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EFFECT OF SPAN LENGTH ON THE TRUENESS OF AN INTRAORAL SCANNER. (AN IN-VITRO STUDY)

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ABSTRACT

Statement of the problem: Digital scanning has been widely used nowadays, however its accuracy in relation to the bridge span length needs further investigations.

Objective: The aim of this study was to determine the effect of span length on the trueness of an intra-oral scanner.

Materials and methods: On a typodont (Nissin Dental Model, Japan) preparations for two bridge span lengths were made. One resembling missing upper second premolar representing short straight span length (SS) while the second resembling missing upper first and second premolars representing long curved span (LS). Then typodont was scanned by a laboratory scanner (InEos X5 scanner) (Sirona Dental System, Bensheim, Germany) to act as a reference model scan to compare measurements for trueness. Then for each group five scans were taken for the typodont by Medit intraoral scanner (iScan version 1.2.0.1; Medit, Seoul, Korea) to be compared with the reference scan. Then data set from the scans were transferred to STL format and then exported to exocad (exocad version 2.3 Matera exocad GmbH,Darmstadt, Germany) software to get the measurements to determine the trueness.

Results: Results of this study showed that in the comparison between short and long span bridges, the long span bridge scans showed statistically significant higher root mean square (RMS) mean value (0.23±0.10 mm), lower trueness than short span bridge scans (0.06±0.04 mm).

Conclusions: Long span fixed bridge had an adverse effect on the scanning accuracy. Trueness of intraoral scanner may be affected by the complexity and length of the scanning area.

KEYWORDS: Span length, trueness, intraoral scanning

INTRODUCTION

Fabrication of an accurate dental prosthesis using conventional techniques could be affected by many factors including the design of the preparation, the impression technique and accuracy of the produced master cast which will eventually affect the final restoration.[1-4]

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Since 1970's digital dentistry has been used in construction of dental prosthesis, accurate reproduction of intraoral soft and hard tissue is important for the success of the restoration. Digital intraoral scanners have been rapidly evolving in dentistry to replace conventional workflow due to their numerous advantages for both the clinician and the patient including saving time, material and making the workflow more cost effective [5-7] it also decreases patient's discomfort and provide a real time visualization, ease and rapid communication. [8]

Intraoral scanners are used to capture a 3D record of the intraoral dental structure which will be transferred to a computer that will generate a 3D model from the scan on which the restoration will be designed to be sent to the milling machine to mill the restoration from the desired material. [9] Thus being able to overcome the drawbacks of conventional impressions, being able to magnify the scan and immediately evaluate it hence can identify any defect and be able to rescan it in the same visit without the need to remake the whole impression again. [10]

However their limitations include its high cost, needing technical skills, difficult in obtaining implant impression and complete arch impression [11] in addition to decreased ability in recording the margins of the preparation in presence of saliva or blood.[12-14]

Nowadays accuracy of a restoration has been a major factor to determine its success as a poorly adapted restoration will result in its failure due to cement dissolution, secondary caries and eventually periodontal complication.[15] Accuracy of an intraoral scanner has been defined in terms of trueness and precision where trueness is the deviation of the measurements from the reference scan while precision determines how close the repeated measurements are to each other. [16,17]

Intraoral scanning accuracy have been found to be affected by many factors including the pattern of the scan, the translucency and reflectiveness of the substrate, the distance of the scanning and scanner head size in addition to the design complexity and the span length.[16,18-21] A review done by Aswani et al in 2020 [22] claimed that intraoral scanning showed similar accuracy in fabrication of single unit and short span prosthesis when compared to conventional methods. However a study done by Su and Sun in 2015 [23] stated that there was a decrease in the precision of the intraoral digital impression when a larger span length was captured and they concluded that the larger and the more complicated the area to be scanned the less is the accuracy of the intraoral digital impression.

Although there are several studies available for the accuracy of intraoral scanning, no studies were conducted to determine the influence of the span length and curvature on the trueness of the intraoral scanning, thus the aim of this study was to determine the effect of span length on the trueness of an intra-oral scanner. The null hypothesis was that the trueness of the intraoral scanner will not be affected by the span length.

