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Three-Dimensional Accuracy of Virtual Casts Obtained from Intra Oral Scanners and Scannable Impression for Three Units Bridge

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Abstract

Aims: For evaluation and comparison of the accuracy of different methods for virtual models obtaining techniques. **Materials and methods**: The reference cast was prepared for 3-unit fixed bridge. Four Groups with 8 samples in each group. Stone models were poured from conventional impressions. Digital impressions of the reference cast were created using two types of intraoral scanner defers in scanning technology and direct impression digitization. Reference cast, stone casts and scannable impressions were subsequently scanned using a laboratory optical scanner; files were exported in a stereolithography file format. All datasets were superimposed using 3D analysis software to evaluate the accuracy (trueness and precession). An independent-samples median test summary was performed to compare trueness among the four impression groups. The independent-samples Kruskal-Wallis test was performed to evaluate the precession of each group of impression techniques .**Results**: with regard to trueness, the Trios Group and Medit i500 Group had the highest trueness of all groups, with no significant differences between them, followed by the conventional impression group, then the scannable impression group which had the largest deviation from the reference model. None of the groups showed significant differences in precession. **Conclusions**: Intraoral scanners have a high accuracy level for both trueness and precession. Scannable impression direct digitization showed significantly higher deviation than conventional impression stone casts with clinically acceptable levels of accuracy.

الخلاصة

الاهداف: تهدف الدراسة الى تقييم ومقارنة دقة الأساليب المختلفة لتقنيات الحصول على النماذج الافتراضية. **المواد وطرائق العمل**: تم تحضير القالب المرجعي لجسر ثابت مكون من 3 وحدات. تم صب النماذج الحجرية من الطبعات التقليدية. تم إنشاء الطبعات الرقمية للمرجع باستخدام نوعين مختلفين من الماسحات الضوئية داخل الفم يختلفان في تقنية المسح الضوئي ومجموعه باستخدام الرقمنة المباشره للطبعه. تم مسح الطبعه القابله للمسح الضوئي و القالب المرجع والحجري باستخدام الماسح الضوئي المختبري ؛ تم تصدير الملفات بتنسيق ملف الطباعة الحجرية المجسمة. تم تركيب جميع مجموعات البيانات باستخدام برنامج تحليل ثلاثي الأبعاد لتقييم الدقة (الصدق والسابقة). تم إجراء ملخص اختبار متوسط العينات المستقلة لمقارنة الصدق بين مجموعات الطبعات الأربع. تم إجراء اختبار Kruskal-Wallis للعينات المستقلة لتقييم التكرار داخل كل مجموعة من تقنيات الطبعات.**النتائج**: فيما يتعلق بالصدق ، كان لدى Trios Group و Medit i500 Group أعلى دقة من بين جميع المجموعات مع عدم وجود اختلافات كبيرة بينهما ، تليها مجموعة الطبعات التقليدية ثم مجموعة الطبعات القابلة للمسح كان لها الانحراف الأكبر عن النموذج المرجعي. أظهرت جميع المجموعات عدم وجود فروق ذات دلالة إحصائية في التكرار.**الاستنتاجات**: الماسحات الضوئية داخل الفم تتمتع بمستوى عالي من الدقة .أظهرت الرقمنة المباشرة للطبعات القابلة للمسح انحرافًا أعلى من القوالب الحجرية للطبعات التقليدية بمستوى دقة مقبول سريريًا.

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INTRODUCTION

The accuracy of the impression technique is the primary element crucially participates in the success of the dental prosthesis's fabrication. Commonly, the conventional impression method involves taking an intraoral impression using an elastomeric material, after that a stone model is fabricated [1]. The gypsum replicas accuracy is ranged or enlarged in comparison to the original tooth, which means that the volume change of the gypsum model occurs [2]. Saliva and blood contaminate the impression and these are considered disadvantages of the conventional impression technique [3]. Elastomeric impressions can be distorted due to inadequate storage or unexpected forces that could be applied to the tray and impression when transported or during shipment until it reaches the dental laboratory [4]. After the rapid development of computer-aided design and computer-aided manufacturing (CAD/CAM) technology and the rapid enhancement of the intraoral scanners (IOS) ability, the dental prostheses and model fabrication have been modified quickly to the full digital production [5]. Three-dimensional (3D) virtual models obtained using an intraoral scanner can eliminate the need for conventional impression and physical model fabrication. They have several advantages, such as the permanent storage of data, and reduction of patient discomfort associated with the use of impression materials [6]. Scannable elastomeric materials have also been introduced. This option is preferred by clinicians who prefer traditional impression techniques. They differ from conventional impression materials in their color, physical properties, and brightness of the surface [7]. This material has been claimed to improve the direct digitization. Reducing the number of steps and making accurate virtual casts for the prosthesis production process could lead to an optimal quality and fast workflow [8]. There are several problems related to the direct digitizing of polyvinylsiloxane (PVS). Owing to their flexibility, noncontact digitizers must be used. Noncontact digitizers are sensitive to the transparency, color, and texture of an object's surface being digitized. PVS is transparent in nature; therefore, digitizers of the type used in dentistry cannot digitize a transparent material accurately. Transparency can be reduced by adding colorants and filler particles, which vary in amount and type, with different effects on the physical properties [9]. The current IOS devices are based on different optical technologies such as optical coherence tomography, confocal microscopy, active and passive stereo vision and triangulation, interferometry and phase shift principles. All these devices integrate more than one of the cited imaging techniques to reduce the noise arising when scanning inside the oral cavity [10]. All types of imaging technologies employed by IOS require the projection of light that is then recorded by the camera as individual images or video stream and compiled by the software, then recognition of the points of interest (POI). The coordination of the two (x and y) firstly of each point are evaluated on the image, then the third coordinate (z) is calculated depending on the distance from object technologies of each camera [11]. Some studies used the scan technology of the IOS as a variable to evaluate the accuracy of digital scanning systems [12].

