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COMPARATIVE ANALYSIS OF 3D DATA ACCURACY OF SINGLE TOOTH AND MULTIPLE TEETH CAPTURED BY DIFFERENT INTRA ORAL DIGITAL IMPRESSION SYSTEMS

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ABSTRACT

Objectives: This study aimed to evaluate and compared the accuracy (trueness and precision) of three different intra oral scanners (Bluecam, Omnicam, Primescan) for single tooth and complete arch. **Material and methods**: A typodont model was used. All ceramic full coverage preparation will be made on acrylic teeth representing 5 upper teeth with preparation depth1.5 mm and two wall angulation 6º with 1mm deep chamfer finish line. The model was reference-scanned with a highly accurate Desktop scanner (InEos X5), and scanned with three intraoral scanner (IOS) Bluecam, Omnicam and Primescan (for complete arch and single tooth).These scans were cropped for 3D Compare Analysis (control X 2018, Geomagic, 3Dsystems, NC, USA). Accuracy was measured and descriptive analysis was performed. **Results**: For complete arch significant difference was noted between Primescan and (Omnicam, bluecam). Primescan had the highest accuracy followed by Omnicam and Bluecam. For single tooth significant difference was noted between (Primescan, Bluecam) and Omnicam. Primescan had the highest accuracy followed by Bluecam and Omnicam. **Conclusions**: For complete arch scanning Cerec Primescan showed more accurate results followed by Cerec Omnicam followed by Cerec Bluecam. For single tooth scanning Cerec Primescan showed more accurate results followed by Cerec Bluecam followed by Cerec Omnicam.

KEYWORDS: Intraoral scanner, trueness, precision, complete arch, single tooth.

INTRODUCTION

Intraoral digital imprints may now capture entire arches as well as single tooth preparations and sextant scanning. Thanks to intraoral digital scanners, now we can make immediate inspection of the digital cast and nearly instantaneous communication to the lab, a three-dimensional (3D) printing, or chairside milling equipment by intraoral digital scanners, which enable dentists to capture the surface of teeth, implant scan bodies, and soft tissues in three dimensions. Similarly, computer-aided designing and computer aided manufacturing (CAD/CAM) has changed dentistry to the point where it is common now as the standard practice. Advances in digital chairside and laboratory technologies have produced a more favorable environment for digital dentistry application [1, 2].

The need for new and better impression techniques has been distinguished by flaws in elastomeric impression materials and procedures[3–7]. There are some common disadvantages with elastomeric impression materials as technique sensitivity, patient pain and dimensional changes after polymerization [8-16].

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Many dentists have used digital impressions beside traditional elastomeric impression materials to overcome the disadvantages of traditional elastomeric impression materials. One benefit of digital impression technology is the capability of using digital magnification and quality control tools to identify the improper imaged areas and offer guidance on how to capture missing elements of the digital picture. This enables the doctor to identify the problems quickly and re-scan those regions instead of having to re-do the whole impression [17]. On the other hand, digital impressions have some disadvantages compared to elastomeric impressions. More distortion is possible in a digital image, which could be caused by improper technique or scanning technological limits [18].

There are numerous advantages to introduce complete-arch intraoral scanning into therapeutic practice. Partial arch impressions were shown to be more accurate than full arch impressions in a previous study that examined the accuracy of full and partial arch impressions that used actual intraoral scanning equipment[19]. Furthermore, the accuracy of digital imprints were evaluated clinically suitable for single crowns and short span fixed dental prostheses (FPDs)[17]. On the other hand, Intraoral scanners were found to save much time than traditional impression procedures in subsequent tests[19,20]. Furthermore, many iantraoral scanners provide an alternate method for a very precise complete-arch scanning, which is required for the manufacturing of many restorations or mouth rehabilitation [19-22].

The current study compared the accuracy (trueness &precision) of single tooth and complete arch digital impressions captured by different intraoral scanners (Cerec Bluecam, Cerec Omnicam, and Cerec Primescan). The acquisition technologies of the three scanners are different. The Primescan uses a Smart Pixel Sensor and the Cerec Omnicam uses video imaging technology while the Cerec Bluecam uses image capture technology. The hypothesis of this study was that single tooth digital impression is more accurate than complete arch.

