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Three-dimensional comparison of accuracy between conventional and digital impressions for dental implants

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Abstract

Aim: To evaluate the three-dimensional accuracy between conventional and digital impressions for implants placed at different angulations and depths in partially edentulous models.

Materials and Methods: Two partially edentulous mandibular models were prepared with implants placed in 46 and 47 regions at (i) an angle of 0 and 20 degrees and (ii) a depth of 2mm and 4mm respectively. Conventional open tray splinted impressions (n=15) and digital scan impressions (n=15) were made for each model. Casts were poured of the conventional impressions which were then scanned to obtain an STL file, whereas for digital impressions, the models were digitally fabricated. The files were superimposed in GOM Inspect software on the scanned master model and linear deviations were noted on the internal hex structure. Statistical analysis was done in SPSS v20 and independent t-test was used for the evaluation of data. Results were statistically significant for p values <0.05.

Results: Group (i) had points 1, 4, 5, 6 with a statistically significant difference in deviation values for the angulated implant and point 1 for the straight implant group. Group (ii) similarly had point 3 with statistically significant values for the 2mm depth implant and point 6 for the 4mm depth implant with all other points being statistically non-significant.

Conclusion: Digital impressions proved to be superior for the angulated implant group whereas they were inferior to the conventional impressions for the depth group.

Keywords: Dental Implant, Dental Impressions, Implant Impressions, Implant Prosthesis

Introduction

The spatial accuracy of an impression material has been a property comprehensively researched and many improvements and advancements have been made in the same throughout the years.[1-2] Although surface reproduction is not the sole property important for reproduction of oral structures in an impression, the three-dimensional relation of the concerned area with the rest of the structures in the oral cavity also has a substantial bearing on the success of the final prosthesis.

Replacement of teeth using dental implants is now emerging as a treatment of choice for partially as well as completely edentulous patients. They are evolving as a successful treatment modality in providing a substitute to removable and as well as fixed dental prosthesis. However, sometimes owing to various limitations, such as operator experience, bone availability, ease of accessibility, presence of vital anatomic structures, and resorption pattern of bone especially in the posterior regions of the arches, it may not be possible to place dental implants in parallel positions or ideal depths. In cases of limited mouth opening, it may become difficult to hold drills parallel to the adjacent teeth leading to an angulated implant placement and in patients with thicker gingival biotype, even an equicrestal placement on the bone would translate to a depth greater than 3mm[3]. Research has also supported the placement of angulated implants to overcome restrictions due to anatomical limitations in patients. Conventional impressions in angulated as well as deeper implants have lesser accuracy relative to parallel implants as has been elaborated in the literature[4]. Recording these angulations in impressions with accuracy is of paramount importance, as this directly influences the passive fit of the framework. The failure to do so eventually leads to many complications like screw loosening, micro-movement, and space in the implants and eventually leads to the failure of the final prosthesis.

Impression-making with angulated or deeply placed implants are known to have slight inaccuracies. Literature states that impressions of parallel implants are superior with respect to accuracy than that of impressions recording the spatial position of angulated or deeply placed implants.[4]

Recording the exact position and orientation of the implants has always proved challenging, with a combination of both, better material choice, as well as technique, being used to make impressions as accurate as possible. Elastomeric impression materials and implant impression techniques have undergone a significant evolution. Impression materials used now have better dimensional stability and excellent tear strength. Research has proven that open-tray splinted impression technique is far more superior to the closed-tray impression technique, especially when it comes to multiple angulated implants. [5,6] However, the technique is fraught with limitations, especially in cases of limited mouth opening.

Overcoming the procedural difficulty associated with this technique is possible due to digital scanning. Conventional impressions usually make static records, that is, recording the 3-dimensional relationship of the oral structures. Hence, distortions introduced are generally due to the property of the material itself or the material used for cast fabrication from the impression. Digital impressions include the merging of various images captured individually to produce a virtual 3-dimensional model. However, the accuracy may sometimes be compromised due to variations in scanner software (post-processing) or the artificial intelligence model trained for stitching the images. Digital impressions have, over time proven to be as accurate, if not more, as conventional impression-making for crowns and fixed partial dentures.

Digital impressions hold numerous advantages over conventional impressions since they are mess-free, contribute to an improved workflow and better communication between the clinician and the laboratory amongst the other advantages.[7] Open tray impression technique has been proven to be very accurate in terms of recording the spatial orientation of the implants even with varying depths and angulations.

However, research is still needed to assess the difference in accuracies of digital scanning and the standard open tray impression technique for implants placed at biomechanically compromised regions at different angulations and depths.

Hence, the purpose of this study is to evaluate and compare the three-dimensional accuracy of the implants placed at different angulations and depths for conventional and digital impression methods, as well as to determine the method providing superior results for the same.