This study aimed to evaluate and compare the accuracy of virtual casts obtained from an intraoral scanner, evaluate and compare the accuracy of virtual casts obtained from scannable impressions.

MATERIALS AND METHODS

1. Groups Distribution:

The reference cast scanned with high-definition laboratory scanner E1 to make the virtual reference cast **(R.VC)**. The size of the comparison group was **n=8** samples for each type in the following manner (Fig. 1):

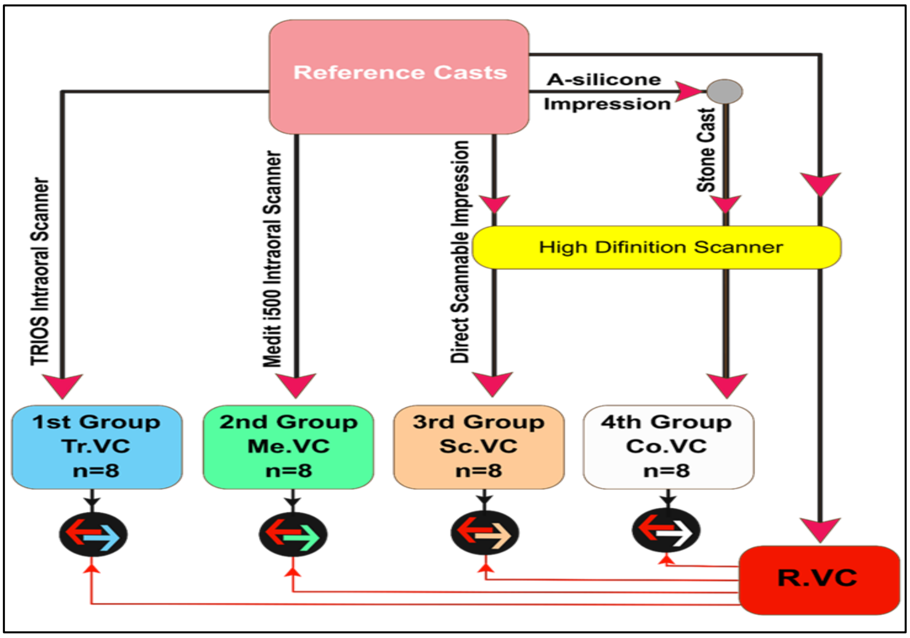

Figure (1): Groups Distribution. The comparisons of the virtual casts obtained from each impression technique

- 1st group of digital impressions of the reference model created using an intraoral scanner Trios from 3Shape **(Tr.VC)**.
- 2nd group of digital impressions of the reference model created using an intraoral scanner Medit i500 from Medit **(Me.VC)**.
- 3rd group by direct scanning of the scannable impression Hydrorise Implant from Zhermack by the high-definition scanner E1 **(Sc.VC)**.

- 4th group of stone models were fabricated from conventional impressions A- Silicone Hydrorise from Zhermack and scanned with the high-definition scanner E1 to obtain **(Co.VC)**.

Each group was superimposed with the reference cast using 3D analysis software Geomagic control X from 3D systems to evaluate the accuracy of each group regarding the target area of interest. Independent-Samples Median Test Summary were performed to compare the trueness among the four impression groups. Independent-Samples Kruskal-Wallis Test were performed to evaluate the precession of each group of impression technique.