MATERIALS AND METHODS

A typodont (Nissin Dental Model Product INC., Kyoto Japan) was selected for this study and according to the span length samples were divided into two groups. For the first group (SS); upper second premolar was removed in order to simulate a clinical condition for missing upper second premolar representing a short straight span length while for the second group (LS); upper first and second premolars were removed to simulate a clinical condition for missing upper first and second premolars representing a long curved span.

For the first group (SS) preparation was done for the upper first premolar and first molar following the principles of all ceramic preparation [24] with 1.5mm axial reduction in which the labial surface was reduced in two planes, 2mm occlusal reduction and 1mm shoulder finish line with rounded internal angle, functional cusp bevel and a 6-10° total convergence angle, then overall finishing and roundation of all line and point angles, preparation was done using diamond tapered stone with rounded.

While for the second group (LS) preparation was done following the principles of all ceramic preparation similar to group one for molar while for the canine preparation was done with 1.5mm facial reduction done in two planes, 2mm incisal reduction, 1.5mm lingual reduction, 1mm shoulder with rounded internal angle using diamond tapered stone with rounded end, fossa reduction in the lingual surface was done by football-shaped diamond stone this was followed by rounding of all line angles.

For both groups preparation dimensions were checked and verified with a digital caliper using a silicon index which was made before the preparation. All preparations were done by a single operator for standardization.

After teeth preparation, indentations were made on the preparations to act as reference points for measurements (Fig. 1). This was made on the mid occlusal of each abutment, line angles of the abutment facing the span area and two points on the mid buccal surface one near the occlusal surface and the other near the cervical area.

Then typodont was first scanned by high accuracy laboratory scanner (inEos X5 scanner) (Sirona Dental System, Bensheim, Germany) based on digital stripe light projection with blue light with accuracy on standard "bridge" test specimens at 2.1 ± 2.8 µm, and on standard "inlay" test specimens 1.3 ± 0.4 µm to act as a reference model scan to compare measurements for trueness.

Then for each group again the typodont was scanned by Medit intraoral scanner (iScan version 1.2.0.1; Medit, Seoul, Korea) which uses two cameras for rapid video-based scans (30 frames per second). Five scans were taken for each group to be compared with the reference scan. All scans were made by a single well trained operator for standardization following the manufacturer's instructions in the following sequence; the scanning was started from the occlusal surface of the posterior teeth of the left side, moving toward the anterior teeth area, the scanner is then moved toward the labial and lingual surfaces of the anterior teeth, centered around the incisal edges, then continuing to the occlusal surface of the posterior teeth of the right side, then the lingual surfaces of the right side moving to the other side, then the buccal surfaces.

Two dimensional measurements

After scanning the data set from the scans were transferred to STL format and then exported to exocad (exocad version 2.3 Matera exocad GmbH,Darmstadt, Germany) software to get linear measurements to determine the trueness.

