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Evaluation Of the imaging accuracy of Different Desktop Scanners, with different restorations designs

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ABSTRACT

Statement of problem. The market is loaded with a variety of digital scanners for dental use, and the quality of the final outcome is not yet consistent. What affect our work more is the precision of the end restoration and this remains to be questionable. With the emergence of large number of digital scanners of inconsistent final outcome, it is of great importance to assess the precision of the end restoration.

Purpose. The primary objective of this study is to assess the accuracy for a model scanned by different types of desktop scanners; Identica hybrid, Kavo arctica, 3Shape D850 in comparison to InEos x5 for different restorations designs as extracoronal restoration, intracoronal restoration, multiple restorations and full model

Material and methods. A typodont with preparations of different restoration: extracoronal, intracoronal and fixed partial denture was scanned with the mentioned dental desktop scanners in comparison with a reference InEosX5. STL files were exported from each scanner and compared with those taken from the reference scanner using geomagic studio 2012 to have accuracy results in terms of trueness and precision, STL files within the same scanners were superimposition on each other.

Results. For trueness and the root mean square, only restoration design had a significant effect on (RMS). For precision and the root mean square, there was a

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significant interaction between type of the scanner and design of the restoration. The effect of restoration design within all scanners, there was a significant difference; the crown was least value, except in kavo, onaly was least value. Effect of Scanner type within each restoration design depth, there was significant difference in the precision of model and the least value was in 3shape D850.

Conclusions. In trueness restoration design has significance effect, the crown was least value of RMS. In precision, there was significance difference between type of scanner and restoration design. Crown was least value in all scanners except in kavo the onlay was the least. And effect of scanners within restorations, no significance difference except in model the least value was in 3shape D850._

INTRODUCTION

Technical breakthroughs is contributing greatly in the digital dental evolution each year(1), staring in the early 80s, when the concept of virtual impression and manufacturing was first introduced as Computer Aided Design and Computer Aided Manufacturing (CAD/CAM)(2). Digital Dental Technology (DDT) is a way to provide more efficient practice compared to conventional methods, added to that the mechanical precision and avoidance of human error, which saves a significant working time. Yet such technology comes in high prices, that might be inconvenient to some practitioners (3) (4).

A 3D scanner is a device serving for the conversion of a real object into digital form. Newly developed pieces of equipment and technology in dentistry have enabled us to respond to various patient requirements. The process of dental restoration fabrication using (CAD/CAM) system, take a place by converting the definitive cast into a virtual one obtained from conventional impression (5).

During the fabrication of dental restorations using a computer-aided design and computer- aided manufacturing (CAD/CAM) system, a definitive cast is often digitized from a conventional impression (5). (CAD/CAM) Technology is an integral role in the new dental practice which grabbed the interest by applying less visits compared to conventional restoration process, with elimination of common errors such as lost-was casting, yet accuracy remain a dilemma concerning (CAD/CAM) technology (6).

Elastomeric impression is an unavoidable step in everyday conventional practice that might provide the dental laboratories with some inaccurate outcomes due to human errors such as flaws such as voids and bubbles at critical regions of the impression (7). Additional to that duplication of casts can sometimes be an obstacle, that's when the new technological advances are here to solve these problems, the desktop scanners is an evolutionary development in the field of Fixed prosthodontics, to duplicate and scan the casts efficacy and to take less time to scan with more accuracy. The accuracy is in the terms of trueness and precision, this two terms is important for evaluating the accuracy (ISO 5725-1) (8)

Trueness and Precision

For trueness measurement, the digital data from each group of scanners is overlapped the reference data of the reference scanner, this is the amount of difference between true value and average value. The true value is agreed with characterization of the object.Precision measurement is the digital data from scanner superimposed on the other data from the same scanner (9).

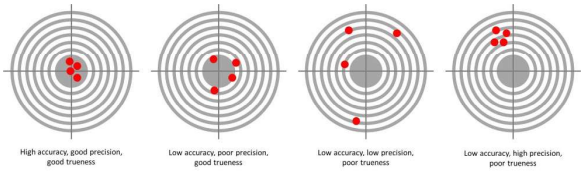

Figure1: trueness and precision

By exporting the result to STL file or Standard Tessellation Language, this file is obtained from the 3D scanners without color and texture. It is

a 3D model with surface geometry of standard computer format. This file format is made from point clouds, this point have specific position in space .this used for creation of 3D object (10).

