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RESEARCH ARTICLE

TRUENESS AND PRECISION OF DIFFERENT DIGITAL SCAN SYSTEMS IN A TWO IMPLANT COMPLETE ARCH MODEL: AN IN-VITRO STUDY

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Abstract

Background: One of the major concerns in implant-retained prostheses is their accuracy which plays an essential role in implant success and prosthesis adaptation. Although many contemplates stated the indications and merits of different digital scanner systems, little is identified about their trueness and precision in scanning dental implants of implant-retained prostheses.
Objectives: This contemplate aimed to evaluate and compare the trueness and precision of two unalike most recent digital scan systems in a mandibular two-implant complete arch model.
Materials and Methods: A completely edentulous mandibular cast was utilized into which two conventional dental implant analogs were drilled in its inter-foramina area from which the distance between the analogs was measured by a caliper (Control). The same space was assessed via scanning the whole assembly 13 scans/each digital scanner system. The final distance of each scan attained from both systems was then compared with the control. The accuracy of each system was assessed in terms of trueness and precision.
Results: Slight advancement of the Dof Freedom X5 premium digital scanner system than the Medit T300-T500 dental digital scanner regarding trueness although they were still insignificantly different, as P=0.66. The Medit digital scanner system was significantly better than the Dof Freedom one concerning precision, as P=0.001.
Conclusion: The two dental laboratory digital scanner systems employed are reliable tools for scanning and reproducing digital dental records accurately for an implant-supported prosthesis. Furthermore, the Medit dental digital scanner system seemed to be more accurate in terms of precision than the Dof Freedom one.

Introduction:-

Impression is demarcated as “The object’s surface negative resemblance or reverse copy; an imprint of teeth, implants, ridges and adjacent structures for usage in dentistry” owing to The Glossary of Prosthodontics Terms. The crucial accurate record desired for the three-dimensional (3D) intraoral relationship among implants, ridges, and adjacent structures ranks the impression-making procedure for being a critical clinical step. Since the precise capturing of implant fixtures and registering the fine specifics of the nearby gingiva and structures are the vital purposes of implant impression, hence replicating the implants’ intraoral relationship via an impression is the initial step in reaching an accurate and passively fitting prosthesis[1-3].

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Various impression materials have been utilized for the implant retained prosthesis construction for their qualities such as; inflexibility and tear resistance of polyether, as well as accuracy, durability, wettability, and affordability of condensation reaction and additional silicones. Although these materials have tremendous merits their shrinkage and dimensional instability are crucial limitations regardless of the versatile factors generally influencing the impression's accuracy such as; impression tray, technique, material, dental stone type, and compatibility together with the potentiality of human and/or material error. Such demerits threaten the impressions' quality, certainly, lead to laboratory inaccuracies, and prevent the construction of a successful, accurate, and passively fitting implant-retained prosthesis[4-6].

Digital impressions and scanning systems created prime alterations in implant retained prosthesis by providing simplicity, speed, efficiency, and facility in fabricating, storing, and transferring the digital scanned impressions among laboratory and dental offices. Moreover, diminishing impression materials' distortion, 3D pre-visualization of the prosthesis, and the probability of both time- and cost-efficiency are further qualities of digital impressions. Additionally, with digital scanners use, the area required is broadly viewed, scanned, free from any linear stitching, and quite accurate. The digital workflow accuracy is multi-factorial and based on the digital scanner system's software, hardware, milling machines, 3D printers, operator's experience, scan bodies, and a few clinical aspects[7-9].

Rendering to the standard International Organization for Standardization (ISO 5725-1) accuracy comprises both trueness and precision. Trueness is a qualitative expression for the degree of closeness between the object's value (the arithmetic mean gained from a large series of test outcomes) and the realistic accepted reference value of that object. Whereas, the possibility of achieving repeatable measurements of the same object within an identical condition and expressed as the standard deviation of the test results is demarcated as Precision. In digital dentistry, trueness can be evaluated by determining the variance between the test scan measurements and the true value for the same object, while precision by deciding how close the test scans of the same object are to each other[10-12].