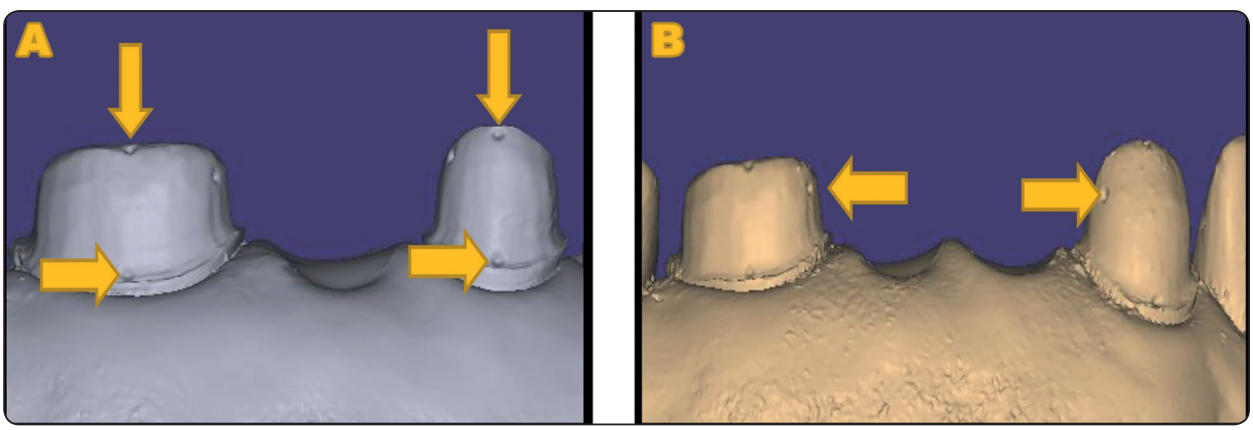

Fig. (1): Scans made by Medit intra-oral scanner for short span (A) and long span (B) arrows pointing to indentations

For each scan 4 linear measurements were made on the software following the indentations made: (Fig 2).

1- Mid-occlusal of mesial abutment to mid occlusal of distal abutment,

2- Line angle of mesial abutment to line angle of distal abutment,

3- Occluso-gingival height of mesial abutment,

4- Occluso-gingival height of distal abutment.

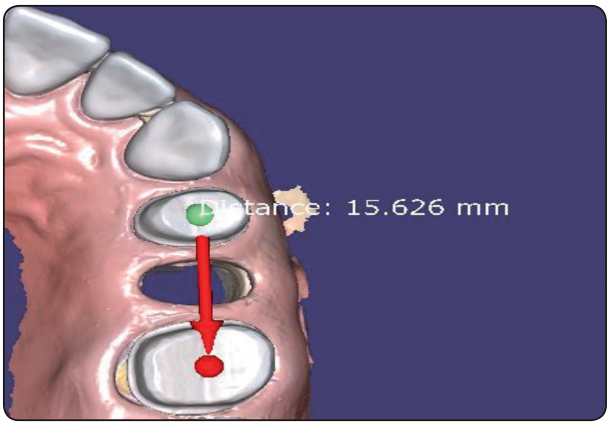

Fig. (2): Linear measurement on the software for short span bridge

Trueness was determined according to the root mean square value (RMS) which determine the amount of deviation where the RMS error value between the scans was calculated using the following formula. (25)

$$RMS = \frac{1}{\sqrt{n}} \times \sqrt{\sum^{n}_{i=0} (x_{1,i} - x_{2,i})^2}$$

Where n is the sum of the points measured, X1 , *i* is the measurement of *i* of the reference model and X2 , *i* is the measurement of *i* of the tested model.

Qualitative (Three-dimensional) analysis:

As a qualitative analysis of the trueness, the STL file data of the reference model obtained using inEos X5 scanner was superimposed with STL file data obtained from Medit intra-oral scanner. A color map representing visual deviation was set in the range of the maximum and minimum nominal values at +/- 50 µm.

RESULTS

Statistical analysis

Numerical data was represented as mean and standard deviation (SD) values. Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Independent t-test was used to analyze intergroup comparison. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.0.5 for Windows* .

There were no outliers, as assessed by boxplot of grouped data presented in figure 3. The data was normally distributed, as assessed by Shapiro-Wilk's test of normality ($p>0.05$). Descriptive statistics for RMS values for both groups were presented in table (1). Levene's test showed both groups to have unequal variances ($p=0.020$). Results of Welch's t-test presented in table (2) showed long span samples (0.23±0.10) to have a significantly higher RMS value than short span samples (0.06±0.04) ($p=0.033$) and the effect size of the difference between both groups was large (2.27 [1.64-10.20]).