MATERIAL AND METHODS

Three scanners were evaluated in comparison with InEosX5 scanner by scanning typodont* olive green model of different restorations with different preparation:

a- Extracoronal restoration: full coverage crown.

b- Intracoronal restoration: onlay.

c- Multiple restorations: fixed partial denture (FPD).

Preparation of different restoration is already done as follows:

For the full coverage upper right central: 1.5 mm incisal reduction, six degrees axial wall convergence, with prepared second plane, and 1mm 360° chamfer finish line located at the cervical area. The sharp angles were rounded and the fossa was prepared.

And for upper left second premolar and canine as abutments and missing upper left first premolar, reduction same as the full coverage for the fixed partial denture with bevel in the palatal cusp of the second premolar and fossa preparation of the canine.

The upper right second molar for onlay preparation: reduced disto-buccal cusp height 1.5mm same morphology of natural cusp with external shoulder finish line and the central cavity depth 2mm with 6 degree axial divergence with rounding internal line angles. Proximal extension of the cavity mesially box extending 1 mm gingivally and distally sliding from cusp and from central cavity extension.

Scanners:

The different types of desktop scanners are:

1. Identica hybrid (Blue LED light)
2. Kavo arctica (Striped light projection)
3. 3Shape D850 (Blue LED)

In comparison to InEos x5 (Blue light radiation UV)

Table 1: Types of scanners used in research with manufacture and corresponding software

Scanner	manufacturer	Software
3shape D850	3shape, denemark	3shape Scanit dental 2017
Ineosx5	Dentsply,sirona,USA	Inlab 15 software
Identica hybrid	MEDIT corp, korea	Collab 2017 software
Kavo arctica	Kavo excellence,germany	Arctica autoscan software

3shape D850:

This scanner is blue LED multi-line with 2 cameras, 5 mega pixels with 3 axis motion system to facilitate scanning more than 350 degree of a sphere and the accuracy of scan is 7 μm (ISO 12836) with texture/color capture for marking design process. This scanner exported open STL file and the time of scanning if full arch is 55 seconds and 25 seconds for single die.

InEos X5:

A blue light stripe scanner with five Axis technology with a robotic arm and automatic placement of the model. Exported the result to open STL file and the time of scanning the whole jaw is < 60 seconds. There are two modes for scanning the manual and automatic, the manual scanning is for the simple procedure, the automatic mode for complex procedure (11) (12). This scanner have large place for scanning articulated model, universal model, multi-die scanning and impression. According to maximum quality values for optical measure systems and the special optics with the blue stripe light projection the camera that designed for dental application allow the scanner to scan all situations and though it recognized in the market as reference scanner. It is very precise due to its 2.1 μm accuracy. Accuracy of results of this scanner with inLab CAD software was demonstrated according DIN EN ISO 12836.2015. The established accuracy that made on the standard bridge test

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specimens was at 2.1 ± 2.8 μm and on inlay 1.3 ± 0.4 μm (13).

Identica hybrid:

Three axis scanning arm with triple camera technology and have blue LED light and color texture support. Tested accuracy for the scanner at ±7μm (ISO 12836) with standard deviation ±2μm (14). Full arch model can be scanned in just 16 seconds with decreased in data size. This scanner can scan models and impressions and the result exported to open STL file.

Kavo arctica:

This scanner has striped light scanning technology with highly sensitive 3D sensors to scan complex geometric with precision in fully automatic scanning. Have a built-in blue filter to scan precisely plaster teeth and reflective plastic without using powder. Also have a large space for measuring with two axis technology. Scanning one single stump as framework for one minute, three minutes for three units bridge with accuracy of 20 μm, and the result exported to open STL file. (15)

Scanning procedure:

The scanning was done in normal conditions of environment of the surroundings (humidity, light and temperature) to keep dimensions of the scanned object as well as the parameters of the scanning system unchanged. 20 Scans were done of master cast after calibration with each system in accordance with the manufacturer's recommended scanning protocols. By scanning the model by the 4 scanners, five scans for the three different restorations types; upper right central crown, upper right second molar onlay, upper left bridge from canine to second premolar to focus every scan on the selected restoration with adjustment of settings of scanning and five scans for the full model without selecting any tooth in the scanning settings, to have five STL files for every restoration focusing on the chosen restoration and the model without focusing on specific tooth. While scanning in progress in all scanners, the model will gradually appear on the screen until the scan complete. The model was inspected if there is any defect. Then the data obtained were exported to the open STL file. Total will be 80 scan of all scanners.