2. Master Model Preparation (R.VC):

Partially Dentated Upper Model Jaw with supragingival finishing line crown preparation (A-3 Partially Dentate Upper Jaw; Frasaco, Germany). Thermoplastic model dimensionally stable with hard gingiva and opaque color to be compatible with the different types of impressions and optical scanning that was used in the study (Fig. 2). Cast was scanned with the blue light laboratory scanner (E1; 3Shape, Denmark) scanner to obtain the Reference virtual cast. Multiple steps of scanning according to the manufacturer instructions. The resulting Reference Virtual Casts exported as Standard Tessellation Language STL files which is the file form that can be recognized and analyzed by the 3D analysis software Geomagic Control X. The master virtual cast and the selected target area for best fit alignment and comparison is shown in (Fig. 3).

Figure (2): Reference Model, Three Units fixed bridge preparation.

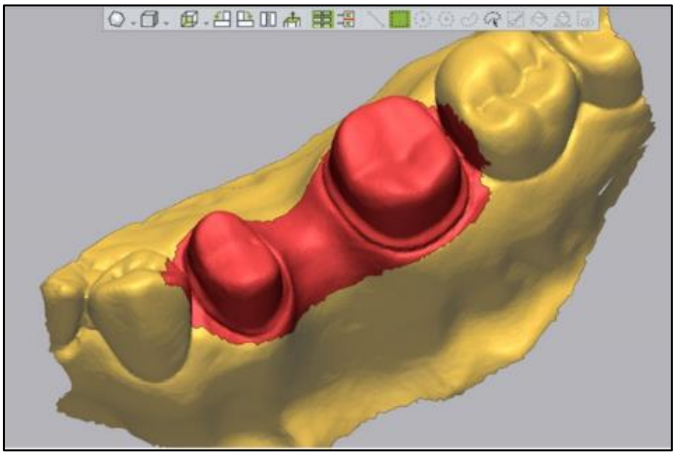

Figure (3): Reference Virtual Cast. The red area represents the target area for the best fit alignment and 3D comparison with the measured casts on each group.

3. Comparison Groups Samples Preparation

3.1 Trios Intraoral Scanner Group (Tr.VC)

The TRIOS (TRIOS™; 3Shape, Denmark) scanner works according to the principle of confocal microscopy, with a fast-scanning time. The scanning by the same person, the path of scanning was done according to the manufacturer instructions for the scanning of the upper dental arch the recommended scanning path consist of three swipes: occlusal, buccal and palatal, to insure good data coverage of all needed surfaces (Fig. 4). The scanner was hold by hand as near as possible to the model. Scanning Exportation: The master cast scanned 8 times making 8 samples. The scanning files exported as STL files to be recognized and adaptable with the analyzing software.

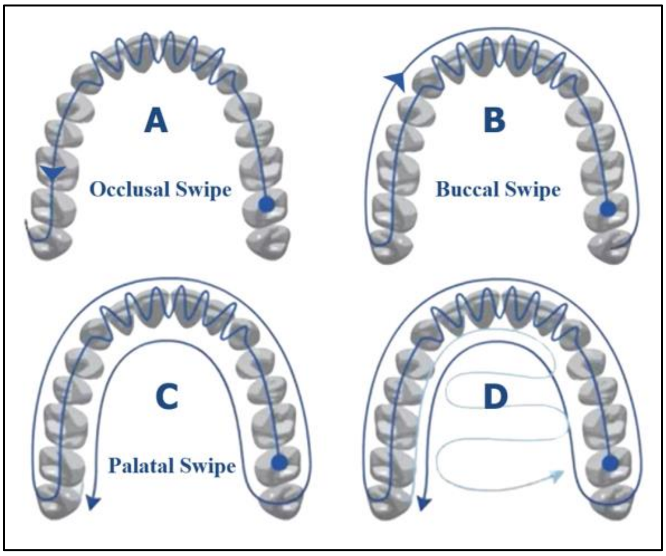

Figure (4): Recommended scanning path

3.2 Medit i500 Intraoral Scanner Group (Me.VC)

The Medit i500 scanner (i500; Medit, South Korea) uses video-type scanning based on triangulation technology. Video-type scanning is able to capture moving objects. The scanner adjusts to the speed you want and is therefore able to follow along when the object is in motion. Scanning path were done in the same scanning strategy that were used in Trio3 scanner as the manufacturer's recommendations. Scanning Exportation: The master cast scanned 8 times making 8 samples. The scanning files exported as STL files to be recognized and adaptable with the analyzing software.

3.3 Scannable Impression Group (Sc.VC)

Eight impressions were taken for the master cast making 8 samples. Scannable Vinyl Polysiloxane Impression Material (Hydrorise Implant heavy body and light body consistencies from Zhermack, Italy) were used for this group of samples. Single-step technique was used, reduces time and saves impression material. According to the literature, the single-step technique leads to very accurate impressions [13].