MATERIALS AND METHODS

Materials:

An acrylic typodont model (Nissin, Japan) representing upper and lower arches, and three intra oral scanners involved in the study (Cerec Bluecam, Omnicam, and Primescan).

Methods:

This study compared the accuracy (trueness &precision) of single tooth and complete arch digital impressions captured by different intraoral scanners (Cerec Bluecam, Cerec Omnicam, and Cerec Primescan).

This research was accepted by the ethical committee. Reference no. 341/459.

Sample size:

a) Complete arch (Trueness & Precision)

According to Ender et al [19], comparing the 3 intra oral scanners revealed mean values of 87.3±18.5, 49.7±8.8 for Omnicam, Bluecam, and 33.9±7.8 for Primescan.

Items used in sample size calculation. Alpha level of significance: α=0.05, results will be considered significant if P<0.05 Effect size used in calculation: 1.21

Power of the study:0.8 Statistical test used: G power, Germany. The calculated sample size:24 (8 in each group).

b) Single tooth (trueness & precision)

According to Ryakhovskiy, Kostyukova [23], for single tooth, comparing the 3 intra oral scanners revealed mean values of 22.3±5.58, 25±1.06 and 54.6±11.58 for bluecam, Omnicam and Primescan. Alpha level of significance: α=0.05, results will be considered significant if P<0.05. Effect size used in calculation: 1.26

Power of the study:0.8 Statistical test used: G power, Germany. The calculated sample size:24 (8 in each group)

Sequence of measurements:

1. Typodont model selection.
2. Preparation of the typodont model.
3. Reference scan with InEosX5.
4. In office scan of the typodont model with (Cerec Bluecam, Cerec Omnicam, Cerec Primescan).
5. Processing of data

1. Typodont model:

An articulated acrylic resin typodont (model representing upper and lower arches was used in this study).

2. Preparation of the typodont model:

On the upper arch of the typodont model five acrylic resin teeth were prepared for ceramic restoration. The prepared abutments represented full dental arch scan and the prepared upper left first molar will represent single tooth scan.

The preparation has the following criteria, figure (1).

- Wall convergence 6°
- Preparation depth 1,5mm.
- 1mm deep chamfer finish line.

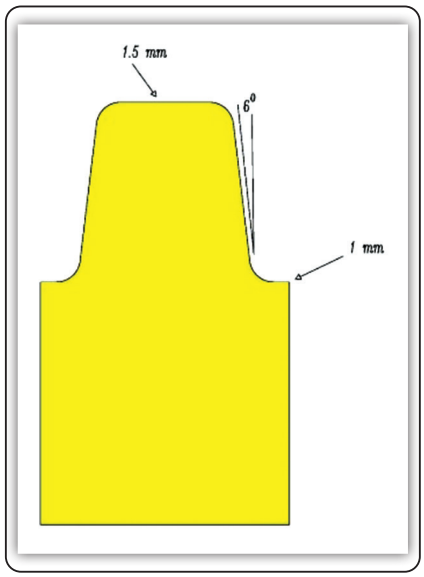

FIG (1) Diagram showing abutments preparation criteria

Abutments preparation:

CNC (Emar Edx5 5axisEgypt) machine was used for preparation of abutments. The CNC router with 1000x600mm machining area was used with maximum Cutting speed. The Max. Cutting Speed is 60.000RPM. The ball Screws / spindles diameter is 12/12 mm.

Abutments teeth scanned by CNC Desktop scanner (CADstar GmbH.CS ULTRA 3D-Scanner. Astria), Figure (2): Before preparation, teeth were mounted in an epoxy blank for ease of preparation. After that the scanned teeth superimposed on previously designed Exocad (DentalDB 3.0 Galway)STL file. Then CNC machine ordered to prepare teeth.

All of the selected abutments were prepared according to specification criteria mentioned before. After preparation the prepared abutments returned to its position in the model.

