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Original Research Article

Effect of different scan patterns on accuracy of angulated and straight implant-
An in vitro studyHarshal Ghanashyam Diwase^{1*}, Aishwarya Diliprao Gholap¹, Kishor Mahale¹,
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ABSTRACT

Background: A recently introduced scan body enables digital scan of implant, giving its perfect position. However, information on the effect of different scan pattern on scan accuracy of digital implant, scan of angulated and parallel implant is lacking.**Aim:** The purpose of this In -Vitro study was to evaluate effect of different scan pattern on scan accuracy of digital implant scan of angulated and parallel implant to adjacent tooth.**Materials and Methods:** Two models were generated secured with lab analog, one parallel to adjacent tooth and one angulated (between 15 to 18degree) to the adjacent teeth at right second molar region in dentate mandibular model. The master reference model was generated by scanning the model with lab scanner. The models were then scanned with 4 different scan pattern (SP-A, SP-B, SP-C, SP-D) by using intra oral scanner (Densply Sirona cerec Omnican). STL file was generated for both (control and study group) and by using Autodesk mesh mixer software measurements were made for accuracy.**Results:** Results were analyzed using One way anova test. No statistical significant difference found between scan patterns in both parallel and angled implant but there was different in the mean deviation in both the models among different scan pattern. In both the models, scan pattern A was found more accurate compared to other scan patterns.**Conclusion:** The scan pattern influenced by accuracy of intra oral scanner in different ways. In terms of both trueness and precision SP-A is found most accurate and SP-D least has least accuracy. Hence full arch scanning will give more accurate results rather than sectional scanning.This is an Open Access (OA) journal, and articles are distributed under the terms of the [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License](https://creativecommons.org/licenses/by-nc-sa/4.0/), which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.For reprints contact: reprint@ipinnovative.com

1. Introduction

With the advancement in computer aided designing and manufacturing (CAD- CAM) technologies intra oral scanners (IOSs) are being used for wide range of applications in implant prosthodontics. Intra oral scans are combination of multiple 3D images that are partially superimposed to form larger 3D image.¹⁻³ Digital scans of the implants by using intraoral scan bodies (SBs) without impression making, minimizes errors which are encountered

by conventional method in clinics and laboratory.⁴⁻⁶

Scan bodies which are commercially available consist of scan region, body and base.^{2,7} An accurate IOS scan is essential considering that the impression stage is critical for implant-supported prosthesis.^{1,8,9} Accuracy is combination of trueness and precision.^{3,10,11} Trueness and precision define accuracy according to the International Organization for Standardization (ISO) standard.^{1,5,12} Trueness can be defined as the proximity of any measurement to the actual dimensions of the measured object, and precision refers to the closeness of the repeated measurements to each other.^{2,5,13}

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A number of studies are available on the effect of scan pattern on the scan accuracy of complete arch implant-supported prosthesis, completely edentulous jaws, and dentate jaws, but information regarding the effect of the scan pattern on the accuracy of single-implant scans in angulated and parallel implant to adjacent tooth is limited.^{1,13,14} Also studies shows that there is decreased accuracy on implant angulation when compared between conventional and digital scans in completely and partially edentulous arches showing no statistical difference.^{2,15,16} Though there are number of factors which influence accuracy of scan like scanning pattern ,image registration algorithms ,intra oral scanning technology, operator experience, ISB design, ambient lighting conditions.^{2,17,18}

So the present study aimed at investigating the effect of 4 different scan pattern(SP-A,SP-B,SP-C,SP-D) on scan accuracy (trueness and precision)of angulated and parallel implant by using scan body. The null hypothesis states that there is no difference in accuracy of different scan pattern on parallel and angulated implants.

2. Material and Methods

A partially edentulous mandibular model was generated with implant at right second molar region (Figure 1). Subsequently model secured with implant lab analog (Adin RS Internal Hex Implant Analog) in place. Parallelism is checked using guide pins with the adjacent tooth (Figure 2). There points are marked on the cast from where the measurements are made.

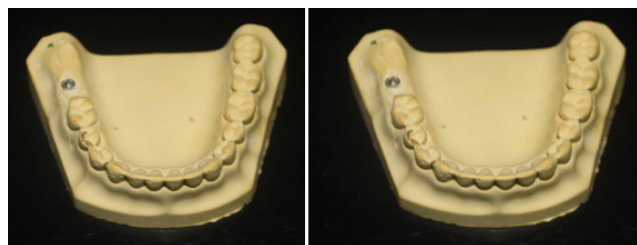


Figure 1: Model generated with implant analog

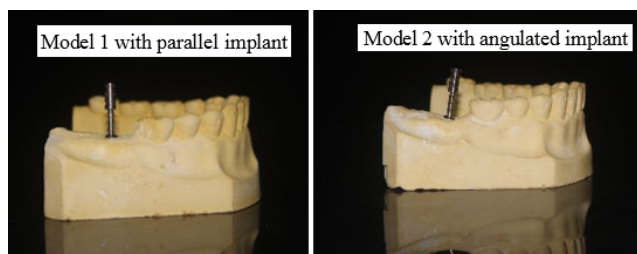


Figure 2: Parallelism checked with guide pins in both models.