Methodology

Fabrication of master model: Two partially edentulous (Kennedy's Class II) mandibular models were prepared in Type III gypsum(Kalstone, Kalabhai Inc., Mumbai) with two right molars removed for the purpose of this study. This cast was scanned and two UV-resin (Anycubic, ALL3DP, Germany) models of the same were fabricated. A surgical guide (Figure 1) was used to place the implants at a predetermined depth of 2 mm and 4 mm in one model, and at an angulation of 0 and 20 degrees in another. The implants (Cowellmedi Inc, ROK) were secured in place with auto-polymerizing resin. This model was further scanned by a lab scanner and corresponding UV-resin models were fabricated with detachable gingival formers for both the models incorporating digital analogues (Cowellmedi Inc, ROK) simulating the implants. An aluminum block (5x10 mm) was attached to the model between the premolars below the gingival margin on the corresponding edentulous side, defining the local coordinate reference on which superimposition would be done for the models. The design of the final models was then subsequently converted to standard tessellation language (STL) format and were used for comparison (Figure 2).

Figure 1: Partially edentulous model used for study with the surgical guide

Figure 2: Scanned file after placement of gauge block and securing implants in the model

Conventional open-tray impression (CI)

Two open-tray impression copings (Cowellmedi Inc.) were attached to the implants in each master model and were splinted together with dental floss and pattern resin (GC, Tokyo, Japan) (Figure 3). The splint was sliced in between to allow for the dispersion of stresses occurring due to polymerization shrinkage, followed by reapplication of the resin. Conventional splinted open-tray impressions (n=15) were made of each model with self-cure acrylic resin custom trays and addition silicone impression material (Hydrorise, Zhermack, Italy). Tray adhesive (Medicept Dental, UK) was applied on the custom trays prior to making the impressions. After the impression material was allowed to set for 6 minutes (as per manufacturer's instructions), the impression was removed from the model and implant analogues were attached to the impression copings. Models were fabricated from the impressions with Type IV gypsum (Ultrarock, Kalabhai Inc., Mumbai) after application of the gingival former (Zhermack, Italy) with the double pour technique (Figure 4). The models were scanned with the 3D lab scanner after removing the gingival former and the digital replicas of the models were obtained in STL format.

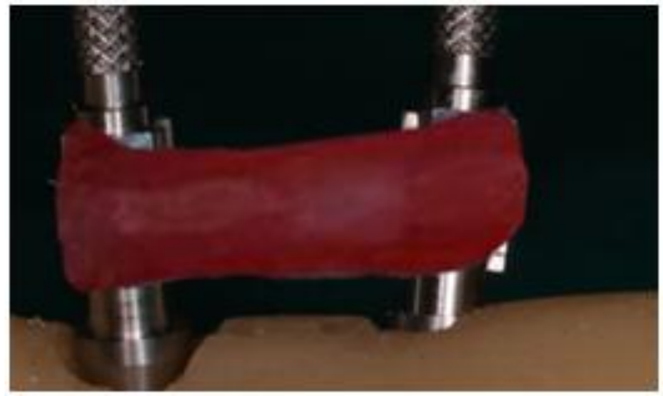


Figure 3: Splinted open tray copings for the impression

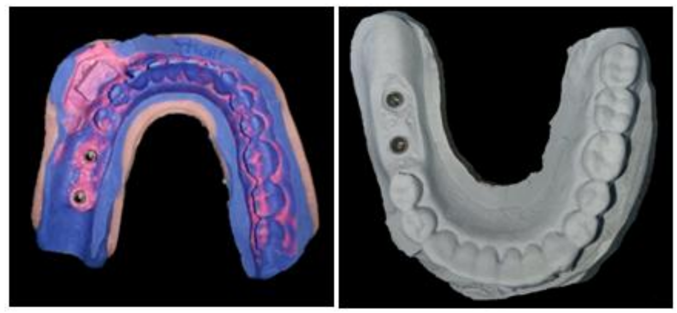


Figure 4: Conventional impression and model without gingival former

Digital impression (DI)

Two scan bodies (Cowellmedi Inc.) were attached to the implants on each master model and both the models were scanned with an intra-oral scanner (Medit i700, Medit Corp., ROK) for digital impressions of each model (n=15). After obtaining the scanned file in STL format, digital analogues were imported from the Cowellmedi library as 3D bodies to the software, (exocad, exocad America, Inc.) and were placed in the corresponding sites. A removable gingival mask was designed for each model. The final model was then converted back to STL format for further comparison (Figure 5).

Figure 5: Scan bodies attached to the implants and the model after scanning

3-dimensional accuracy evaluation:

The STL models obtained by scanning the conventional open-tray impression casts and the digital impressions were evaluated for accuracy with the master model by the superimposition of their respective STL files in the GOM Inspect 3-dimensional co-ordinate analyzing software and the differences in accuracy were estimated. The models were inserted as a 3D body and mesh structure and were aligned with the local best-fit alignment algorithm by marking the points on the reference aluminum block below the premolars (Figure 6).The cloud points were overlapped to observe any incorrect alignments. Subsequently, after verification of correct alignment, the linear deviations were measured and recorded (in mm) between the models on the 6 points marked in the internal hexagonal attachment of the implants and analogues (Figure 7) and were noted in a tabular format in Microsoft Excel.