Scanning modes:

3. Reference scan with InEosX5:

Acquisition modes of scans:

Ineosx5: It is a desktop scanner used as a reference scanner. Scan done by InEos X5 (Sirona, Bensheim, Germany) Figure (3) by automatic jaw scan. The automatic jaw scans capture the model fully automatically in the "Capture Jaw" mode. Because of Ineos accuracy ranged from 1.3micron to 2.1micron it used for all tasks especially for large, complex tasks or tasks with especially high accuracy requirements. InEos arm moved in different axes during scanning the model. All scanning data was focused correctly all data were reserved as STL file for measurement.

Typodont model seated in InEos robot arm and by using unique 5-axis scanning technology complete arch and single tooth scanning were obtained as shown in.

4. In office scan of the typodont model:

In office scans for complete arch and single tooth were done by (Cerec Bluecam, Cerec Omnicam, Cerec Primescan).

Scanning mode:

For complete arch scanning mode started from upper right third molar ended by upper left third molar.

While scanning mode for single tooth started from upper right third molar ended by upper right first premolar.

Scanning done by single scanning technique (sextants method) in all intra oral scanners used in the study.

The occlusal surfaces are first, followed by the vestibular surfaces, and ultimately the palatal surfaces, from the right third molar to the right first premolar. Second, from right to left canine, then back via vestibular and palatal surfaces, occlusal surfaces. Third, from the left first premolar to the left third molar, returning via the vestibular and palatal surfaces. Any unfocused scan was repeated again for reaching correct scan.

Bluecam: Before scanning the typodont model was sprayed by contrast powder.

Eight scans for complete arch were obtained.

Eight scans for single tooth were obtained.

Omnicam: Eight scans for complete arch were obtained.

Eight scans for single tooth were obtained.

Primescan: Eight scans for complete arch were obtained.

Eight scans for single tooth were obtained.

5. Processing of data

All STL datasets from the intraoral scanner were imported into the inspection programme (control X 2018, Geomagic, 3Dsystems, NC, USA). To match the orientations of the coordinate systems, the STL data from each test group were pre-superimposed using CAD software (control X 2018, Geomagic, 3Dsystems, NC, USA). A best-fit approach was utilised[4,5]. The datasets were restricted to the field of interest to provide an accurate superimposition (the dental arch, including the tooth surface and about 1 mm of attached gingiva). To guarantee accurate superimposition and equal borders across all datasets, all extraneous portions were methodically removed. For a final 3D comparison, the shrunk models were saved as STL files and loaded back into Geomagic Control. For statistical analysis, all of the data was acquired and processed.

RESULTS

The Kruskal-Wallis test was used to analyse the findings, followed by the Mann-Whitney test for pairwise comparisons between groups. The Shapiro Wilk test was performed to test the normality of the data, and P0.05 was judged statistically significant (95 percent significance threshold). The SPSS statistics software was used to conduct the statistical analysis (version 25, IBM Co. USA).

Comparing the trueness and precision for every scanner model (Intra-group comparison)

1. Bluecam

The mean of root mean square (RMS) of trueness was (34.34±4.57μm) for Single tooth, and (427.46±195.47 μm) for complete arch. There was statistically significant difference in the trueness between single tooth and complete arch in favor of complete arch which have the highest mean of RMS. The mean of root mean square (RMS) of precision was (24.70±18.92 μm) for Single tooth, and (638.16±453.17 μm) for complete arch. There was statistically significant difference in the precision between single tooth and complete arch in favor of complete arch which have the highest mean of RMS.

2. Omnicam

The mean of root mean square(RMS) of trueness was (87.71±34.94 μm) for Single tooth, and (302.98±67.01 μm) for complete arch. There was statistically significant difference in the trueness between single tooth and complete arch in favor of complete arch which have the highest mean of RMS. The mean of root mean square (RMS) of precision was (214.84±237.47μm) for Single tooth, and (254.99±78.84μm) for complete arch. There was statistically significant difference in the precision between single tooth and complete arch in favor of complete arch which have the highest mean of RMS.