Precise transmission of the 3D implant position to the prosthesis design software is a crucial step in fabricating a long-term successful implant-retained prosthesis. Inaccurate transferee sequentially ends up with an ill-fitting prosthesis and biomechanical difficulties such as; screw lessening and bone loss. The indirect approach for implant prosthetics digital workflow is one of the computer-aided design and computer-aided manufacturing (CAD-CAM) technology advancements by digitizing the conventional implant impression or cast via utilizing an optical desktop scanner. Since new digital scanner systems and their software are frequently evolving in the market, both their trueness and precision evaluation are crucial, especially with a complete arch implant model for comprising regular geometry shapes and interpreting easily performed measurements[12-14].

Hence, this contemplate aimed to evaluate and compare the trueness and precision of different most recent digital scan systems in a mandibular two-implant complete arch model.The current investigation's hypothesis is Null as there is no difference in the trueness and precision of the two digital scan systems employed.

Materials and Methods:-

Materials:-

1. Dental stone (Fujirock EP; type IV dental stone; lot 0718856 2013 14 GC Lisbon; GC Europe; Portugal, Europe).
2. Conventional dental implant analog (Implus Cylindrical, leader, Italy).
3. Cyanoacrylate adhesive (Parson Adhesives, Inc., Auburn Road, Rochester, MI 48309 USA).

Study Design:

This in-vitro study was conducted by utilizing a completely edentulous mandibular cast into which two conventional dental implant analogs were drilled in its inter-foramina area from which the distance between the analogs was measured by a caliper (Control). The same space was assessed via scanning the whole assembly 10 scans with each of the two most recent digital scanner systems. The final distance of each scan attained from the two systems employed was then compared with the control. Accuracy of each digital scanner system was assessed in terms of trueness (comparing scan and reference) and precision (determining the deviation between different test scans).

Sample Size Calculation:
Sample size was estimated liable on preceding research as a reference (**Kang et al 2020**). Accordingly, the minimally accepted sample size was 11 scansin each group with 0.925 mean difference when the assessed standard deviation was 1.000,the power was 80%, probability error was 5% and T-test was performed by using P.S power 3.1.6.Although thefinally estimated sample size for the current research was 11 scans/Group, but 13 scans were performed in each group (13 scans/Group) for providing more means of accuracy[15].

Grouping:
Grouping in the current contemplate took place owing to the digital scanner system employed. Two Groups (13 scans /Group); Group I (Dof Freedom) and Group II (Medit).

Methods:-

1. **Model Used:**
   An educational cast of type IV dental stone (Fujirock EP; type IV dental stone; lot 0718856 2013 14 GCLisbon; GC Europe; Portugal, Europe) of a mandibular completely edentulous arch was utilized as the model.
2. **Placement of Implant Analogs:**
   Two conventional dental implant analogs (Implus Cylindrical, Leader, Italy) with 3.75mm width and 13mm height were drilled into the inter-foramina area of the fully edentulous lower stone cast and guided by the clear acrylic stent, succeeding the manufacturer's guidelines via employing the implants' kit, as displayed in figure (1).

Fig (1):-The dental implant kit and its analogs.

Cyanoacrylate adhesive (Parson Adhesives, Inc., Auburn Road, Rochester, MI 48309 USA)was utilized in the prepared sites for implant analogsstabilization, ending up with the whole cast and its two dental implant analogs, as presented in figure (2).

Fig (2):- The model with the two dental implant analogs.

3. Measuring Distance Between Implant Analogs Manually:
Distance between implant analogs was measured by an electronic automated digital caliper (SE SAE and Metric electric Digital Caliper-Precision Measuring tool- Stainless Steel-Extra-Large LCD Display screen-6 Inch-784EC, accuracy +/- 0.02mm, 0.001”), Fowler, Newton Massachusetts, USA.) with an 0.05 mm exactness, as revealed in figure (3).

Fig (3):- The electronic digital caliper.

This was carried out thru a single well-trained examiner who assessed that space randomly for 13 times to evaluate the exact locationof implant analogs and distance between themthen the average was attained. Assessment took place from the reference point at the mesial flat beveled surface of both implant analogs and the resulting outcome was considered as Control with which all other dimensions were compared, as displayed in figure (4).