Accuracy measurements

Five STL files was segmented to upper right central crown, five Stl files was segmented to upper right second molar onlay, five STL files was segmented to upper left canine and second premolar bridge, the last five STL files will be a complete model.

After all the restoration segmented of every scanner by the geomagic studio 12, the alignment of these files was done. The reference file (InEosX5) pinned, so when superimposition the test file (3shape, kavo arctica and identica hybrid) with best fit alignment to superimpose the two files on each other. 3D analysis was done for trueness measurements. For precision measurement one file as a reference then superimposed by others files of the same scanner of same restoration. This was done for every restoration (segmented central, onlay, bridge and the whole model). A color mapped model appears of 3D compare and root mean square of each superimposition was collected to evaluate accuracy.

RESULTS

Statistical analysis:

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Two-way ANOVA was used to study the effect of different tested variables and their interaction. The significance level was set at P ≤0.05 within all tests.

Trueness 1-Descriptive statistics for trueness:

Table2: Descriptive statistics for root mean square (RMS) for trueness of different scanners

Scanner	Restoration design	Mean	Std. Deviation	Median	Range
Identica hybrid	Crown	0.17	0.01	0.17	0.04
	Onlay	0.22	0.10	0.23	0.25
	Bridge	0.25	0.04	0.24	0.10
	Model	2.20	0.26	2.08	0.66
Kavo arctica	Crown	0.20	0.06	0.20	0.18
	Onlay	0.27	0.09	0.32	0.19
	Bridge	0.40	0.15	0.43	0.31
	Model	2.20	0.26	2.08	0.66
3Shape D850	Crown	0.15	0.03	0.15	0.09
	Onlay	0.36	0.01	0.36	0.02
	Bridge	0.18	0.01	0.19	0.03
	Model	2.20	0.26	2.08	0.66

2-Effect of different variables and their interaction for trueness: Only restoration design had a significant effect on (RMS).

Table3: Effect of different variables and their interactions on root mean square (RMS) for trueness

Source	Type III Sum of Squares	df	Mean Square	F	p-value
Scanner type	0.04	2	0.02	0.93	0.401ns
Restoration design	43.17	3	14.39	688.49	<0.001*
Scanner * Restoration design	0.14	6	0.02	1.15	0.350ns

df =degree of freedom*; significant ($p \leq 0.05$) ns; non-significant (p>0.05)

3-Main effects:

A-Effect of Scanner type:

There was no significant difference in the trueness of different types of scanners. Kavo arcti ca>3shapeD850>idetica hybrid.

Table 4: Mean ± standard deviation (SD) of root mean square (RMS) for different scanner types

Scanner (mean±SD)			p-value
Identica hybrid	Kavo arctica	3Shape D850	
0.71 ± 0.89^{A}	0.77 ± 0.86^{A}	0.72 ± 0.89^{A}	0.401ns

Different superscript letters indicate a statistically significant difference within the same horizontal row*; significant ($p \leq 0.05$) ns; non-significant (p>0.05)

B-Effect of restoration design:

There was a significant difference in the trueness.

Model > onlay > bridge > crown.

Table 5: Mean ± standard deviation (SD) of root mean square (RMS) for trueness of different restoration designs

Restoration design (mean±SD)				p-value
Crown	Onlay	Bridge	Model	
0.17±0.04^{B}	0.29±0.09^{B}	0.28±0.13^{B}	2.20±0.24^{A}	<0.001*

Different superscript letters indicate a statistically significant difference within the same horizontal row*; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

Precision

1-Descriptive statistics for precision:

Table 6: Descriptive statistics for root mean square (RMS) for precision of different scanners

Scanner	Restoration design	Mean	Std. Deviation	Median	Range
Identica hybrid	Crown	0.12	0.03	0.12	0.09
	Onlay	0.30	0.05	0.31	0.16
	Bridge	0.18	0.05	0.18	0.15
	Model	1.88	0.08	1.92	0.20
Kavo arctica	Crown	0.26	0.07	0.29	0.19
	Onlay	0.21	0.03	0.22	0.10
	Bridge	0.31	0.08	0.32	0.24
	Model	2.15	0.01	2.15	0.02
3Shape D850	Crown	0.07	0.03	0.07	0.10
	Onlay	0.37	0.01	0.37	0.03
	Bridge	0.11	0.04	0.12	0.11
	Model	1.31	0.81	1.78	1.88
InEos x5	Crown	0.08	0.01	0.08	0.03
	Onlay	0.17	0.11	0.12	0.28
	Bridge	0.21	0.18	0.11	0.39
	Model	2.30	0.27	2.32	0.82

2-Effect of different variables and their interaction:

There was a significant interaction between type of the scanner and design of the restoration.