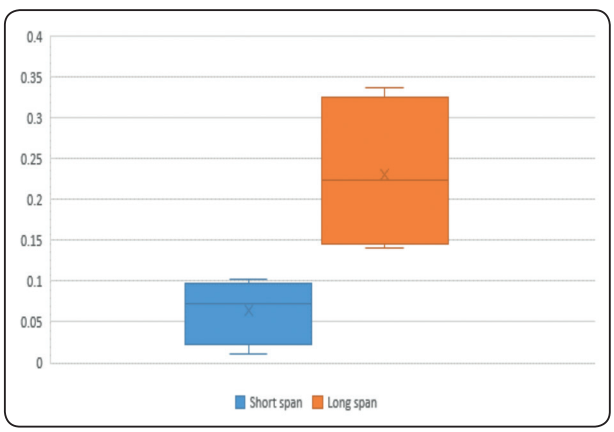

Fig. (3): Box plot showing RMS values in different groups

TABLE (1): Descriptive statistics for RMS (mm)

Group	*Mean*	*95% CI*		*SD*	*Median*	*IQR*
		Lower	*Upper*			
Short span	0.06	0.03	0.10	0.04	0.07	0.04
Long span	0.23	0.14	0.33	0.10	0.22	0.14

95%CI= 95% confidence interval for the mean; SD=Standard Deviation; IQR=Interquartile Range

TABLE (2): Intergroup comparison

RMS (Mean±SD)		*Mean difference[95%CI]*	*Cohen's d [95%CI]*	*t-value*	*p-value*
Short span	**Long span**				
0.06±0.04	0.23±0.10	0.17 [0.02-0.31]	2.27 [1.64-10.20]	3.21	**0.033***

SD=Standard deviation; 95%CI= 95% confidence interval; *significant (p<0.05)

The color map analysis

The color difference map for the short span group is shown in (Fig.4), which shows high matching between the sample scans (Medit) and the reference scan (blue and green areas) that is consistent with the two-dimensional analysis which showed trueness of 60 µm for the short span group. The color difference map for the long span group is shown in (Fig.5), which shows higher mismatch than the short span group (more yellow and green areas) that is consistent with the two-dimensional analysis which showed trueness of 230µm for the long span group.

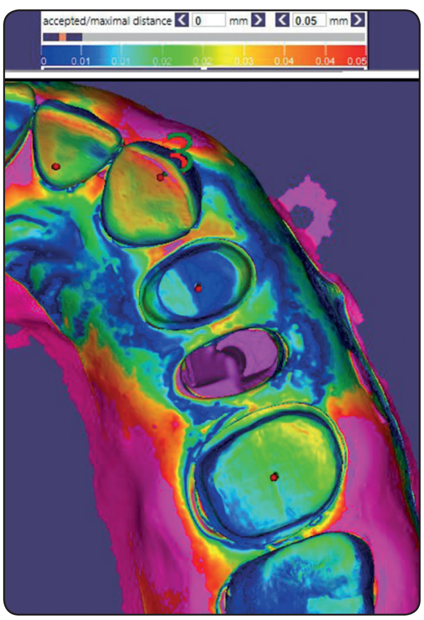

Fig. (4): Color difference map showing the trueness of the short span group from 0 µm (blue) to 50 µm (red)

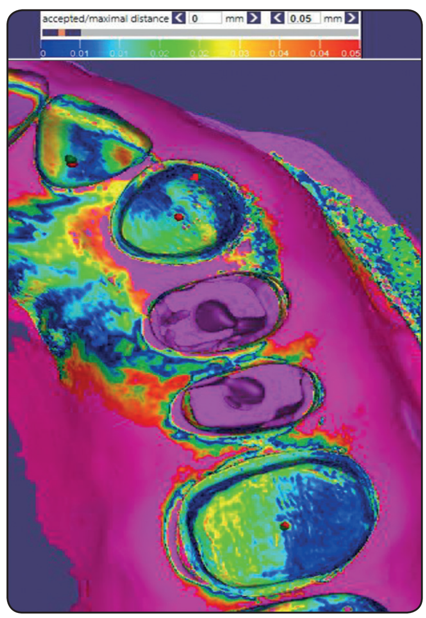

Fig. (5): Color difference map showing the trueness of the long span group from 0 µm (blue) to 50 µm (red)

