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TRUENESS OF EXTRA-ORAL SCANNER IN RELATION TO TWO SPAN LENGTHS. AN IN-VITRO STUDY

Karim Aboubakr *

ABSTRACT

Statement of the problem: Extraoral scanners have been used widely nowadays however there are certain conditions that could affect their accuracy which will subsequently affect the success of the final restoration.

Objective: The aim of this study was to determine the accuracy of extraoral scanner in relation to two span lengths.

Materials and methods: A typodont (Nissin Dental, Kyoto Japan) was used and two bridges with different span lengths were prepared, the first one with missing upper left second premolar (short straight span (GS)) and the other with missing upper left first and second premolars (long curved span (GL)). Indentations were made on each abutment to be taken as a reference for measurements. For both groups reference scan was taken by in Eos X5 extra-oral scanner. Then five physical impression was taken for each group using vinylpolysiloxane impression material (Honigum, Germany) and then poured into type IV dental stone. Casts of each group were scanned using DOF extraoral scanner (DOF Company, Korea). Measurements were made from the indentations on the reference scan and the sample scans, compared with each-other and root mean square value (RMS) was obtained to evaluate the trueness.

Results: Comparison between short and long span bridges revealed that there was no statistically significant difference between trueness values of short and long span bridges. Where RMS mean for the short span was 0.0727 mm and that for the long span was 0.1069 mm.

Conclusions: Different span lengths do not seem to affect the trueness of the extra-oral scanner tested.

KEYWORDS: Trueness, span lengths, extraoral scanner.

* Lecturer of Fixed Prosthodontics Department Faculty of Dentistry, Cairo University, Egypt.

INTRODUCTION

Since the introduction of CAD/CAM technology in dentistry, it has been routinely used in dental practice as it was claimed to facilitate the restorative procedure by eliminating some procedural steps as tray selection and storage, material storage, dispensing and disinfection and this was only replaced by digital impression that can be digitally evaluated and stored. [1,2]

However digital impressions have not totally replaced the conventional impression as a result of the high cost of the intraoral scanners in addition that they need an expert to use them and also possess some problems as artifacts that affect the precision of the impression.[3] In addition to difficult or restricted area of scanning and movement of patients thus may increase the time of scanning to 27 % more than taking a conventional impression, in certain clinical conditions accuracy of intraoral scanning have not yet been proven.[4-8] Extraoral scanning requires taking a conventional impression to produce a stone cast, many studies have shown the accuracy and excellent long- term results of prosthetic restorations fabricated by using extraoral scanners.[9-11] One of the parameters that determine the accuracy of the scanner is the trueness which describes how far the measurements differ from the actual measurements of the object.[12]

Different extraoral scanners are available in the market such as laser scanners, blue light or white light scanners. Laser scanners have slow speed of scanning and low initial repeatability and uses a line pattern, white light scanners have a good speed of scanning but lack repeatability and error occurs especially in scanning narrow and deep areas while blue light scanners have higher precision as a result of shorter wavelength so it produces less errors and have greater scanning repeatability. [13-15]

Extraoral scanning will require impression taking which will either be scanned or poured into cast which will later be scanned, errors may occur as a result of defective impression or gypsum cast.[16] Studies have shown that extraoral scanners is able to reach an acceptable accuracy level; [17-19] however, there are many known and unknown factors that may affect accuracy of the produced scan, nevertheless the effect of span length on the accuracy of the extraoral scanner has not yet been determined. Thus the aim of this study was to determine the trueness of an extraoral scanner in relation to different span lengths. The null hypothesis was that there will be no statistically significant difference in the trueness of the extraoral scanner in relation to the different span lengths.

MATERIALS AND METHODS

Reference model preparation

On a Typodont (Nissin Dental Model Product INC., Kyoto Japan) two different bridges with different span lengths were simulated; in the first group (short straight span (GS)) resembling missing upper left second premolar and the second group resembling missing upper left first and second premolars (long curved span (GL)). Before preparation a silicon index was performed in order to check the dimensions of the preparations afterwards.

In the first group (GS) preparation was done for upper left first premolar and first molar following the guide lines of all ceramic preparation [20] with 2mm occlusal reduction, 1.5 mm axial reduction with the buccal surface reduced in two planes and 1mm deep chamfer finish line, preparation was done using diamond tapered stone with rounded end. After checking the dimensions of the preparation all line angles were rounded.

For the second group (GL) preparation was done for upper left canine and first molar also following the principles of all ceramic preparation, molar preparation was done as group (GS) while canine preparation was done with 2mm incisal reduction, 1.5 mm labial reduction done in two planes, for lingual reduction football-shaped diamond stone was used for 1.5 mm fossa reduction, 1mm deep chamfer finish line was made with diamond tapered stone with rounded end this was also followed by checking of the preparation with the silicon index using digital caliper and rounding of all line angles. Preparation was done by the same operator for both groups.