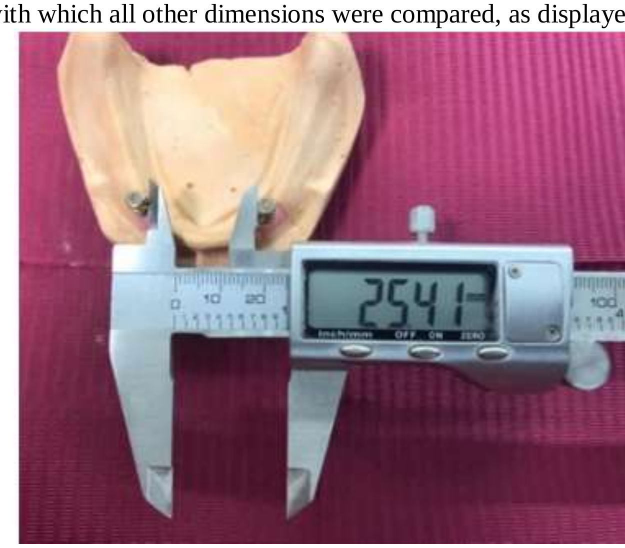

Fig (4):- Distance between implant analogs measured by the electronic digital caliper.

4. Scanning and Measuring the Distance Digitally:
The same cast was scanned 13 scans randomly and out of sequence with each of the two testeddigital scanner systems; Dof Freedom X5 premium dental lab scanner (5MP Scanner, 100-240V(AC), 50-60 Hz, 5µm* Accuracy, #602, 77 Seongsuil-ro, Seongdong-gu, Seoul, 04790 Korea) with Exocad Generation Dental Cad 2.4 Plovidiv software and Medit T300-T500 dental lab scanner (Pearson Dental Supply Company, 13161 Telfair Ave ; Sylmar Acres ; P M 274-89 LOT B ; Los Angeles ; California, USA.) with Exocad Dental Cad 3.1 Rijika softwareemployed in the current research.

Scanning was carried out by the same operator and with the same digital scanning protocol to evaluate the positional accuracy of the two implant analogs. Every scanner was adjusted following its manufacturer’s instructions. Accordingly, scanning of the whole assembly took place by capturing images occlusally initiating from the distal area of the most distal analog on the right occlusal surface till the left distal one. Consecutively, the buccal surface of the left distal analog was scanned and images were captured till reaching the same area buccally for the right distal one and terminating by capturing images for the lingual side of the whole model. as displayed in figures (5 a and b).

Fig (5 a & b):-Scanning the whole model with is implant analogs position by theDofFreedom X5 premium and Medit T300-T500 dental lab scanners.

The same reference points at the mesial flat beveled area of both analogs was utilized for calculating the distance between them. The digital scanner systems were employed according to their manufacturer's regulations. All scans in the were obtained with the most recent gained software available at that period for each digital scanner used. The whole scans were attained at room temperature 20+1^{o}C (37^{o}C)with the same environments concerning both light and humidity (50%). Each scan obtained was saved as a Standard Tessellation Language (STL) file, and a total number of 26 STL files were achieved from the two digital scanner systems utilized (13 STL files /digital scanner system). Each file was imported and distance between the same reference points of two implant analogs was measured by its digital scanner software, as presented in figures (6a and b).

Fig (6 a & b):-Distance between the two implant analogs measured from the same reference pints by Software's of DofFreedom X5 premium and Medit T300-T500 dental lab scanners.

5. Calculation of Trueness:

The digitally calculated distance between both analogs' reference points in each scan system utilized was compared separately with the manually gauged master model (Control). The trueness of each scanner system was finally estimated from the 26 scans obtained.

6. Calculation of Precision:

Precision was assessed separately by comparing between the digitally calculated distance among both analogs' reference points in each scan attained from the same scanner system utilized. The precision of each scanner system was estimated from its 13 scans obtained.

Results:-

Statistical Analysis:

Statistical analysis was performed with SPSS 16 ® (Statistical Package for Scientific Studies), Graph pad Prism, and Windows Excel and was presented in 3 tables and 3 graphs. Exploration of the given data was performed employing the Shapiro-Wilk test and Kolmogorov-Smirnov test for normality which revealed that data originated from normal data distribution. Accordingly, a comparison between 2 different groups was performed by the Independent T-test. The significance level was set at $p \leq 0.05$.