A Desktop Dental Lab scanner (Densply sirona inEos X5) with stereo camera (Figure 3) working on principle

of triangulation was used to scan the master model and to generate standard tessellation language (STL) file of the master reference model (STL- Control group). Three points were marked on the cast for measurements. One on the centre fossa of adjacent tooth (Right first molar), second in centre between two Centre incisors on the lingual side, third point on Left second molar. This STL file was reverse- engineered in Auto desk mesh mixer software and measurements were made for accuracy

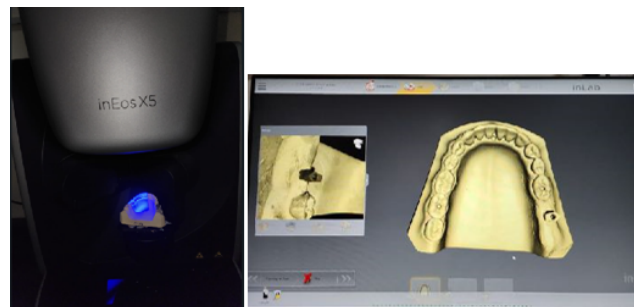


Figure 3: Scanning is done using lab scanning to generate master model

Both the models scanned using Intraoral scanner(Densply sirona cercic Omnicam) (Figure 4) when scan body is in place (RS 7 ADIN IMPLANT). All scans were made by same operator in humidity and temperature controlled room with commonly used IOSs. Calibrations were made before each scan with 5 minute break to prevent fatigue.



Figure 4: Scanning is done using Lab Scanning to Generate study Model for study group 4, different scan patterns were used to scan both the models. Five digital scans were made for each scan pattern. (Densply sirona cercic Omnicam).

1. Scan pattern A (Figure 5a), scan was started by capturing the occlusal surfaces of the teeth in the entire arch and then turning to the lingual surfaces starting from the contralateral distal molar and terminating at the original starting point. Then, the buccal surfaces

were captured starting from the original starting point until the contralateral distal molar was scanned. The scan was then completed by buccolingual rotational movements starting from the contralateral distal molar throughout the arch.

2. For Scan pattern B (Figure 5b), scans of the occlusal, lingual, and buccal surfaces were similar to those of SPA. However, buccolingual rotational movements were limited only to the area of interest (implant site).
3. Scan pattern C (Figure 5c), the whole arch was scanned twice with buccolingual rotational movements without any interruption. Except the scan pattern D all scan patterns are performed in one continuous motion starting from occlusal surface of right second molar.
4. For Scan pattern D (Figure 5d), the scan started from the occlusal aspect of the right canine and the occlusal surfaces of the teeth in the quadrant and then the SB were captured with distal movement. The lingual surfaces of teeth in this quadrant were then scanned starting from the molar and then turning buccally around the canine for buccal surface scans. The buccal scans were completed at the original starting point, and the whole arch was then scanned as performed in SP-A without any buccolingual rotational movements.

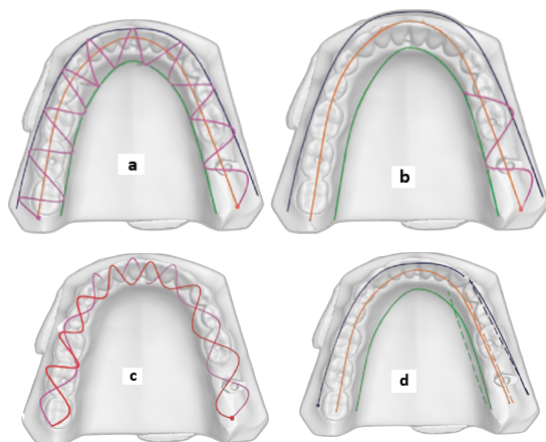


Figure 5: Diagrammatic representation of different scan patterns; **a:** Scan pattern (SP-A); **b:** Scan pattern (SP-B); **c:** Scan pattern (SP- C); **d :** Scan pattern (SP-D)

All scans were converted to STL files and digital calibrations were made in Autodesk mesh mixer software for accuracy (Figure 6) using following Points

Point 1- Represents centre fossa of adjacent tooth (Right first molar), , third point

Point 2- Represents centre between two Centre incisors on the lingual side

Point 3- Represents centre fossa of Left second molar

Point X- Represents Centre of scan body

Line joining Point X-1, X-2, and X-3 were measured and values were recorded.