3. Primescan

The mean of root mean square (RMS) of trueness was (20.93±1.93 μm) for Single tooth, and (193.86±34.54 μm) for complete arch. The difference in trueness between single tooth and whole arch was statistically significant, with the complete arch having the greatest mean RMS. For a single tooth, the root mean square (RMS) of precision was (8.52±2.57 μm)) and for a whole arch, it was (158.73±23.04 μm). There was a statistically significant difference in precision between single teeth and the entire arch, with the complete arch having the greatest mean RMS.

Inter-group comparison between different scanner models

1. Trueness

For single tooth

Between the Bluecam and the Omnicam, there was no statistically significant difference in RMS mean (the means had the same superscript letter (A)). Between the Prime scan and the Bluecam scan, the mean did not differ statistically significantly. RMS (the means had the same superscript letter (B)). Between the Omnicam and Prime scans, there was a statistically significant difference in the mean RMS. According to the results of the Kruskal-Wallis test, the overall p-value for inter-group comparison was (p = 0.001), meaning there was a statistically significant difference between the different scanner models in the mean of root mean square in favor of Omnicam which have the highest deviation from reference model. The scanners can be arranged in ascending order according to deviation from the reference model as follows: Primescan<Bluecam<Omnicam. Table (1).

TABLE (1) Mean ±SD of RMS values (μm) indicating the trueness of different scanners models for single tooth and complete arch.

	Single tooth	Complete arch	P-value*
Bluecam	34.34±4.57^{AB}	427.46±195.47^{A}	**0.001^{S}**
Omnicam	87.71±34.94^{A}	302.98±67.01^{A}	**0.001^{S}**
Prime scan	20.93±1.93^{B}	193.86±34.54^{B}	**0.001^{S}**
P-value**	**0.001^{S}**	**0.005^{S}**	

For complete arch

Between the Bluecam and the Omnicam, there was no statistically significant difference in RMS mean (the means had the same superscript letter (A)). Between the Prime scan and the Bluecam scan, there was a statistically significant difference in the mean RMS. Between the Omnicam and Prime scans, there was a statistically significant difference in the mean RMS. The overall p-value for inter-group comparison according to the Kruskal-Wallis test was (p = 0.005), indicating that there was a statistically significant difference between the different scanner models in the mean of root mean square in favour of the Bluecam scanner, which has the highest deviation from the reference model. The scanners can be arranged in ascending order according to deviation from the reference model as follows: Primescan<Omnicam<Bluecam.

2. Precision

For single tooth

Between the Bluecam and prime scan, there was no statistically significant difference in RMS mean (the means have the same superscript letter (B)). Between the Omnicam and the Bluecam, there was a statistically significant difference in mean RMS. Between the Omnicam and Prime scans, there was a statistically significant difference in the mean RMS. The overall p-value for inter-group comparison according to the Kruskal-Wallis test was (p = 0.000), indicating that there was a statistically significant difference between the different scanner models in the mean of root mean square in favour of Omnicam, which has the highest deviation from the reference model. The scanners can be arranged in ascending order according to deviation from the reference model as follows: Primescan<Bluecam<Omnicam. Table (2).

TABLE (2) Mean ±SD of RMS values (μm) indicating the precision of different scanners models for single tooth and complete arch.

	Single tooth	Complete arch	P-value*
Bluecam	24.70±18.92^{B}	638.16±453.17^{A}	**0.000^{S}**
Omnicam	214.84±237.47^{A}	254.99±78.84^{B}	**0.027^{S}**
Prime scan	8.52±2.57^{B}	158.73±23.04^{B}	**0.000^{S}**
P-value**	**0.000^{S}**	**0.000^{S}**	

For complete arch

Between the Prime scan and Omnicam, there was no statistically significant difference in RMS mean (the means have the same superscript letter (B)). There was a statistically significant difference in the mean RMS between the Prime and Bluecam scans. There was a statistically significant difference in mean RMS between the Omnicam and the Bluecam. The overall p-value for inter-group comparison according to the Kruskal-Wallis test was (p = 0.000), indicating that there was a statistically significant difference between the different scanner models in the mean of root mean square in favour of the Bluecam scanner, which has the highest deviation from the reference model. The scanners can be arranged in ascending order according to deviation from the reference model as follows: Primescan<Omnicam<Bluecam.