3.3.1 Impression Making: **Standardization of the impression making was considered in all steps of the work.**

a- Using the Test Apparatus: is the mechanical apparatus that secures a consistent position of the master model within the impression tray, giving the desirable thickness of impression materials, and identical direction of insertion and removal of the upper metal plate with the metal tray that contains the impression material in addition to constant pressure during impression holding against the master cast (Fig. 5) [14].

b- Mixing time and ratio: According to the manufacturer instructions the automatic dynamic mixer (Mixstar emotion; DMG, Germany) for the mixing of heavy body base and catalyst mixing also manual dynamic mixer used for light body base and catalyst mixing.

c- Impression placement and holding: For the period of setting placing the upper base of the test apparatus for (10 minutes) according to the manufacturer instructions after the impression material had set, the impression was removed. The mixing time, setting time, and the time for separation of the impression from the master model were controlled by a timer and the method was kept almost constant for all the trials and according to the manufacturer instructions.

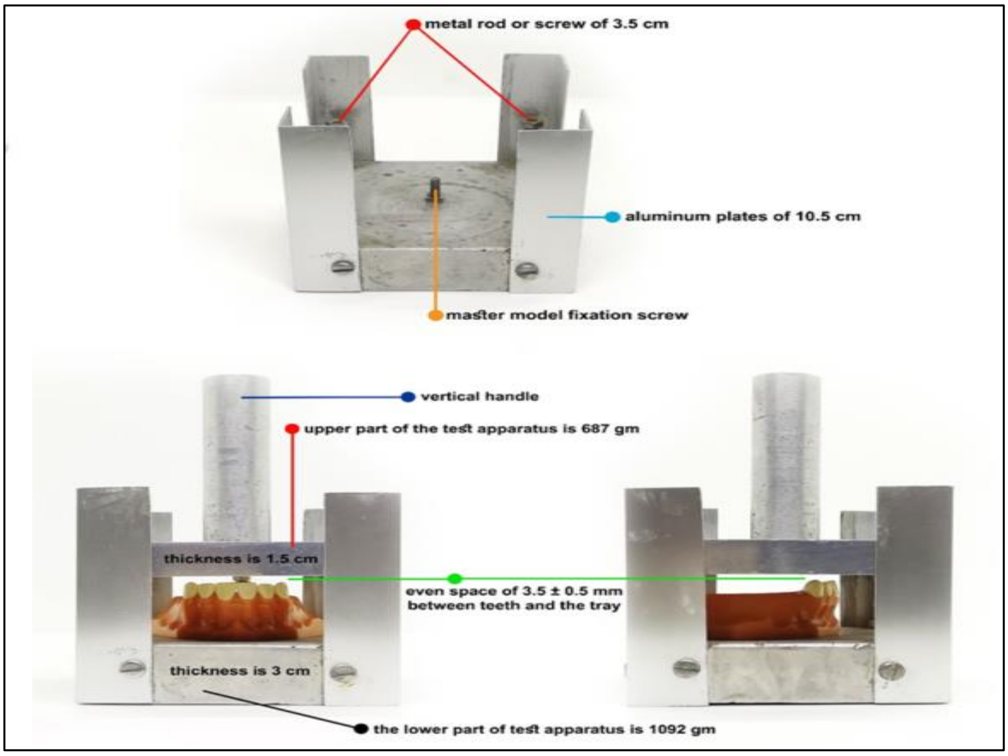

Figure (5): Test apparatus components

3.3.2 Direct Impression Scanning

Cutting of the excess flanges of the impression material is important to make a clear way for the light of the optical scanner to reach the deep areas of the impression. The samples (Fig. 6) scanned within the first hour after complete setting of the material according to the manufacturer instructions.

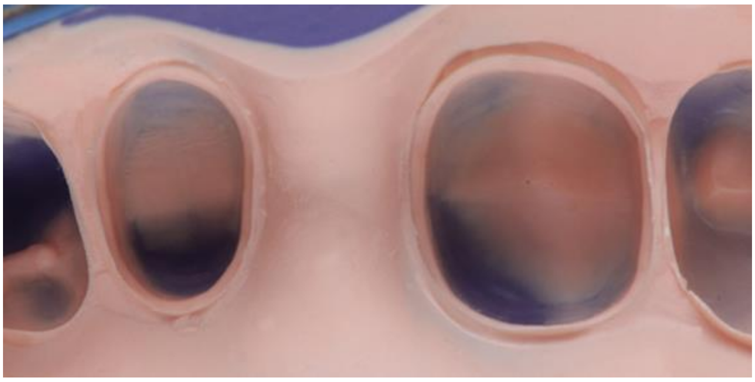

Figure (6): Sample of scannable impression.