Descriptive Results:

Descriptive results of both groups regarding trueness and precision were displayed in table (1)and figure (7).

Table (1):- Descriptive Results of Trueness and Precision of Both Groups:

		Minimum	Maximum	Mean	Standard Deviation
Trueness	**Dof Freedom X5 premium digital scanner system**	0.01	2.69	1.96	0.68
	Medit T300-T500 dental digital scanner system	1.41	2.66	2.06	0.40
Precision	**Dof Freedom X5 premium digital scanner system**	1.63	2.87	2.18	0.36
	Medit T300-T500 dental digital scanner system	0.00	0.93	0.44	0.28

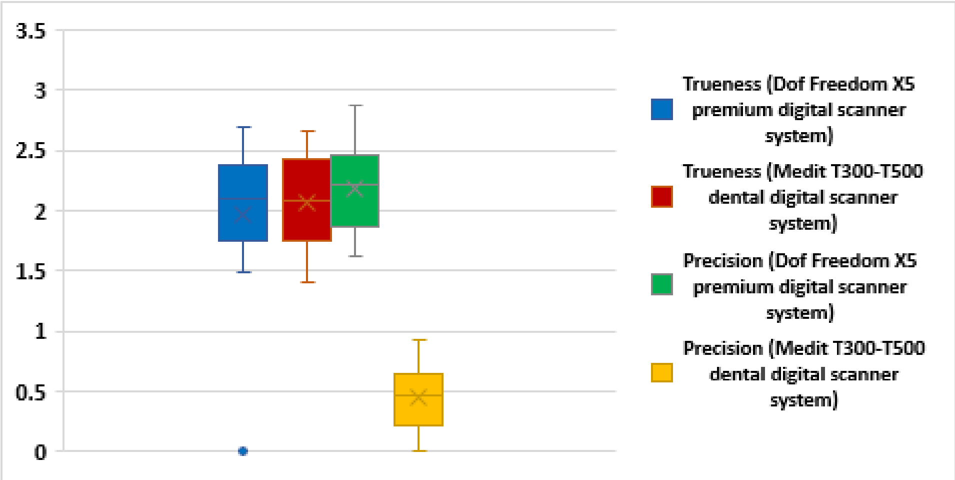

Figure (7):- Boxplot representing descriptive results of trueness and precision in both groups.

Evaluation of Trueness:

Comparison between groups demonstrated insignificant difference between them as P=0.66 (Dof Freedom X5 premium digital scanner system showed lower deviation than group Medit T300-T500 dental digital scanner system), as presented in table (2) and figure (8).

Table (2):- Mean and Standard Deviation of Trueness In Both Groups and Comparison Between Them:

	Trueness			Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
	N	mean	standard deviation			Lower	Upper	
Dof Freedom X5 premium digital scanner system	**13**	1.96	0.68	-0.10	0.22	-0.55	0.36	0.66
Medit T300-T500 dental digital scanner system	**13**	2.06	0.40					