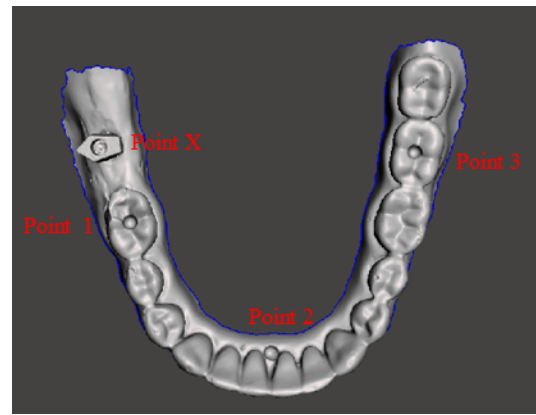


Figure 6: STL file of model showing reference points

This step (i. e. scanning and measurement of the scan) was repeated for both the models using 4 Different Scan patterns (Figure 7).

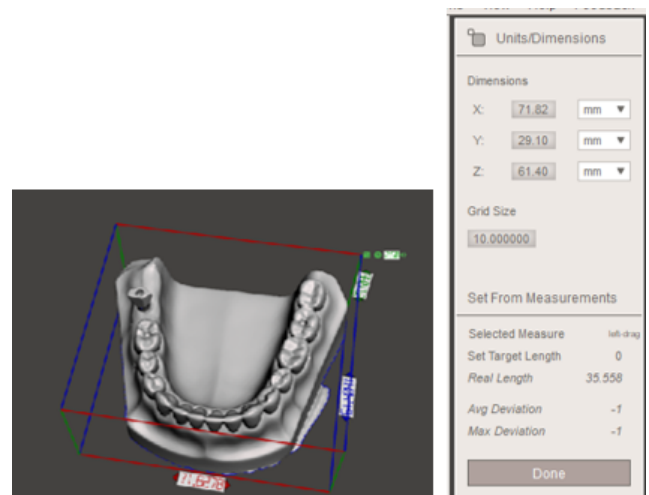


Figure 7: Generated STL file is opened in Autodesk mesh mixer software where measurements using 3 points for accuracy

3. Results

Descriptive statistics such as mean and standard deviation were calculated for quantitative variables. The p value was fixed at 0.05. Data normality was checked using Shapiro Wilk test. One way anova test for overall intergroup comparison between different groups followed by Turkey's post hoc test for pairwise comparison between groups. Data entries will be done in Microsoft Office Excel 2010 and analysis of results were done using Statistical product and service solution (SPSS) version 22 software. Results obtained were tabulated and graphs were made.

Comparison of mean standard deviation of trueness between different scan pattern of Model 1 and 2 with reference model P value > 0.05 (Table 1). Hence, mean

Table 1: Overall Intergroup comparison of trueness between desktop scanner (control) with different scan pattern of Model 1 and Model 2 respectively

	Model 1 Mean (SD)	Model 2 Mean (SD)
Extraoral scanner	35.52 (0.06)	34.74 (0.04)
Intraoral scan : SP-A	35.46 (0.15)	34.6 (0.09)
Intraoral scan : SP-B	35.51 (0.15)	34.93 (0.27)
Intraoral scan : SP-C	35.57 (0.08)	34.56 (0.62)
Intraoral scan : SP-D	35.33 (0.3)	34.4 (0.47)
One way Anova F test, p value (overall)	F = 1.114	F = 1.154
P value, Significance	p =0.382 (NS)	p =0.365 (NS)

Table 2: Pairwise intergroup comparison of trueness between extraoral scanner (control) with different scan pattern of Model 1 and Model 2 respectively

		Model 1 Mean (SD)	Model 2 Mean (SD)
Extraoral vs SP-A	Mean Difference	0.013	0.141
	P value	p = 1.000	p =0.993
Extraoral vs SP-B	Mean Difference	0.061	0.191
	P value	p = 0.995	p =0.979
Extraoral vs SP-C	Mean Difference	-0.045	0.177
	P value	p =0.998	p =0.984
Extraoral vs SP-D	Mean Difference	0.191	0.337
	P value	p =0.742	p =0.855

p> 0.05 – no statistical significant difference

Table 3: Overall Intergroup comparison of precision between different scan pattern of Model 1 and Model 2 respectively in intraoral scanners