Figure 6: Superimposition of both models on master model in GOM Inspect software

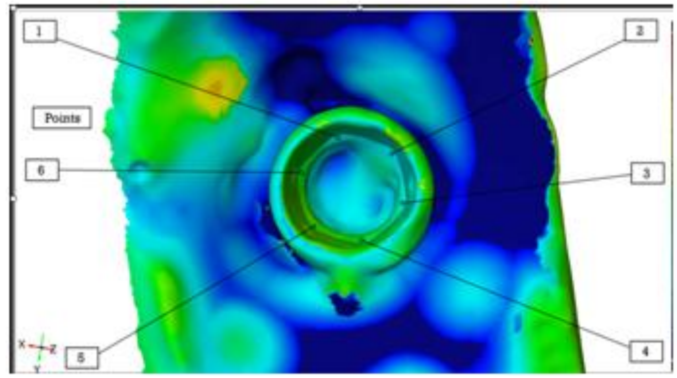
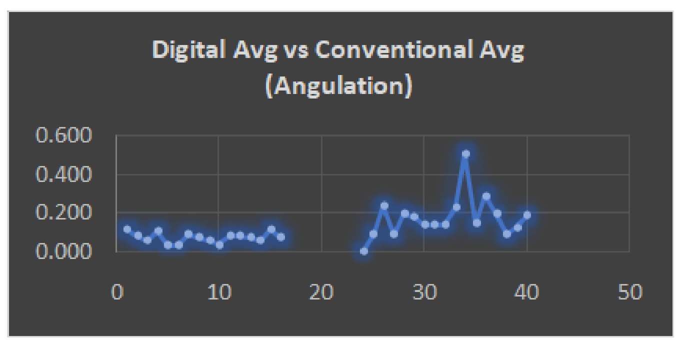
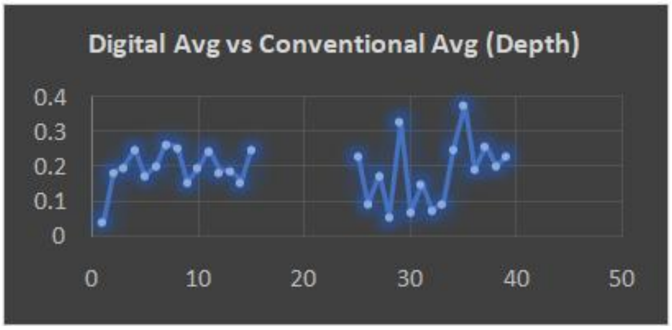


Figure 7: Six points marked on the internal hex structure used for comparison

Results

Statistical Analysis: Conventional models (n=15) and scan models (n=15) were made for the master models with implants placed at different angulations and depths. The overall accuracy of the models obtained from both impression techniques was compared to the master model. Based on the observations, data was analyzed using SPSS (version 20) software. Independent t-test was used for the evaluation of the intergroup comparison of dimensional changes between the two groups and the master model and paired t-test was used for comparison between the two implants in the same sample. The results were considered to be statistically significant for p-value <0.05.





Graph 1: Mean deviation values compared for digital and conventional models for both groups (in mm).

Angulated implant group: The linear and angular deviations were calculated for each point on the internal hex of the implant, which revealed statistically significant deviation values for comparison between points 1, 2, 5, 6 and the average of all these points in the angulated implant group. Similarly, the values were statistically significant for all points and the mean of all the points in the straight implant group. Table 1 demonstrates the evaluation of mean values from the angulated group.

Table 1: Comparative evaluation of data from angulated implant model

	Digital(n=15)	Conventional(n=15)		
	Mean ± sd	Mean ± sd	t	P Value
HEX - 1 (ANGULATED) Point-1	0.06±0.03	0.2±0.15	-3.471	0.003
HEX - 1 (ANGULATED) Point-2	0.09±0.05	0.2±0.14	-2.976	0.008
HEX - 1 (ANGULATED) Point-3	0.08±0.06	0.17±0.2	-1.58	0.133
HEX - 1 (ANGULATED) Point-4	0.06±0.04	0.1±0.09	-1.575	0.126
HEX - 1 (ANGULATED) Point-5	0.06±0.06	0.21±0.24	-2.394	0.03
HEX - 1 (ANGULATED) Point-6	0.06±0.04	0.26±0.23	-3.409	0.004
HEX - 1 (ANGULATED) Point-AVG	0.07±0.02	0.19±0.14	-3.279	0.005
HEX - 2 (STRAIGHT) Point-1	0.08±0.05	0.21±0.09	-4.819	<0.001
HEX - 2 (STRAIGHT) Point-2	0.09±0.06	0.21±0.09	-4.456	<0.001
HEX - 2 (STRAIGHT) Point-3	0.07±0.04	0.17±0.13	-3.066	0.007
HEX - 2 (STRAIGHT) Point-4	0.06±0.02	0.12±0.1	-2.344	0.033
HEX - 2 (STRAIGHT) Point-5	0.06±0.07	0.16±0.15	-2.269	0.035
HEX - 2 (STRAIGHT) Point-6	0.1±0.06	0.2±0.15	-2.436	0.025
HEX - 2 (STRAIGHT) Point-AVG	0.08±0.03	0.18±0.08	-4.739	<0.001

A paired t-test between the straight and the angulated implant provided statistically non-significant values for all points and their average in the conventional group and were statistically non-significant for all points in the digital group as well except for point 6.