Scanning steps: The scanner was calibrated before each scanning session using the calibration table according to the manufacturer instruction. The impression scanning option is activated to be processed automatically into a positive replica. The impression placed on the scanning stage and fixed using the blue tag. The target teeth have been determined and the primary scanning (Fig. 7 A) is done after that the important areas determined with green color (Fig. 7 B and C) to be rescanned in high-definition scanning then checked about any missed area or unclear spots to be rescanned again in adaptive scanning (Fig. 8). The missing unclear areas represented as red spots couldn't be scanned perfectly in the high-definition scanning prosses and need specific light angulation by selecting them with green color to be rescanned by adaptive scanning. The green color striations represent the adaptive scanning targeted areas. 8 samples were completed successfully the file exported in STL format to be ready for analysis.

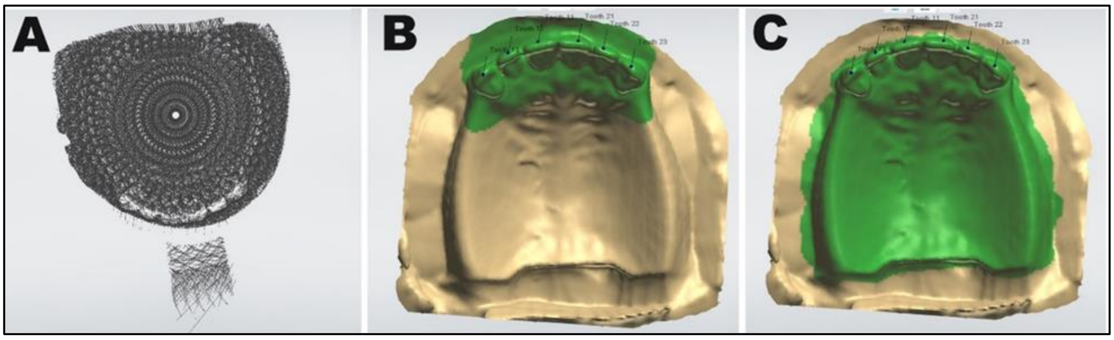

Figure (7): Scanning Steps. A. Primary scanning. B, C. Important areas determination.

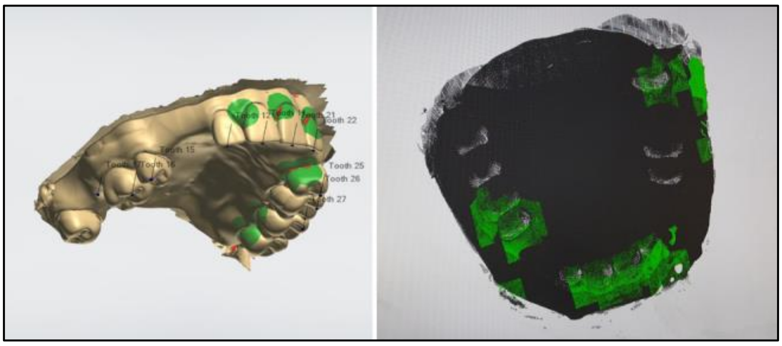

Figure (8): Adaptive scanning. Red spots need specific light angulation, The green color striations represent the adaptive scanning targeted areas.

3.4 Conventional Impression Group (Co.VC)

Eight impressions were taken for the master cast making 8 samples. Addition type Vinyl Polysiloxane Impression Material (Hydrorise heavy body and light body consistencies from Zhermack, Italy) were used for this group of samples. Single-step technique was used like the scannable impression group in order to preserve standardization of the samples.

3.4.1 Impression Making:

The same procedure, equipments and steps that have been used in the scannable impression group just replacing the scannable material with conventional one with the same brand of material. The resulting impressions samples (Fig. 9).

Figure (9): Conventional Impression sample

3.4.2 Impression Pouring with Stone:

The impressions were poured after (20 minutes) for greatest accuracy elastic recovery occurs after 20 to 30 minutes [15]. All the impressions were poured with Elite Rock die stone. The water/powder ratio (100 gm of powder was added to 20 ml of distilled water) was carefully controlled for optimum working properties according to the manufacturer instructions. All stone casts (Fig.10) were allowed to dry for 24 hours before they were scanned, in order to obtain maximum dryness, hardness and strength.

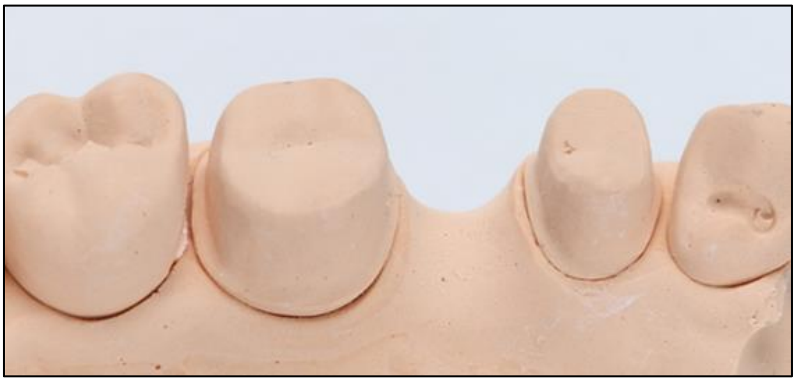

Figure (10): Conventional Impression Stones Casts sample

3.4.3 Scanning of the Stone Casts:

The scanner was calibrated before each scanning session. The same steps of impression scanning were done when the scan is completed successfully the file exported in STL format to be ready for analysis.