To standardize the points of measurements, indentations were made on the typodont on each abutment. Four indentations were made on each abutment; at the line angels of each abutment facing each other, mid occlusal of each abutment and two indentations on the middle of the buccal surface: one near the cervical area and one near the occlusal surface.

A reference scan of the Typodont was made directly with inEos X5 scanner (Sirona Dental System, Bensheim, Germany) (Fig. 1), which is a highly accurate laboratory scanner that uses a digital stripe projection scanning technology with blue light.

Stone model fabrication using a conventional workflow

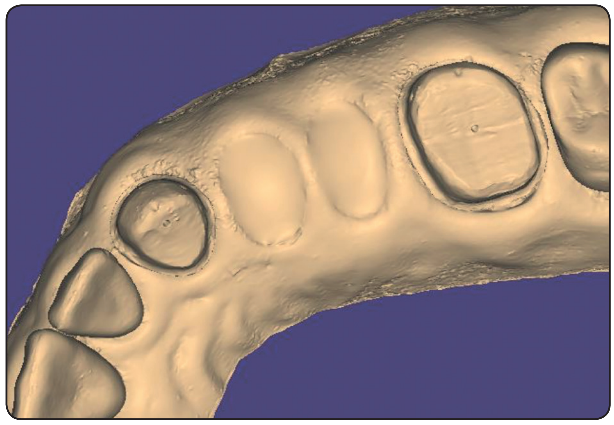

Fig. (1): Reference scan made by inEos X5 extra-oral scanner for long span bridge

Then to simulate normal workflow for using extra-oral scanner (Fig.2), physical Impression using double mix single step technique with light and heavy body polyvinyl siloxane impression material (Honigum, Germany) was made for the typodont using a special tray after application of an adhesive (Identium Adhesive, Germany) to ensure