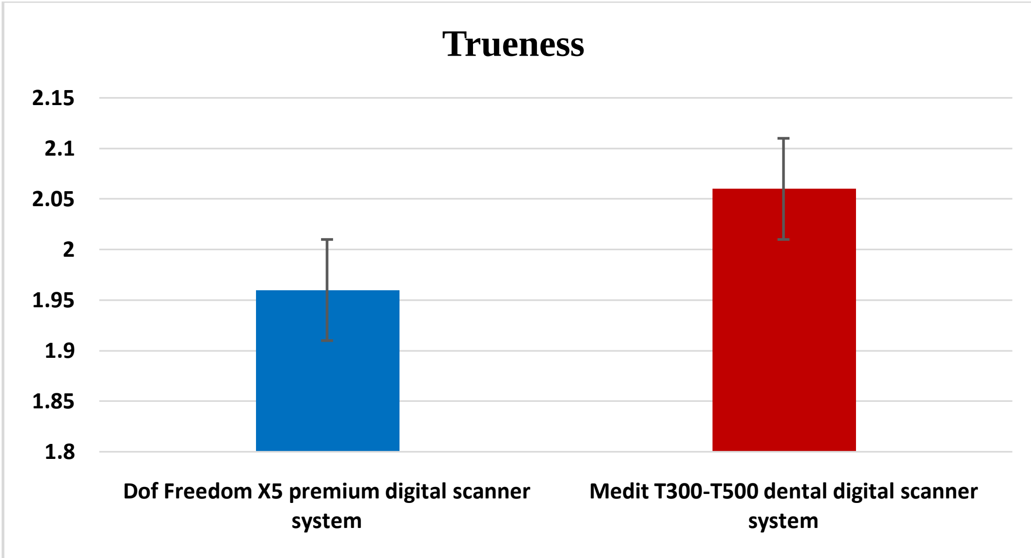

Figure (8):- Bar chart representing trueness in both groups.

Evaluation of Precision:

Comparison between groups demonstrated a significant difference between them as P=0.001 (Dof Freedom X5 premium digital scanner system displayed significantly higher deviation than group Medit T300-T500 dental digital scanner system), as revealed in table (3) and figure (9).

Table (3):- Mean and Standard Deviation of Precision in Both Groups and Comparison Between Them:

	Precision			Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
	N	mean	standard deviation			Lower	Upper	
Dof Freedom X5 premium digital scanner system	**12**	2.18	0.36	1.73	0.13	1.46	2.01	0.0001*
Medit T300-T500 dental digital scanner system	**12**	0.44	0.28					

*Significant difference as P<0.05.

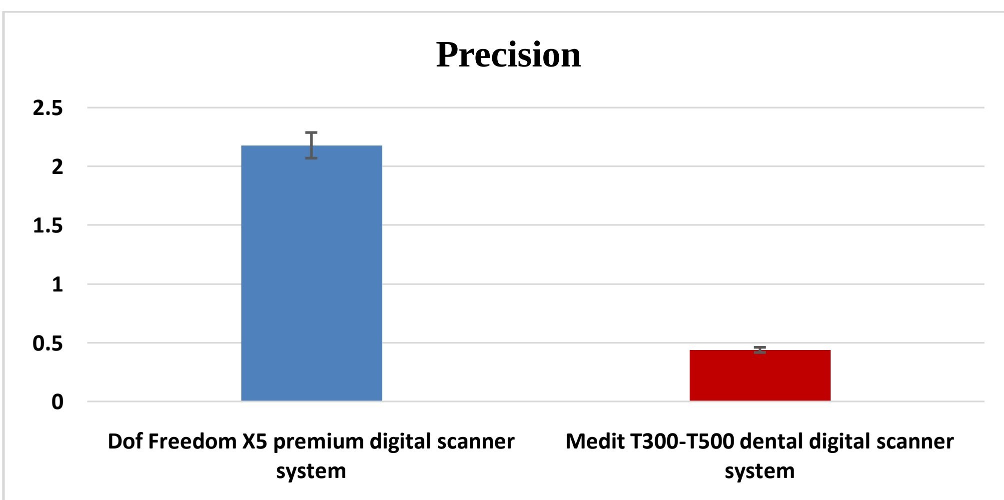

Figure (9):- Bar chart representing precision in both groups.

Discussion:-

This in-vitro study was conducted to evaluate and compare the trueness and precision of two dissimilar most recent digital scan systems in a mandibular two-implant complete arch model. Although the estimated sample size was 11 scans/Group, 13 scans were performed in each group (13 scans/Group) for providing more means of accuracy.

An educational cast of Type IV dental stone was elected for its merits such as; availability, effortless usage, delayed linear expansion and premature contraction ongoing up to 120 and 168 hours, where its maximum range of expansion has been reported as 0.08% to 0.28%[16].

A reference mandibular completely edentulous arch model was utilized into which two conventional dental implant analogs of simple geometry were drilled in its inter-foramina area from which the distance between the analogs was measured to simulate a clinical case of a mandibular edentulous patient with two implants, allowing measurements to take place across well-defined points and avoiding errors due to the landmark identification[14].

A clear acrylic resin stent as a drilling guide was employed for guiding the implant placement, directing the implant drilling process, and ensuring that each implant analog was properly positioned in accordance with the study protocol[17].