DISCUSSION

Dental impression is a routine procedure that is required in many disciplines of dentistry. IOS impressions may potentially enhance patient comfort and allow for visualizing the adequacy of the impression immediately. The hypothesis of this study was that single tooth digital impression is more accurate than complete arch. According to the result of the current study the hypothesis was accepted.

The current study was in vitro study. An accurate Nissin typodont model was selected representing upper and lower arch to simulate the clinical situation. Standardization was achieved during abutment teeth preparation by using CNC machine in order to avoid manual hand errors. Complete arch and single tooth scanning were done by reference scanner (InEosX5) which the manufacturer claims to have an accuracy of 2.1 μm, followed by tested intra oral scanners (Cerec Bluecam, Omnicam, and Primescan).

Regarding the result of this study, the trueness and precision of single tooth digital impression was more accurate than accuracy (trueness and precision) of complete arch. This might be attributed to most of the digital systems showed some deviations at the terminal end of the arch during imaging complete arch [22]. The result of this study was agreed with Ender et al [19] research examined the accuracy of entire and partial arch impressions from real intraoral scanning devices, and found that partial arch impressions especially posterior segments were more accurate than complete arch impressions.

For complete arch scanning Cerec Primescan showed more accurate results than Cerec Omnicam and Cerec Bluecam. This significant difference might be attributed to the difference in non-contact optical acquisition technologies used by (Cerec Primescan, Cerec Omnicam and Cerec Bluecam) hand held cameras to produce precise three-dimentional interpretations of patients oral soft and hard tissues. The Primescan uses a Smart Pixel Sensor that processes more than one million 3D data points per second while Cerec Omnicam and Cerec Bluecam using triangulation mechanism.

This also agreed with Ender et al [19] study that according to the study, Primescan produced the most accurate digital imprints of the entire arch model, with statistically significant differences when compared to Omnicam.

Regarding the result of this study the trueness and precision of complete arch digital impression for Cerec Omnicam was more accurate than trueness and precision of Cerec Bluecam. This results agreed with study done by Renne et al [21]. While study done by Treesh et al [22] found that Cerec Bluecam had more accurate results than Cerec Omnicam for complete arch scanning.

This might be explained by difference in technologies between the two scanners. While Cerec Omnicam technique is non powder technique and depend on video stream scanning. However Cerec Bluecam is a powder technique and quality of the images might affected by powder distribution and powder thickness.

For single tooth scanning the present study found that Cerec Primescan showed more accurate results than Cerec Omnicam and Cerec Bluecam. Burcu Diker and ÖnjenTak [24] study found that Primescan showed high accuracy results than Omnicam for single crown scanning.

For single tooth scanning the present study found that Cerec Bluecam showed more accurate results than Cerec Omnicam. This could be because the cerec Bluecam's wand automatically records many images after focussing on the area to be captured. Five photos are required to capture a single crown and its surrounding teeth. The Cerec Omnicam, on the other hand, records a video of the teeth. Keeping the wand steady (as with the Cerec Bluecam) instead of moving it may make it simpler to maintain the tooth surfaces in focus (as in Cerec Omnicam). [25]

Results of the present study come in accordance with a study done by Ryakhovskiy and Kostyukova[23] that found that Cerec Bluecam showed more accurate results than Cerec Omnicam for single tooth scanning. While other studies found that powder-based digital impression systems showed very accurate results for partial impressions.

Because the current study was an in vitro study, no conclusions can be drawn or direct correlations made to the clinical situation. So that the future studies should be supported by an in vivo scanning or case reports that might show different results in presence of saliva and intra oral challenges. The current study was limited to three types of scanners for the same company. The future studies should include several types of scanners.

CONCLUSIONS

Within the limitation of this in vitro study, the following conclusions may be drawn.

1. For complete arch scanning Cerec Primescan showed more accurate results followed by Cerec Omnicam followed by Cerec Bluecam.
2. For single tooth scanning Cerec Primescan showed more accurate results followed by Cerec Bluecam followed by Cerec Omnicam.

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