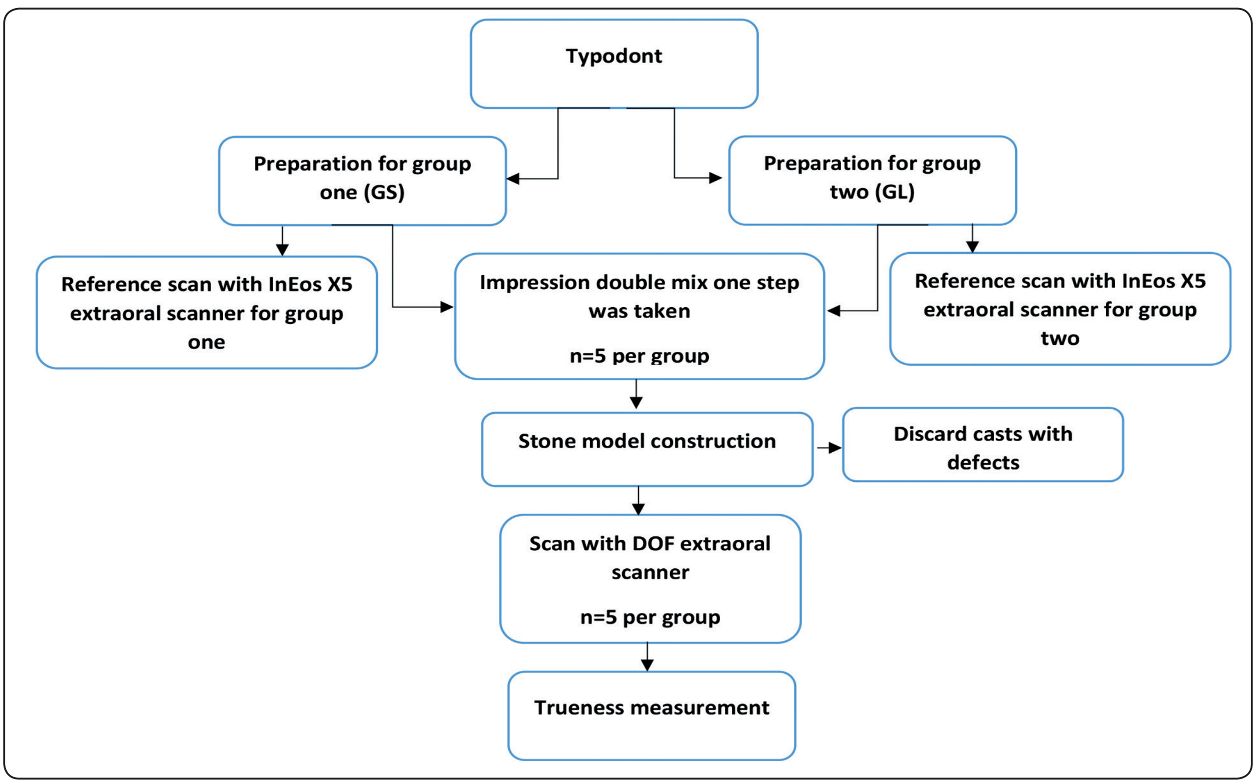

Fig. (2): Study design

maximum adhesion of the impression to the tray and the impression was left to completely set three times more than the manufacturer recommendation to ensure complete polymerization at room temperature [21] then the impression was cleaned and disinfected with iodoform then poured into type IV dental stone (GC FUJIROCK, EP, GC America Inc.) after one hour which was vacuum mixed for 45 seconds and poured under vibration. After complete setting the cast was removed and visually inspected for any defects. Any defected cast was discarded. For each group five impressions were taken and hence five stone casts were available for each group. Then the stone casts were scanned with DOF Extra-oral scanner (intervention) (DOF Company, Korea) which uses a camera moving system technology to move the 3D scan engine in several directions, so the teeth model does not need to be fixed with a jig and even the uneven bottom model is scanned easily, the scanner uses a white light LED. So, for each of the intervention groups, five Scans were made (Fig. 3).

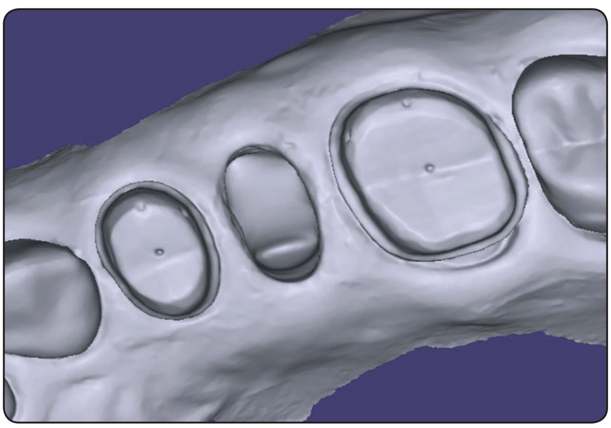

Fig. (3): Scan made by DOF extra-oral scanner for short span bridge

Quantitative (Two-dimensional) analysis:

The scans were then transferred to STL files and exported to exocad software (exocad version 2.3 Matera exocad GmbH, Darmstadt, Germany). On the software four linear measurements were made: Mid-occlusal of mesial abutment to mid occlusal of distal abutment, Line angle of mesial abutment to line angle of distal abutment, Occluso-gingival height of mesial abutment and Occluso-gingival height of distal abutment. Root mean square (RMS) was then obtained from the measurements taken which determines the deviation of the scans from the reference to evaluate the trueness.

Trueness was obtained from (RMS) root mean square which determines the deviation of the scanning from the reference scan and determining the RMS error using the following formula: [22]

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

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 of the tested model.

Qualitative (Three-dimensional) analysis:

As a qualitative analysis of the trueness, the STL file data of the reference model was superimposed with STL file data obtained from the conventional stone using DOF extra-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 were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and ShapiroWilk tests. All data showed normal (parametric) distribution except for trueness values which showed non-parametric distribution. Data were presented as mean and standard deviation (SD) values. Wilcoxon signed-rank test was used to compare between short and long span bridges. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Measurements of reference standard, short and long span bridges are presented in Table (1). Trueness values are presented in Table (2). Comparison between short and long span bridges revealed that there was no statistically significant difference between trueness values of short and long span bridges.

Analysis on the color difference map:

The color difference map for the short span group is shown in (Fig.4), which shows notable difference in the premolar abutment (pink color) above the set value +/-50 µm that is consistent with the two-dimensional analysis which showed trueness of 72.7 µm for the short span group. The color difference map for the long span group is shown in (Fig.5), which shows notable difference in the molar abutment (pink color) above the set value +/-50 µm that is consistent with the two-dimensional analysis which showed trueness of 106.9 µm for the long span group.

TABLE (1): Descriptive statistic of the different measurements by DOF extra-oral scanner and the reference measurement

Measurement site	Short span			Long span		
	Reference (mm)	Mean	SD	Reference (mm)	Mean	SD
Mid occl to mid occl	15.701	15.728	0.035	22.94	22.709	0.36
Occ/Ging. Posterior abutment	4.909	4.82	0.039	4.862	4.842	0.055
Occ/Ging. Anterior abutment	5.416	5.386	0.016	7.409	7.281	0.044
Line angle to line angle	9.77	10.121	0.112	16.609	16.754	0.135

TABLE (2): Descriptive statistics and results of Wilcoxon signed-rank test for comparison between trueness values in short and long span bridges expressed in mm.