Table 2: Comparative evaluation of straight and angulated implant accuracies

			N	Mean ± SD	Mean difference ± SD	P Value
Digital	Pair 1	HEX - 1 (ANGULATED) Point-1	15	0.06±0.03	-0.02±0.05	0.116
		HEX - 2 (STRAIGHT) Point-1	15	0.08±0.05		
	Pair 2	HEX - 1 (ANGULATED) Point-2	15	0.09±0.05	0±0.04	1
		HEX - 2 (STRAIGHT) Point-2	15	0.09±0.06		
	Pair 3	HEX - 1 (ANGULATED) Point-3	15	0.08±0.06	0.01±0.03	0.134
		HEX - 2 (STRAIGHT) Point-3	15	0.07±0.04		
	Pair 4	HEX - 1 (ANGULATED) Point-4	15	0.06±0.04	0.01±0.04	0.525
		HEX - 2 (STRAIGHT) Point-4	15	0.06±0.02		
	Pair 5	HEX - 1 (ANGULATED) Point-5	15	0.06±0.06	0±0.06	1
		HEX - 2 (STRAIGHT) Point-5	15	0.06±0.07		
	Pair 6	HEX - 1 (ANGULATED) Point-6	15	0.06±0.04	-0.04±0.05	0.008
		HEX - 2 (STRAIGHT) Point-6	15	0.1±0.06		
	AVG	HEX - 1 (ANGULATED) Point-AVG	15	0.07±0.02	-0.01±0.02	0.212
		HEX - 2 (STRAIGHT) Point-AVG	15	0.08±0.03		
Conventional	Pair 1	HEX - 1 (ANGULATED) Point-1	15	0.2±0.15	-0.01±0.15	0.809
		HEX - 2 (STRAIGHT) Point-1	15	0.21±0.09		
	Pair 2	HEX - 1 (ANGULATED) Point-2	15	0.2±0.14	-0.01±0.16	0.871
		HEX - 2 (STRAIGHT) Point-2	15	0.21±0.09		
	Pair 3	HEX - 1 (ANGULATED) Point-3	15	0.17±0.2	-0.01±0.19	0.885
		HEX - 2 (STRAIGHT) Point-3	15	0.17±0.13		
	Pair 4	HEX - 1 (ANGULATED) Point-4	15	0.1±0.09	-0.01±0.06	0.361
		HEX - 2 (STRAIGHT) Point-4	15	0.12±0.1		
	Pair 5	HEX - 1 (ANGULATED) Point-5	15	0.21±0.24	0.06±0.12	0.093
		HEX - 2 (STRAIGHT) Point-5	15	0.16±0.15		
	Pair 6	HEX - 1 (ANGULATED) Point-6	15	0.26±0.23	0.06±0.13	0.084
		HEX - 2 (STRAIGHT) Point-6	15	0.2±0.15		
	AVG	HEX - 1 (ANGULATED) Point-AVG	15	0.19±0.14	0.01±0.09	0.579
		HEX - 2 (STRAIGHT) Point-AVG	15	0.18±0.08		

Statistically non-significant values were similarly obtained for comparison in points 3, 4 of the angulated implants. A statistically significant difference was observed in comparing the average values of all the points on the internal hex of the angulated and straight implants.

Depth implant group

Values were statistically significant for comparison in point 6in the 2mm depth implant group.

Statistically non-significant values were similarly obtained for comparison in points 1, 2, 3, 4, 5, and the average of all points in the 2mm group, and points 1, 2, 4, 5, and 6 for the 4 mm depth group. The difference was not statistically significant upon comparison of average values of all the points on the internal hex of the 4mm depth implants. Table 3 demonstrates the evaluation of mean values from the depth group.

Table 3: Comparative evaluation of data from the depth implant model

	Digital(n=15)	Conventional(n=15)		
	Mean ± SD	Mean ± SD	t	P Value
HEX 1 (4MM) Point-1	0.22±0.07	0.17±0.16	1.271	0.219
HEX 1 (4MM) Point-2	0.39±0.12	0.27±0.2	2.01	0.056
HEX 1 (4MM) Point-3	0.32±0.1	0.19±0.15	2.713	**0.012**
HEX 1 (4MM) Point-4	0.06±0.05	0.13±0.14	-1.922	0.071
HEX 1 (4MM) Point-5	0.29±0.09	0.21±0.18	1.443	0.164
HEX 1 (4MM) Point-6	0.17±0.05	0.19±0.18	-0.338	0.74
HEX 1 (4MM) Point-AVG	0.24±0.07	0.19±0.12	1.371	0.184
HEX 2 (2MM) Point-1	0.12±0.05	0.18±0.2	-1.172	0.258
HEX 2 (2MM) Point-2	0.23±0.08	0.19±0.16	0.752	0.458
HEX 2 (2MM) Point-3	0.21±0.07	0.18±0.1	0.787	0.438
HEX 2 (2MM) Point-4	0.09±0.04	0.14±0.1	-1.913	0.071
HEX 2 (2MM) Point-5	0.18±0.06	0.16±0.14	0.323	0.75
HEX 2 (2MM) Point-6	0.1±0.03	0.22±0.19	-2.339	**0.034**
HEX 2 (2MM) Point-AVG	0.15±0.04	0.18±0.11	-0.923	0.368