An electronic automated digital caliper was anticipated for calibrating the distance between implant analogs(Control) for its minimal time consumption which is less than one second (0.5) as well as its accuracy of 0.05 mm exactness. Manual techniques for measuring distances through employing digitally automated appliances are still much more rapid in terms of time than the non-automated ones which are demarcated with the prolonged time intake and are labor-intensive due to the identification of the remarkable point which is accompanied by the distance calibration. Despite the manual techniques' merits especially in terms of time, but the fact that these procedures are cumbersome in requiring an actual physical cast, large storage space for organizing and retrieving together with the burden of storing and sorting them. Accordingly, digital scanning of the casts is the best alternative for their advancement in accuracy, repeatability, and speedy measurements[18,19].

Aiming to avoid the incidence of any variables and diminish the number of aspects that could have influenced this contemplate's outcomes, the same reference points at the mesial flat beveled area of both analogs were utilized for calculating the distance between them both manually by the digital automated caliper and digitally scanning by the two dissimilar laboratory digital scanning systems. Moreover, all the assessments whether manually or digitally were carried out by the same well-trained operator, and both systems' scanning was applied with the same digital scanning protocol to evaluate the positional accuracy of the two implant analogs after adjusting every scanner owing to its manufacturer's instructions.

According to the current study's results, the Null hypothesis was rejected. This is attributed to the slight advancement of the Dof Freedom X5 premium digital scanner system rather than the Medit T300-T500 dental digital scanner one regarding trueness although they were still insignificantly different, as P=0.66. In other terms, the Dof Freedom X5 premium digital scanner system's outcomes deviation was less than the manually assessed cast ones (Control) when compared with those of the Medit T300-T500 dental digital scanner regarding trueness.

Furthermore, the Medit T300-T500 dental digital scanner system was significantly better than the Dof Freedom X5 premium digital scanner one concerning precision, as P=0.001. Whereas, the Dof Freedom X5 premium digital scanner system's outcome deviations were statistically higher than that of the Medit T300-T500 dental digital scanner system in terms of precision.

Although an insignificant difference between the two digital scanner systems concerning trueness, upon comparing the two employed digital scanner outcomes in this study with the manually assessed ones their mean difference was (-0.10) and the Dof Freedom digital scanner was slightly better than the Medit one. Accordingly, this research's findings are consistent with other contemplates which stated that once the mean difference is less than 0.20 mm as a result of comparing any digital scanner system's outcomes with those of its manually assessed ones, hence it is clinically acceptable as it is almost identical to the reliability found for manual measurements [20,21].

The insignificant difference between the two digital scanner systems relating to trueness might also be attributed to the solo dependence of these assessments on human identification and measurements. Therefore, the identification of the remarkable point from which assessments should take place as well as measurements taking or reading are elements in which human error can occur either in one or all of them is a simple reason[19, 21].

The significant difference and advancement of the Medit dental digital scanner system and the Dof Freedom one concerning precision was in harmony with other research which stated that although the versatile digital scanner systems available in the market are reliable for scanning the analog models together with their trueness and precision are within the acceptable clinical levels even though there are differences between them and stated that the Medit digital scanner system usually had the highest accuracy among the versatile investigated scanners[13, 15].

On the other side, another study compared the Medit laboratory digital scanner system with other digital laboratory scanners and many intra-oral scanner (IOS) systems and stated that it had the best trueness and precision compared to all IOSs used but it had low means of accuracy in terms of trueness and precision when compared with all the digital laboratory scanner systems in their research. A study claimed that although greater levels of accuracy are demanded accuracy increase usually requires more megapixels which will result in capturing more data while scanning but this may not result in the acquisition of useful information, and will always slow down the scanning process. Additionally, direct comparisons are hard to apply among diverse studies as all the scanners' dates of release are dissimilar and their software has been upgraded over the years[10, 19,22].

Conclusion:-

Within the limitations of the present study, it has been concluded that:

The 3D dental laboratory scanner with its different systems not only has proven to be accurate but also saves time, effort, and space. The two dental laboratory digital scanner systems employed in this study were reliable tools for scanning and reproducing digital dental records for a removable implant-supported prosthesis. Furthermore, the Medit T300-T500 dental digital scanner system seemed to be more accurate in terms of precision than the Dof Freedom X5 premium digital scanner system.

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