4. Three-dimensional analyses:

The study comparison was to measure the accuracy (trueness and precision) Precision (The closeness of agreement between the results of an independent test obtained under specific circumstances). Trueness (The closeness of an agreement between the average value obtained from a large series of test results and an accepted reference value) virtual casts of the four types of the impression techniques, The datasets were superimposed via a best-fit alignment method utilizing a 3D analysis program (Geomagic Control X; 3D Systems). The trueness of the four virtual models was evaluated by superimposing the STL file data of the reference model with STL file data obtained from the Trios IOS (n = 8), Medit i500 IOS (n = 8), Scannable Impression (n = 8) and the Conventional Impression (n = 8). The precision of each model type was evaluated by superimposing the scan data within each group (n = 32). The quantitative values were automatically calculated by the 3D analysis program based on the root mean square (RMS).

4.1 Three-dimensional Comparison Steps

The STL file of the virtual reference cast is imported to the software and considered as a reference data. The STL file of the virtual cast from Sample group is imported as measured data. 3D comparison accomplished concerning only the points located in the selected area which have been selected by the region subtraction option in the software, this eliminates any deviations located out of the area of interest which represents the clinical importance. A color map representing visual deviation was set with 20 color segments. Report generation then to export the data representing the statistical analyses data and the color map information (Fig. 11).

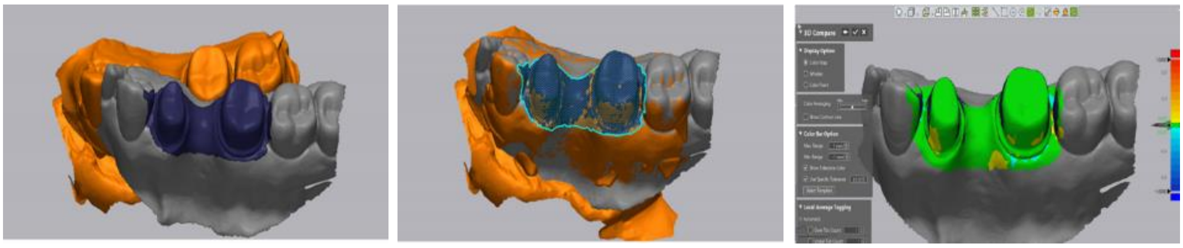

Figure (11): 3D comparison steps.

5. Statistical Analysis:

The statistical analysis done with the consultation of the Statistical Consultancy Bureau **(SCB)** in the University of Mosul, using the SPSS (statistical package for social sciences) software version 19. Descriptive Statistics and Inferential Statistics include:

A- Shapiro-Wilk Test.

B- Independent-Samples Median test.

C- Independent-Samples Kruskal-Wallis Test.

D- Pairwise Comparisons.

RESULTS

After superimposing the STL file data of the reference model with STL file of the four groups. The data obtained from the Trios IOS (n = 8), Medit i500 IOS (n = 8), Scannable Impression (n = 8) and the

Conventional Impression (n = 8) for each group. The trueness of each sample was evaluated by superimposing the scan data of each sample from all groups. The quantitative values were automatically calculated by the 3D analysis program and the results exported in statistic table, color map of positive and negative deviations and histogram (Fig. 12-15) each report represent one sample comparison. The average from the table represents the mean of each sample. The descriptive analysis is done. Then the trueness and precision are estimated. The average of deviation from the reference virtual model in the 3D comparison table results considered in the following trueness and precision analysis. The unit in tables are in millimeter. The data weren't distributed normally in all groups, according to the (Shapiro-Wilk Test). Therefore, it was necessary to use the nonparametric tests in comparing these totals, so we used the Independent-Samples Median Test which depends on the median in comparisons. Trios Group had a mean of (2.2 ± 0.9 µm), the statistically highest trueness of all groups, followed by Medit i500 Group (5.8 ± 5 µm), Conventional Impression Group (6.1 ± 0.9 µm) and Scannable Impression Group (19 ± 4.4 µm) was the larger deviation from the reference model (Table 1).