Table 4: Comparative evaluation of 2mm and 4mm implant accuracies

			N	Mean ± SD	Mean difference ± SD	P Value
Digital	Pair 1	HEX 1 (4MM) Point-1	15	0.22±0.07	0.11±0.04	<0.001
		HEX 2 (2MM) Point-1	15	0.12±0.05		
	Pair 2	HEX 1 (4MM) Point-2	15	0.39±0.12	0.16±0.04	<0.001
		HEX 2 (2MM) Point-2	15	0.23±0.08		
	Pair 3	HEX 1 (4MM) Point-3	15	0.32±0.1	0.12±0.05	<0.001
		HEX 2 (2MM) Point-3	15	0.21±0.07		
	Pair 4	HEX 1 (4MM) Point-4	15	0.06±0.05	-0.02±0.03	0.005
		HEX 2 (2MM) Point-4	15	0.09±0.04		
	Pair 5	HEX 1 (4MM) Point-5	15	0.29±0.09	0.11±0.04	<0.001

		HEX 2 (2MM) Point-5	15	0.18±0.06		
	Pair 6	HEX 1 (4MM) Point-6	15	0.17±0.05	0.07±0.03	<0.001
		HEX 2 (2MM) Point-6	15	0.1±0.03		
	AVG	HEX 1 (4MM) Point-AVG	15	0.24±0.07	0.09±0.03	<0.001
		HEX 2 (2MM) Point-AVG	15	0.15±0.04		
Conventional	Pair 1	HEX 1 (4MM) Point-1	15	0.17±0.16	-0.02±0.17	0.738
		HEX 2 (2MM) Point-1	15	0.18±0.2		
	Pair 2	HEX 1 (4MM) Point-2	15	0.27±0.2	0.08±0.16	0.083
		HEX 2 (2MM) Point-2	15	0.19±0.16		
	Pair 3	HEX 1 (4MM) Point-3	15	0.19±0.15	0.01±0.12	0.744
		HEX 2 (2MM) Point-3	15	0.18±0.1		
	Pair 4	HEX 1 (4MM) Point-4	15	0.13±0.14	0±0.11	0.866
		HEX 2 (2MM) Point-4	15	0.14±0.1		
	Pair 5	HEX 1 (4MM) Point-5	15	0.21±0.18	0.05±0.13	0.19
		HEX 2 (2MM) Point-5	15	0.16±0.14		
	Pair 6	HEX 1 (4MM) Point-6	15	0.19±0.18	-0.03±0.23	0.627
		HEX 2 (2MM) Point-6	15	0.22±0.19		
	AVG	HEX 1 (4MM) Point-AVG	15	0.19±0.12	0.01±0.11	0.637
		HEX 2 (2MM) Point-AVG	15	0.18±0.11		

Whereas for the paired t-test between the 2mm and 4mm groups, the digital impressions showed statistically significant values for all points and their average, whereas for conventional group, the difference in deviation was statistically non-significant for all the points and their average.

Discussion

Based on the results obtained, for the angulated implant group, it was observed that values of deviation on all 6 points varied greatly for the conventional models, with minimum and maximum values of 0.01 mm and 0.92 mm which demonstrated significant variance in accuracy.

Whereas for the digital group, the minimum and maximum values were 0.01 mm and 0.3 mm which showed lesser variance in comparison. The differences between the deviation values between conventional and digital groups were also found to be significant for 4 out of 6 points on the internal hex structure on the angulated implant. In contrast, for the straight implant, all 6 points showed significant differences. This suggests the reliability of digital impression accuracy due to the angulation of the implant. Intergroup comparison between the straight and the angulated implant also suggested that there was no significant difference in accuracies of digital and conventional group.

The depth implant group demonstrated similar results with minimum and maximum values of 0.01mm and 0.81mm for the conventional group and 0.01mm and 0.53mm for the digital group. Variation in values between the conventional and digital impression groups was not significant for any point on the internal hex connection for the 4mm group except point 3 where it was found to be significant, and for point 6 in the 2mm group, which was suggestive of similar accuracy despite change in depth for both the digital and conventional impressions, although digital impressions were marginally superior at both depths with lower deviation values. Comparison between the 2mm and 4mm groups also suggested significant difference in the accuracy of the digital impression group with 4mm group demonstrating greater deviation. However, no significant difference in accuracy was observed in the conventional impression group. It may be implied from these results that the accuracy of digital impressions is less than that of the conventional impressions as the depth of the implant increases.

Impressions aid the dentist in capturing the details of the patient's oral cavity without the patient's presence, facilitating chair-side or laboratory procedures. An accurate implant impression will produce an accurate master cast, which in turn will lead to the fabrication of an accurately fitting prosthesis. Over the years, the evolution of impression materials for conventional cases has shifted from irreversible hydrocolloids to silicone-based elastomeric materials and, presently, to digital scanning software. Errors in impressions have similarly also varied, encompassing distortions, voids due to material properties, and three-dimensional inaccuracies in scanning software. Spatial accuracy is a chief factor required for an accurate impression as it demonstrates the 3-dimensional relationship of the implant with the surrounding soft and hard structures, leading to better predictability, fit, design, and favorable prognosis.