	Model 1 Mean (SD)	Model 2 Mean (SD)
Intraoral scan : SP-A	35.36 (0.08)	34.67 (0.08)
Intraoral scan : SP-B	35.37 (0.15)	34.67 (0.36)
Intraoral scan : SP-C	35.42 (0.15)	34.08 (0.1)
Intraoral scan : SP-D	35.37 (0.3)	34.33 (0.4)
One way Anova F test, p value (overall)	F = 0.058	F = 4.081
P value, Significance	p =0.979 (NS)	p = 0.104 (NS)

p> 0.05 – no statistical significant difference

Table 4: Pairwise intergroup comparison of precision with different scan pattern of Model 1 and Model 2 respectively

		Model 1 Mean (SD)	Model 2 Mean (SD)
SP-A vs SP-B	Mean Difference	0.052	0.590
	P value	p = 0.990	p =0.132
SP-A vs SP-C	Mean Difference	0.054	0.590
	P value	p = 0.989	p =0.133
SP-A vs SP-D	Mean Difference	0.069	0.247
	P value	p =0.977	p =0.644
SP-B vs SP-C	Mean Difference	0.002	0.0005
	P value	p = 1.000	p = 1.000
SP-B vs SP-D	Mean Difference	0.0171	0.3435
	P value	P =1.000	p = 0.426
SP-C vs SP-D	Mean Difference	0.0149	0.342
	P value	P =1.000	P =0.427

deviation and standard deviation were used to compared accuracy of different scan patterns.

Table 2 shows Pairwise intergroup comparison of trueness between extraoral scanner (control) with different scan pattern of Model 1 and Model 2 respectively. For both the models Least mean difference was found with SP-A followed by SP-C then SP-B and lastly SP-D compared with reference model. Hence in the scenario where both parallel and angled implants are present in the same arch SP-A is more accurate because it is more consistent.

3.1. Least difference was observed with Group A when compared with extraoral scanners (Control group)

Overall Intergroup comparison of precision between different scan pattern of Model 1 and Model 2 respectively in Intraoral scanners whereas Table 4 shows Pairwise intergroup comparison of precision with different scan pattern of Model 1 and Model 2 respectively

For Model 1 least difference of SD was observed with SP-A, SP-B and SP-C had equal precision and more difference with SP-D. Thus in terms of precision accuracy of SP-A is more than SP-C is equal to SP-B which is more than SP-D (SP-A>SP-C=SP-B>SP-D)

For Model 2, least difference of SD was observed with SP-A followed by SP-C then SP-B then SP-D. Hence SP-A found most accurate. SP-C is more precise than SP-B and SP-D is least accurate. (SP-A>SP-C>SP-B>SP-D). Hence in scenario where both parallel and angulated implants are present SP-A will give more accurate results and SP-C can be considered more accurate than SP-B as it is more precise in both the models.

4. Discussion

The null hypothesis states that there is no significant difference in accuracy of different scan patterns in parallel and angulated implant. The null hypothesis was accepted. Also there was difference in mean and SD showing accuracy of SP-A is more than SP-C is more than SP-B is more than SP-D (SP-A>SP-C>SP-B>SP-D).

The present study aimed at investigating to compare the accuracy of different scan pattern on parallel and angulated implant to adjacent tooth. In this study the P value was found more than 0.05 (P value >0.05) therefore mean deviation and standard deviation was used to compare the accuracy of different scan patterns. The accuracy was affected by different scan patterns in both models (parallel and angulated implants). Among the scan patterns SP-A and SP-C resemble most recommended scan pattern explaining perhaps favourable scan accuracy achieved with SP-A and SP-C. SP-D show least accuracy and showed higher deviations than other scan patterns. Also for both the models least difference was observed between SP-B and SP-C, Hence precision for B and C is almost similar. Therefore when there is parallel and angulated implant in

same arch we can consider SP-C after SP-A. Since, SP-A is more accurate for both models (parallel and angulated). Angulation of implant in this study was between 15 - 18 degree, so further studies are recommended in greater degrees of angulation of implants.

Limitations of the present study included the scan accuracy of one implant and experienced by one operator only. In addition present study does not replicate intra oral conditions. In this study 4 scan patterns and 2 models were used, hence more sample size is recommended for further studies. In addition only one type scanning technology (1 intra oral scanner) and one design of ISB (intra oral scan body) is used.

5. Conclusion

The scan pattern influenced by accuracy of intra oral scanner in different ways. In terms of both trueness and precision SP-A is found most accurate and SP-D least has least accuracy. Accuracy of SP-B and SP-C is almost similar for parallel implants while SP-C is more accurate than SP-B in angulated implants. Hence in scenario where both parallel and angulated implants are present in same arch SP-A is most accurate whereas SP-C is more accurate than SP-B.

6. Conflict of Interest

None.

7. Source of Funding

None.

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