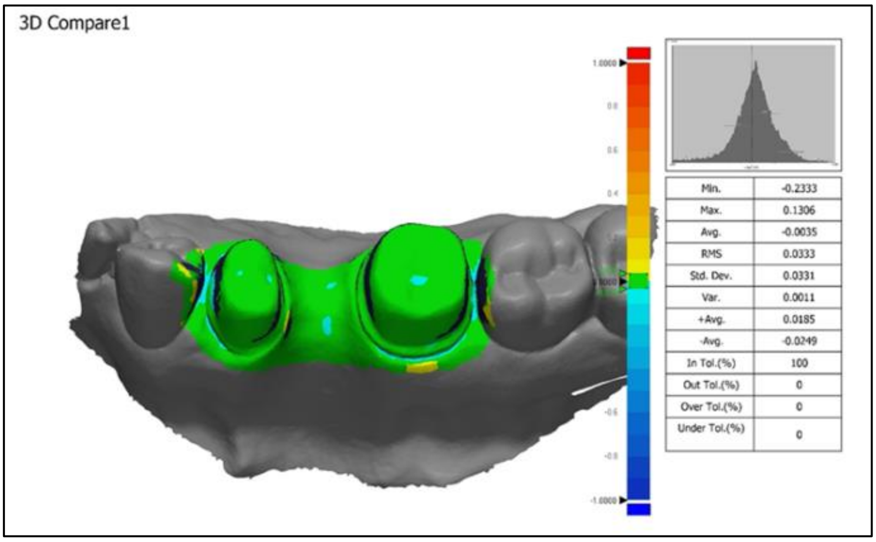

Figure (12): 3D Analysis Program report. Superimposition of the R.V. model with the virtual model obtained from Trios IOS.

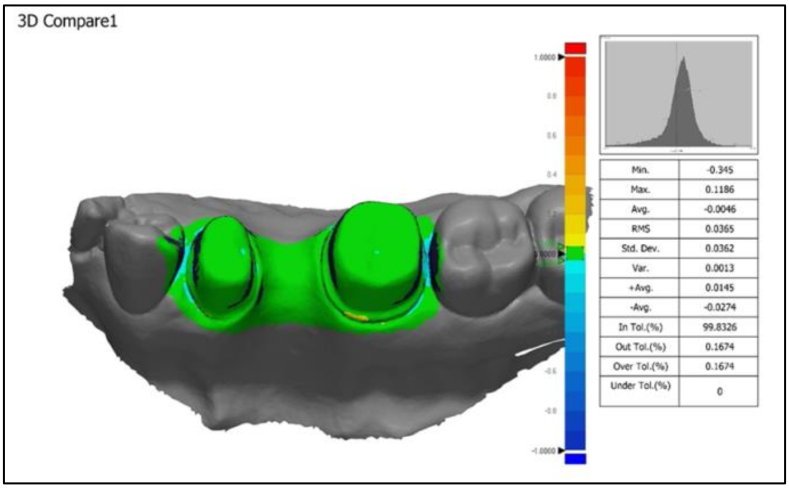

Figure (13): 3D Analysis Program report. Superimposition of the R.V. model with the virtual model obtained from Medit I 500 IOS.

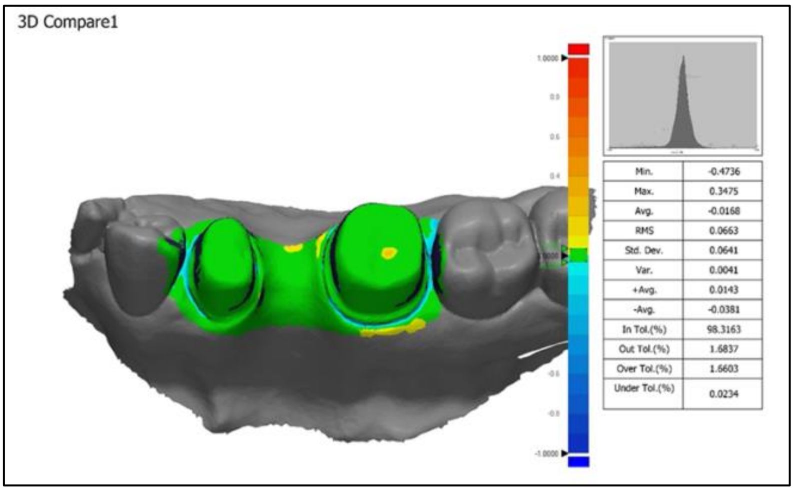

Figure (14): 3D Analysis Program report. Superimposition of the R.V. model with the virtual model obtained from Scannable Impression.

