varying resolutions, and lower accuracy which can introduce deviations. However, digital impressions offer an additional advantage by eliminating potential errors associated with material shrinkage and distortion, which are inherent risks in conventional impressions.

The present study showed that the angular deviation for open tray splinted polyvinyl siloxane impression material was highest followed by polyether impression material and least by digital impression technique with no significant difference ($p>0.05$) between groups. The results are in accordance to the study conducted by Kurtulmus et al. who compared polyvinyl siloxane, polyether impression material and found that the three-dimensional accuracy in reproduction of master models was comparable for polyether impression material, polyvinyl siloxane impression material and digital implant impressions.

However, Ortega et al. found that conventional methods, especially with materials like polyether and PVS were more reliable. Baig et.al reported that the polyether impression material stiffness is beneficial for keeping the impression copings in place. However, this same property may make removal challenging which may have higher deviations due to material distortion and manual steps. Also, polyvinyl siloxane or polyether materials may experience shrinkage or expansion, leading to errors in the recorded angulation. Moreover, loosening or slight movement of the impression coping during impression taking can cause angulation errors. Whereas in case of digital impression if the scan body is not fully seated or secured, the scan will record an incorrect implant angulation. Also, factors such as operator experience, specific clinical scenario and the type of digital system used could contribute to discrepancies.

The present study also evaluated total treatment time taken for the open tray polyvinyl siloxane impression, polyether impression and digital impression technique. The treatment time was found to be highest for open tray polyvinyl siloxane impression followed by polyether impression material and least by digital impression technique with a significant difference ($p<0.05$) in treatment durations between the groups. This indicates that the time efficiency outcomes of the digital impression technique were found to be higher than that of the conventional implant impression technique. The results are corroborated with the study conducted Lee at al. who found that the digital scans to be more efficient than conventional impressions and require less rescan time due to the ability to rescan certain areas without the need to repeat the entire impression.

Several studies have demonstrated that digital impression techniques for implant dentistry are more time-efficient compared to conventional methods. Yolanda et al. reported that the conventional impressions required an average of 24 minutes and 42 seconds, whereas digital impressions took significantly less time, averaging 12 minutes and 29 seconds with a significant difference between conventional impression and digital impression technique ($P < 0.001$). Digital impressions offered a streamlined workflow, reducing chairside time and potentially enhancing patient comfort. Similarly, Seo et al. documented that the time required for impression taking was significantly shorter for digital scanning, with an average duration of 7 minutes and 33 seconds, compared to 11 minutes and 33 seconds for the conventional technique ($P < 0.01$). Likewise, Garcia et al. stated that the total procedure time was significantly shorter for the digital workflow, compared to conventional method as the material setting time is not required and there is no need for tray selection and impression material mixing.

The results are contradictory with the study conducted by Amirhossein et al. compared the digital and conventional impression technique and found that the learning curves associated with the digital impression, focusing on increased time required for dental students to perform full-arch digital implant. Further, Marghalani et al. reported that the conventional technique required 658 seconds on average, whereas digital methods took longer. The longer duration for digital impressions in this study may be attributed to the larger area of the impression, which can affect digital impression accuracy.

The findings provide insights into the clinical implications of using digital or conventional techniques in implant prosthodontics. Digital impressions eliminate the discomfort associated with conventional impression materials, making them a preferred option for patients with gag reflexes or limited mouth opening. The study supports the growing consensus that digital impressions provide superior accuracy over full-arch implant impressions, reducing prosthetic misfits and complications. Digital workflows had an added advantage where it integrates seamlessly with CAD/CAM systems, enabling faster production of implant restorations. Clinicians can reduce chairside adjustments and improve overall treatment efficiency.

However, the adoption of digital impressions depends on scanner availability, initial investment costs, and the learning curve associated with digital systems. Also, factors such as the extent of the area being scanned and the specific digital system used can influence the time required.

However, there are certain limitations in the study. The controlled environment may not fully replicate intraoral conditions such as saliva, soft tissue movements, and patient cooperation. The study attempted to minimize operator-related errors, but scanning technique differences could still influence results. Different intraoral scanners have varying levels of accuracy and software algorithms may introduce minor deviations. Future studies should compare multiple scanner brands to assess their impact on accuracy. A larger sample size, including different implant configurations and angulations, would provide a more comprehensive evaluation.

Conclusion:

In light of the study's limitations, the following conclusions have been established:

1. The three-dimensional accuracy of the open tray splinted polyvinyl siloxane impression technique, the open tray splinted polyether impression technique, and the digital complete arch implant-level impression technique were found to be comparable, with no statistically significant differences ($p>0.05$).

2. The duration required for the impression was greatest for the open tray splinted polyvinyl impression technique, followed by the open tray splinted polyether impression technique, while the digital impression technique required the least time, exhibiting a statistically significant difference in impression duration ($p<0.05$). The time efficiency of the digital impression technique was superior when compared to the conventional impression technique.

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