Short span (n = 5)		Long span (n = 5)		*P*-value	*Effect size (d)*
Mean	SD	Mean	SD		
0.0727	0.0396	0.1069	0.1549	0.893	0.06

: Significant at P ≤ 0.05

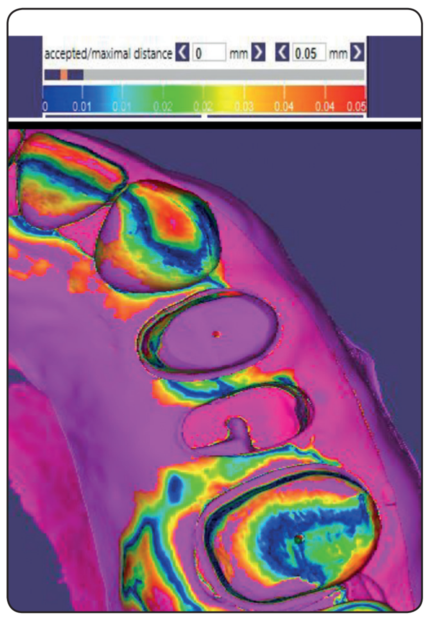

Fig. (4): Color difference map showing the trueness of the short span group from 0 µm (blue) to 50 µm (red)

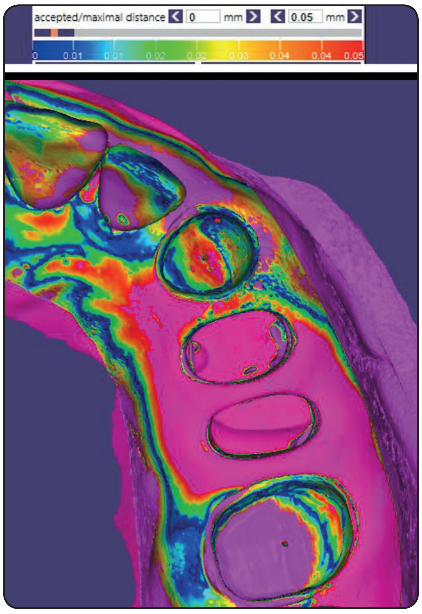

Fig. (5): Color difference map showing the trueness of the long span group from 0 µm (blue) to 50 µm (red)

DISCUSSION

This study was performed to determine the trueness of an extraoral scanner in relation to different span lengths. This was done by performing preparation for the two groups on the typodont, where preparations were done following the guidelines for all ceramic preparation and is done by a single operator for standardization. Indentations were made on the abutments for standardization of the points of measurements.

In order to make a reference scan instead of using an industrial scanner a dental laboratory scanner has been used as described previously with a highly accurate extraoral scanner inEos X5 as according to DIN EN ISO 12836.2015, its accuracy have been verified. [23]

After preparation five impressions were taken for each group using addition silicone impression material due to its excellent handling characteristics and physical properties expressed mainly in its high dimensional stability which is important to obtain an accurate replica without change in dimensions or size.[24-26] Impression was made using single step double mix technique as studies had shown that single step had lesser discrepancies and are more accurate than two stage technique. [27-28]

Type IV dental stone was then used to obtain the master cast. Then casts were scanned using DOF Extra-oral scanner (DOF Company, Korea) to be compared with the reference scanner.

Trueness was determined by calculating the RMS value as used in previous system analysis. [4,7,29]

Results of this study showed that extraoral scanning of a short span bridge showed better trueness than long span but with no statistically significant difference between them. Thus the null hypothesis was accepted. Previous studies have shown decrease in accuracy with the increase of the scanned area; [13,29] scanning large areas produce a higher inaccuracy and progressive distortion resulting from the merge of multiple images. [12]

Studies have shown that extraoral scanning of a cast was found to be better than intraoral scanning where the scanning time has to be short to avoid blurred images. [30] Intraoral scanning accuracy is limited to the size of the camera and its ability to enter as posterior as possible to capture all teeth. A study done by Su and Sun in 2015[1] stated that intraoral scanning precision decreases with the increase in the scope of scanning while that for extraoral scanning was clinically acceptable regardless of the scope of scanning. Cho et al in 2015[29] also stated that conventional cast showed better scanning accuracy of an entire cast when compared to digital cast.

Hayashi et al in 2013[31] declared a trueness of 50-55 um of two optical scanners when scanning a full arch. While another study found trueness of an extraoral scanner to be 43.6 um when scanning a full arch model.[32] It is challenging to compare our results with other studies due to difference in tested scanners, reference scanners and master model used.

Limitations of this study include the use of a typodont which does not simulate the clinical conditions and problems that may be encountered during impression taking, in addition only one scanner and one impression material is used. Further studies are required with different scanners in addition to clinical studies to validate the results of the study.

CONCLUSIONS

Different span lengths do not seem to affect the trueness of the extra-oral scanner tested.

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