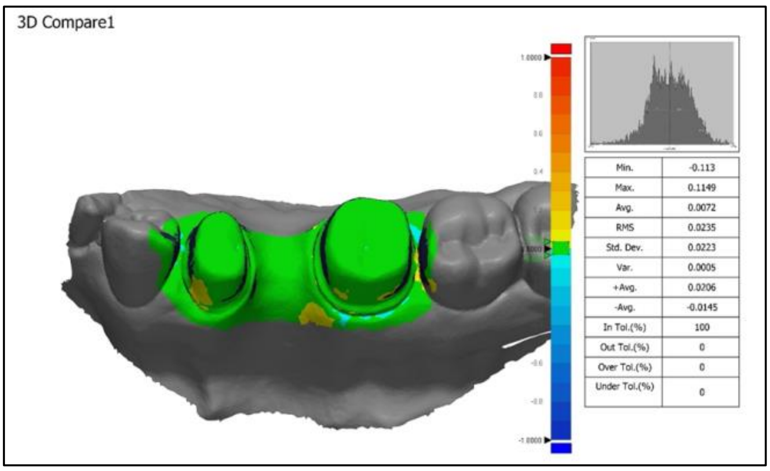

Figure (15): 3D Analysis Program report. Superimposition of the R.V. model with the virtual model obtained from Conventional Impression.

Table (1): Descriptive analysis. Mean, the median, the confidence limits (at the level of significance (0.05) Std. deviation from the reference virtual model in the 3D comparison table results

Groups	Mean	Median	95% Confidence Interval		Std. Deviation	Minimum	Maximum
			Lower	Upper			
1st Group	.0022125	.0021	.0013783	.0030467	.00099777	.0004	.0035
2ndGroup	.0058875	.00405	.0016541	.0101209	.00506372	.0003	.0138
3rd Group	.019875	.0209	.0161542	.0235958	.0044506	.0138	.0258
	.0061	.00585	.0053443	.0068557	.00090396	.0053	.0077

The (Table 2) represents the results of the (Median) test, and it reveals that there is a significant difference between at least a pair of the four groups in terms of the probability value (P-value), which appeared equal to (0.000) which is less than (0.05), and the (Table 3) the (Median) test for pairwise comparisons, we found that there are significant differences between (1st Group- 3ndGroup), (1st Group-4th Group), (2ndGroup-3rd Group), (2ndGroup-4th Group) and (3rd Group - 4th Group), in terms of the probability value (P-value), which appeared equal to (0.000), (0.000), (0.012) (0.000) and (0.000), respectively, which is less than (0.05). As for the comparison between the two groups (1st Group-2ndGroup), we find that there are no significant differences between them in terms of the probability value (P-value), which appeared equal to (0.273), which is greater than (0.05).

The precision was evaluated by superimposing the scan data within each group (n = 8). The quantitative values were automatically calculated by the 3D analysis program. (Table 4) demonstrate that there was no significant difference in each type of impression groups.

Table (2): Independent-Samples Median Test.

Independent-Samples Median Test	
Total N	32
Median	.003
Test Statistic	20.000
Degree Of Freedom	3
P-value	.000

Table (3): Pairwise Comparisons of Groups for the Fixed bridge type of preparation Samples.

Pairwise Comparisons of Groups		
Sample 1-Sample 2	Test Statistic	P-value
1st Group- 2ndGroup	4.000	.273
1st Group -3rd Group	16.000	.000
1st Group-4th Group	16.000	.000
2ndGroup- 3rd Group	9.600	.012
2ndGroup-4th Group	16.000	.000
3rd Group-4th Group	16.000	.000

Table (4): Independent-Samples Kruskal-Wallis Test

		Independent-Samples Kruskal-Wallis Test	
		Kruskal-Wallis H	Sig
Fixed bridge	1stGroup	3.925	.788
	2ndGroup	4.068	.772
	3rdGroup	.721	.998
	4thGroup	2.029	.958

DISCUSSION

Based on the results of this study, the null hypothesis was rejected because significant differences were found among the trueness of the tested groups. There was no significant difference between the Trios and Medit i500 groups while significant differences were found between each pair of the remaining tested groups.

The findings of this study are consistent with those of a recent study, The TRIOS had the best accuracy for the single crown's scans but no statistically significant difference was found in the tolerance range values among the different scanners tested [16], TRIOS to be the most precise scanner for complete crown abutments with an error below 6.9 mm for trueness[17].

In contrast to these results regarding the larger deviation of the scannable impression, direct scanning of impressions made from polyvinyl siloxane materials provided superior overall accuracy, making it advisable to fabricate restorations based on impression scans whenever possible[18]. This disagreement may be due to differences in the methodology between the two studies, as they used a thin layer of scan spray in their work to dispense with interfering reflections, according to the conclusion that in the 3D analysis, the deviation of the scanning-aid material applied groups was significantly lower than that of the not treated group[19].

CONCLUSIONS

With the Limitations of our study the following conclusions are achieved:

1. The intra oral scanners have a high accuracy level in both (trueness and precession) in single crown and three-unit preparation casts.
2. No significant differences were found between the two types of IOS technologies (Confocal imaging by TRIOS group and video streaming by Medit i500)
3. Scannable impression direct digitization showed significantly higher deviation than conventional impression stone casts with clinically acceptable level of accuracy.

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