Conventional impressions capture the oral structures altogether, thus preserving the spatial relationship, which is different from scan impressions which although stitches the different images captured of the soft and hard tissues, are also affected by factors such as operator experience, software technology, and post-processing corrections as reported by Gimenez et al.[8] Operator experience is particularly crucial in digital impressions, influencing the accuracy and quality of the result, especially in implant cases.[9] However, the ease of learning digital impression-making is more effortless and efficient as concluded by Lee et al.[10,11]

Angulation in implants poses a significant risk to the accuracy of the impression itself, as noted by Mahrous et al.[12] Although not desirable, but can be unavoidable owing to limitation of mouth opening, bone availability, angulation of the bone, the position of anatomic structures, operator experience, use of surgical guides, especially in the posterior regions of the arches. For the same reasons, the depth of the implants may also vary especially in the posterior region where the thickness of gingiva varies greatly due to the different gingival phenotypes present in the population and various systemic factors affecting the thickness of the gingiva. Varying rates of resorption in the abovementioned sites make it difficult to maintain this minimum bone thickness around the implant. Especially the crestal regions in the mandibular alveolus require that the implant be placed at a greater depth to obtain the minimum osseous collar for knife-edge/tapering ridges. Current knowledge shows that at least 3 mm of vertical soft tissue thickness must be present to avoid any crestal bone loss during the formation of the biologic width around implants.[13] Therefore, to compute the spatial accuracy for these cases a value of 20 degrees and a depth of 4 mm was fixed for the implants on both models respectively.

In the current study, a mandibular model was used to simulate a partially edentulous arch of a patient to assess impression accuracies. The goals of the study included testing the difference between the accuracies in straight and angulated implants, implants placed at different depths, and digital and conventional impression materials. Study results rejected the null hypothesis which claimed that there is no difference between the two impression techniques. A third reference block was inserted to serve as a non-biased reference. The best-fit alignment of the reference block was to ensure that the surface of the rectangle completely overlaps, unlike manual alignment which could lead to errors in overlapping and would compromise the quality of the study.

A similar study was employed by Chia et al[14] and Chew et al[15], where it was performed on an acrylic block and hence no relation to the adjacent dentition was considered, whereas, this study design employed a reference block as well as the dentition to limit the error caused by other factors.

For the depth group, due to the lesser surface of the coping being embedded in the impression, a lesser force was required to displace the coping, an observation similar to that shown by Linkevicius et al[16], Lee et al[17], Ongul et al[18] and Taduri et al[19], hence leading to compromised accuracy.

The results demonstrated that the difference between digital and conventional impression-making was significant, there was greater variation in conventional impression accuracy while the digital impressions showed stability in impression accuracy values. This is owing to the various factors that influence the dimensional stability of conventional impressions themselves and the models fabricated from them, such as polymerization shrinkage, setting reaction of the stone, and the tolerance of the impression coping itself. The i500 scanner, employing triangulation technology, provided stable 3D images without relying on confocal microscopy, contributing to its accuracy. Debates among researchers regarding the accuracy of digital versus conventional impressions persist, considering factors like trueness, global distortion, linear and angular distortion, and marginal fit of final prostheses. The shift in literature from conventional superiority to digital impressions being on par or more accurate is attributed to advancements in digital scanning technologies and artificial intelligence.[20-21]

While considering the values obtained for accuracy during the study it was noted that the implant angulation did have a considerable effect on the accuracy of the conventional impressions, with straight implants outperforming the angulated implants for the conventional group. Digital impressions were not significantly affected by the implant angulation. This wide variation in the conventional impression accuracy can also be attributed to the design of the study where the conventional impressions were poured into physical models and then were scanned for accuracy evaluation whereas the digital impressions were directly imported into the 3-dimensional software for evaluation. The second model, notably, demonstrated that when the implant was placed 2mm and 4mm sub-crestal, digital impressions were marginally superior with a non-significant difference for capturing the implant placed at a depth of 2mm. The scan bodies provided in the library have a fixed height, and with most of the surface of the scan body being captured in the digital scan (for 2mm sub- crestal), the placement accuracy of the analog in the software may increase, leading to the observation. This, accompanied by the fact that digital impressions do not have any undue forces applied while the fabrication of the model takes place, which is the case for conventional impressions owing to the attachment of the lab analogs along with the pouring of the casts, which potentially leads to distortions by the operator. The same factors might act as a disadvantage when capturing the implant position at a greater depth as demonstrated in the results.

Open-tray splinted impressions have been known to improve the accuracy of the impressions made. According to the studies conducted by Del'Acqua et al.[22], Assif et al[23]. and Mostafa et al[24], it has been proven that open-tray impressions are more accurate in transferring the spatial orientation of implants than the closed-tray impression technique. There can be many reasons for this but one of the primary reasons why open-tray impressions are more accurate than closed-tray impression technique is due to lesser distortion happening in the material upon removal from the mouth.