DISCUSSION

This study aimed to determine the effect of span length on the trueness of an intra-oral scanner. Digital dentistry has been found to provide many advantages including 3D diagnostic information, ease of communication and elimination of fabrication errors that may be attributed with the conventional methods.[26,27] The accuracy of the intraoral scanners have been found to be dependent on many factors including data processing, scanning technology, image acquisition or weather a powder was used for scanning or not.[18] A study done by park in 2016[18] reported that the outline of the preparation in addition to the restoration type and scanning technology affects the trueness of the intraoral scanner.

As previously determined the accuracy of the dataset was done by comparing it with a reference dataset from an accurate scanner. In this study inEos X5 machine was used as the standard reference scanner instead of industrial scanner as its accuracy was verified according to DIN EN ISO 12836.2015. It was previously found that a laboratory scanner can be used to create a reference model instead of industrial one.[20,28-32] Thus each group was scanned by inEos X5 (Sirona Dental System, Bensheim, Germany) once to obtain a reference scan then each group was scanned five times by Medit intraoral scanner (iScan version 1.2.0.1; Medit, Seoul, Korea) and then compared to the reference scan.

In order to maintain standardization; preparation was done following the principle guidelines for all ceramic preparation and was done by a single operator also scanning was done with no powder applied and with an average timing to exclude the effect of scanning time on the accuracy of the scan and a single well trained operator performed all the scans.[20,33]

Results of this study revealed that long span bridges showed statistically significant higher RMS (0.23±0.10 mm) values, lower trueness than short span bridges (0.06±0.04 mm). Hence the null hypothesis was rejected. This was in accordance with study done by Su and Sun in 2015[23] which showed that there was a decrease in the accuracy of the intraoral scanner when the area to be scanned is increased. Other studies also concluded that scanning showed a clinically accepted accuracy when less than half the arch was scanned while there was a decrease in accuracy when a larger and more complicated area were scanned. [23,34]

The lower accuracy of scanning large span was attributed to difficulty in both recording an accurate tooth surface in addition to difficulty in recording the occlusal relationship after preparing several teeth, hence studies have claimed that intraoral scanner can be used and produce similar accuracy to conventional techniques when scanning single tooth or short span prosthesis.[35-41] Also it was noted that large area scanning results in multiple single images merging together which results in progressive distortion and hence decrease in the accuracy of the resultant data set.[11]

It was suggested by Ender et al in 2016[42] that the final restoration may not be adequately fitted if the accuracy of the scanning was more than 100 μm. The same was claimed by Fukazawa et al in 2017[43] who related this to the acceptable cement space for the restoration.

There are many previous studies that have evaluated the accuracy of digital scanners. A study done by Park et al in 2019[44] evaluated the accuracy of four different intraoral scanners and found variations in accuracy in relation to the type of the scanner; where CS3600 showed accuracy to be 118.9 ± 42.1 μm while for CS3500 it was 209.9 ± 53.7 μm while trios 2 and trios 3 showed accuracy of 343.4 ± 56.4 μm and 183.9 ± 49.7 μm respectively. Michael Braian et al in 2019[45] also studied the accuracy of five intraoral scanners and they found it to be less than 193 μm. Differences in results between studies may be attributed to different types of intraoral scanners, different scanning areas and difference in the method of evaluation of the accuracy.

Limitations of the study were that it was conducted in-vitro and not in-vivo as clinical conditions including patient's movement, soft tissue movement, limited intraoral space and presence of bleeding and saliva might have had an adverse effect on the scanning accuracy. Another limitation was the use of only one intraoral scanner. Further studies are recommended with different intraoral and extraoral scanners and with complete work flow including the manufacturing of the restoration.

CONCLUSIONS

Within the limitations of this study the following can be concluded:

1. Long span fixed bridge had an adverse effect on the scanning accuracy.
2. Trueness of intraoral scanner may be affected by the complexity and length of the scanning area.

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