Table 7: Effect of different variables and their interactions on root mean square (RMS) for precision

Source	Type III Sum of Squares	df	Mean Square	F	p-value
Scanner type	1.64	3	0.55	10.97	<0.001*
Restoration design	88.24	3	29.41	591.96	<0.001*
Scanner * Restoration design	4.70	9	0.52	10.50	<0.001*

df =degree of freedom*; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

3- Interactions:

1-Effect of restoration design within each scanner:

There was a significant difference in the precision achieved with different restorations designs in all scanners, the highest (RMS) value was found with the whole model in the four scanners and the least value was crown in all scanners except in kavo the onlay restoration was the least (RMS) value.

2-Effect of Scanner type within each restoration design depth:

There was no significant difference in the precision of different types of scanners in crown, onlay and bridge except in model there was a significant difference in the precision of different types of scanners.

-In model: Ineosx5 > kavo arctica > identica hybrid > 3shapeD850.

Table 8: Mean ± standard deviation (SD) of root mean square (RMS) for different scanner types and restoration designs

Scanner	Restoration design (mean±SD)				p-value
	Crown	Onlay	Bridge	Model	
Identica hybrid	0.12 ± 0.03^{Ba}	0.30 ± 0.05^{Ba}	0.18 ± 0.05^{Ba}	1.88 ± 0.08^{Ab}	<0.001*
Kavo arctica	0.26 ± 0.07^{Ba}	0.21 ± 0.03^{Ba}	0.31 ± 0.08^{Ba}	2.15 ± 0.01^{Aa}	<0.001*
3Shape D850	0.07 ± 0.03^{Ba}	0.37 ± 0.01^{Ba}	0.11 ± 0.04^{Ba}	1.31 ± 0.81^{Ab}	<0.001*
InEos x5	0.08 ± 0.01^{Ba}	0.17 ± 0.11^{Ba}	0.21 ± 0.18^{Ba}	2.30 ± 0.27^{Aa}	<0.001*
p-value	0.214ns	0.186ns	0.247ns	<0.001*	

DISCUSSION

The aim of our study was to evaluate trueness and precision of 3 desktop scanners in comparison to reference scanner (InEosX5) for different restoration designs; in axial convergence in a full crown preparation witch has a major role in the retention and durability of the restorations and in axial divergence of onlay preparation witch has a major role in durability and the proper fabrication of restorations and for bridge preparation witch the design and number of missing tooth effect the durability of the restoration, finally a full model. In this study we used a typodont model. STL files of each scanner were superimposed on the imported reference STL file to calculate the trueness and the data of the root mean square of each superimposition was collected to evaluate accuracy. STL files within the same scanners were superimposition on each other to calculate precision. Each scan is considered as the reference for the remaining scans all done in "geomagic studio 2012".

For statistical analysis for trueness and the root mean square, only restoration design had a significant effect on (RMS). The lowest value was in crown for its simple design without sharp angles and the heights value was in model because when scanning scope increase the accuracy decreased. For statistical analysis for precision and the root mean square, there was a significant interaction between type of the scanner and design of the restoration. The effect of restoration design within the scanners, there was significant difference within all scanners, the heights RMS was model in all scanners and least was the crown except in kavo was onlay. Effect of Scanner type within each restoration design depth, there was no significant difference in the precision of different types of scanners except the model the least RMS value was in 3shape D850.

CONCLUSION

Within the limitation of our study, the following conclusion may be drawn. Only restoration design had a significant effect on (RMS) in statistical analysis for trueness. The highest (RMS) value

was found whole model while the least value was found with single crown preparation. For precision there was a significant interaction between type of the scanner and design of the restoration. Effect of restoration design within each scanner, the highest (RMS) value was found with the whole model and the least value found in crown except the kavo the least value found in onlay. Effect of Scanner type within each restoration design depth, there was no significant difference in the precision of different types of scanner, in crown, onlay and bridge except the model there was a significant difference in the precision, the highest (RMS) value was found with InEos x5 while the least value was found with 3Shape D850.

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