The type of tray used for impression-making also influences implant impressions. J Burns et al[25] stated that rigid custom trays produced significantly more accurate impressions than stock trays. Del'acqua et al[22] found rigid support of impression by custom trays yields more accurate and consistent impressions than the stock trays, which can be attributed to the increased rigidity of the custom tray material. Several strategies have been suggested to minimize the distortion of the implant framework. The master cast plays a vital role in improving the fit of the prosthesis, thus accurate reproduction of the cast is essential. It provides a 3-dimensional visualization of the intraoral relationships of implants and of the implant with other oral structures. It proves beneficial in cases where the patient has limited mouth opening and the intraoral scanner cannot produce sufficient accuracy.

The splinted impression technique has been shown to be a primary factor in increasing the fitting precision of the restorative complex. According to the studies conducted by various authors like Del'Acqua[22], D Assif[23], and P Papaspyridakos[26] the implant-level splinted impression was more accurate compared to the implant-level non-splinted impressions.

With advancements in the field, the application of computer-guided surgery and CAD-CAM in implantology has simplified the treatment steps for the fabrication of prosthesis in completely edentulous patients. Studies conducted by Papaspyridakos et al[26,27,28] and Stimmelmayr et al[29] showed that the accuracy of digital impressions had the same level of precision as the conventional impressions.

Mahrous et al.[12] specified that the benefits of using a partially edentulous model align with the commonly observed clinical scenario of missing posterior teeth following which rehabilitation with dental implants are planned. The remaining dentition also serves as a better reference for evaluating the impression.

Comparison of the accuracy of the implant impression has been carried out by various methods. The present study uses 3-dimensional coordinate analyzing software and the best-fit algorithm for evaluation and comparison of the implant impressions accuracy. Which was also used in other studies done by Lin et al[30], Amin et al[31], etc. Various studies like Menini et al[32], Alikhasi et al[7], Kim et al[33,] and many more have made use of the coordinate measuring machine. Other superimposition techniques include the "least squares method" and the "zero method" as seen in studies by Jemt& Hjalmarsson et al[34]; and Gimenez et al[8].

The limitations of this study include in vivo comparison of different implant impression techniques in full arch cases and completely edentulous patients, and in clinical settings where the introduction of saliva, blood, gingival crevicular fluid, ease of inserting the scanner tip, retrieval of conventional impressions play a significant role in defining the final accuracy of the impression which can represent a challenge in the intraoral scanning impression technique. The comparison between implant level and abutment level impression techniques is also considered a limitation of this study. This study compares different implant impression techniques in free-end saddle partially edentulous cases[35]. The different implant impression techniques in bonded posterior or anterior partially edentulous patients are also considered a limitation of this study. It is recommended to utilize the adopted methodology in this study in a large sample size, comparing the mandibular and maxillary partially edentulous patients. Furthermore, the distortions measured were also linear and hence distinction of the 3 axes was not done to assess if there were distortions in a specific axis.

It is therefore imperative that due to the ease of learning digital impression-making and the efficiency associated with digital impressions, intraoral scanners should be preferred for implant impressions as they may provide with sufficient accuracy required to deliver a long-lasting prosthesis.

Conclusion

It was concluded that for implants placed at different angulations, digital impressions are significantly more accurate than conventional impressions, whereas for implants placed at deeper depths, digital impressions performed better at 2 mm whereas conventional impressions were better at 4 mm depths.

References

1. Wee AG. Comparison of impression materials for direct multi-implant impressions. J Prosthet Dent 2000;83(3):323-331.
2. Shankar Y R, Sahoo S, Harikrishna M, Shameen P, Satyendra T, Narula S. Accuracy of implant impressions using various impression techniques and impression materials. J Dent Imp 2016; 6(1):29-36.
3. Degidi M, Perrotti V, Shibli JA, Novaes AB, Piattelli A, Iezzi G. Equicrestal and subcrestal dental implants: a histologic and histomorphometric evaluation of nine retrieved human implants. J. Periodontol. 2011;82(5):708-715.
4. Vojdani M, Torabi K, Ansarifard E. Accuracy of different impression materials in parallel and nonparallel implants. J. Dent. Res.. 2015;12(4):315.
5. Tsagkalidis G, Tortopidis D, Mpikos P, Kaisarlis G, Koidis P. Accuracy of 3 different impression techniques for internal connection angulated implants. J Prosthet Dent 2015;114(4):517-523.
6. Izadi A, Heidari B, Roshanaei G, Allahbakhshi H, Fotovat F. Comparative study of dimensional accuracy in three dental implant impression techniques: open tray, closed tray with impression coping, and snap cap. J Contemp Dent Pract. 2018;19(8):974-981.
7. Alikhasi M, Siadat H, Nasirpour A, et al: Three-dimensional accuracy of digital impression versus

conventional method: Effect of implant angulation and connection type. Int J Dent 2018:376.

8. Gimenez, B., Ozcan, M., Martinez-Rus, F. &Pradies, G. Accuracy of a digital impression system based on active wavefront sampling technology for implants considering operator experience, implant angulation, and depth. Int. J of Oral Maxfac Implants.2014;29:853–862.
9. Asawa N, Bulbule N, Kakade D, Shah R. Angulated implants: an alternative to bone augmentation and sinus lift procedure: systematic review. J Clin Diagn Res 2015;9(3): ZE10-ZE13.
10. Lee SJ, Gallucci GO. Digital vs. conventional implant impressions: efficiency outcomes. Clin. Oral Implants Res. 2013;24(1):111-115.
11. Lee SJ, Macarthur RX 4th, Gallucci GO. An evaluation of student and clinician perception of digital and conventional implant impressions. J Prosthet Dent 2013;110(5):420-423.
12. Mahrous HI, Shehab GI, Sallam HI. Effect of implant angulation and tray type on dimensional accuracy of open tray implant impressions. Egypt. Dent. J. 2016;62:463-475.
13. Puisˇys A, Vindasˇiūtė E, Linkevicˇienė L, Linkevicˇius T. The use of acellular dermal matrix membrane for vertical soft tissue augmentation during submerged implant placement: A case series. Clin Oral Implants Res 2015;26:465–470.
14. Chia VA, Esguerra RJ, Teoh KH, Teo JW, Wong KM, Tan KB. In Vitro Three-Dimensional Accuracy of Digital Implant Impressions: The Effect of Implant Angulation. Int J Oral Maxillofac Implants. 2017;32(2):313-321
15. Chew AA, Esguerra RJ, Teoh KH, Wong KM, Ng SD, Tan KB. Three-Dimensional Accuracy of Digital Implant Impressions: Effects of Different Scanners and Implant Level. Int J Oral Maxillofac Implants. 2017;32(1):70-80
16. 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.
17. 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;99:107–113.
18. Ongul D, Gokcen-Rohlig B, Sermet B, Keskin H. A comparative analysis of the accuracy of different direct impression techniques for multiple implants. Aust Dent J. 2012;57:184–189.
19. Taduri T, Mathur S, Upadhyay S, Patel K, Shah M. Effect of Implant Angulation and Depth on the Accuracy of Casts Using the Open Tray Splinted Impression Technique. J Oral Implantol. 2021 Dec 1;47(6):447-454.
20. Kihara H, Hatakeyama W, Komine F, Takafuji K, Takahashi T, Yokota J, Oriso K, Kondo H. Accuracy and practicality of intraoral scanner in dentistry: A literature review. J Prosthodont Res. 2020;64(2):109-113.
21. Richert R, Goujat A, Venet L, Viguie G, Viennot S, Robinson P, Farges JC, Fages M, Ducret M. Intraoral Scanner Technologies: A Review to Make a Successful Impression. J Healthc Eng. 2017;8427595.
22. Del'Acqua MA, Filho J, Compagnoni MA, Mollo Jr D. Accuracy of impression and pouring techniques for an implant-supported prosthesis. Int J Oral Maxillofac Implants. 2008;23:226–236.
23. Assif D, Fenton A, Zarb G, Schmitt A. Comparative accuracy of implant impression

procedures. Int J Periodontics Restorative Dent. 1992;12: 112–121.

24. Mostafa TM, Elgendy MN, Kashef NA, Halim MM. Evaluation of the precision of three implant transfer impression techniques using two elastomeric impression materials. Int J Prosthodont. 2010;23:525–528.
25. Burns J, Palmer R, Howe L, Wilson R. Accuracy of open tray implant impressions: an in vitro comparison of stock versus custom trays. The J prosthet dent. 2003;89(3):250-255.
26. Papaspyridakos P, Chen CJ, Gallucci GO, 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
27. Papaspyridakos, P., Lal, K., White, G.S., Weber, H.P. & Gallucci, G.O. Effect of splinted and nonsplinted impression techniques on the accuracy of fit of fixed implant prostheses in edentulous patients: a comparative study. Int J Oral Maxillofac Implants.2011(26): 1267–1272.
28. Papaspyridakos P, Gallucci GO, Chen CJ, Hanssen S, Naert I, Vandenberghe B. Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin. Oral ImplantsRes.2016;27(4):465-472.
29. Stimmelmayr M, Güth JF, Erdelt K, Edelhoff D, Beuer F. Digital evaluation of the reproducibility of implant scanbody fit—an in vitro study. Clin. Oral Investig. 2012;16:851-856.
30. Lin WS, Harris BT, Elathamna EN, et al: Effect of implant divergence on the accuracy of definitive casts created from traditional and digital implant-level impressions: an in vitro comparative study. Int J Oral Maxillofac Implants 2015;30:102-109.
31. Amin S, Weber HP, Finkelman M, et al: Digital vs. conventional full-arch implant impressions: a comparative study. Clin Oral Implants Res 2017;28:1360-1367.
32. Menini M, Setti P, Pera F, et al: Accuracy of multi-unit implant impression: traditional techniques versus a digital procedure. Clin Oral Investig 2018;22:1253-62
33. Kim KR, Seo KY, Kim S. Conventional open-tray impression versus intraoral digital scan for implant-level complete-arch impression. J Prosthet Dent 2019;122:543-549.
34. Jemt, T. & Hjalmarsson, L. In vitro measurements of precision of fit of implant-supported frameworks. A comparison between “virtual” and “physical” assessments of fit using two different techniques of measurements. Clin. Impl. Dent and Related Research 2012:14(4(Suppl 1):175–182).
35. Dohiem MM, Abdelaziz MS, Abdalla MF, Fawzy AM. Digital assessment of the accuracy of implant impression techniques in free end saddle partially edentulous patients. A controlled clinical trial. BMC Oral Health. 2022;22(1):486