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EVALUATION OF RECENT AURICULAR SCANNING TECHNOLOGIES USING DIFFERENT INTRA ORAL SCANNER TECHNOLOGIES (CLINICAL DIAGNOSTIC EVALUATION)

AMR I. YOUSSEF[1*] BDS, MOHAMED SHERINE EL ATTAR[2] BDS, MSC, PHD, INGY S. SOLIMAN[3] BDS, MSC,PHD

ABSTRACT

INTRODUCTION: The dental industry has seen a significant push toward digitization in recent years; as a result, digital approaches utilizing intraoral scanner devices, which enable data entry into computers without the need for physical contact, are replacing traditional 2D models. Traditionally, clinicians have planned cases using 2D images.

OBJECTIVE: To evaluate the effectiveness and accuracy of using intraoral scanner (Medit i700) to register the anatomy of normal auricular morphology using 3D software assessing the reliability of different scanning protocols.

METHODOLOGY: Ten auricles were scanned using Proface 3D Imaging (reference group) and using Medit i700 in three different techniques (without markers, with markers and with spray opaquer using Geomagic Control X).Geomagic X is used for super imposition of the scans from IOS with proface scans.

RESULTS: Using (Medit i700), there was a statistical significance difference in total deviation (RMS) as well as point deviation in the seven selected deviation points using no marker, markers and spray technology on being compared to reference model. However, the clinical significance of the total deviation as well as for the point deviation for the three technologies showed between mild to moderate clinical deviation to be SD <1.5

KEYWORDS: auricular scan, Medit i700, markers , accuracy .

DISCUSSION: The clinical significance of using IOS (Medit i700) to produce an auricular scan showed a significant clinical anatomical morphology that can resemble the normal auricle. The concept of data recording of scanned auricles showed a reduced clinical significance for both total deviation as well as point deviation as selected.

CONCLUSION: Intraoral scanner is a significant alternative to conventional impression and can eliminate the use of such conventional data registration.

RUNNING TITLE: Evaluation of auricular scanning using different intra oral scanner technologies

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1- Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
2 -Professor, Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
3 -Associate professor, Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.

Corresponding author:
amr.youssef91@gmail.com

INTRODUCTION

In recent years there has been a strong push to digitize the dentistry sector therefore conventional 2D models are being replaced by digital approach using intraoral scanner device allowing the entry of data into the computer without any physical touch. Clinicians have typically used 2D images to plan cases. Normal images do show the patient in the static posture in which the picture was taken, limiting the clinician's and the lab's ability to see the patient's other features.(1)

The scan data is then saved as STL or PLY files to be utilized for production of 3D models that allow visualization to produce models to simulate the defect simpler and quicker. The created files can be saved and transmitted eliminating the chance of impression distortion or dimensional changes of conventional impression techniques. it is also undeniable that the digital model created by iOS is efficient in terms of securing storage space. (2-6,7-10). Studies have demonstrated improvements in the IOS accuracy and precision as well as their ability to displace more traditional methods. (11,12). Scanning soft tissues in 3D with an IOS device is just as exact and precise as scanning extraoral objects like the ear, which need for high resolution images. The advancement of CAD technology in dentistry sought to eliminate the flaws in conventional impression techniques and associated faults. (13,14)

In maxillofacial the traditional method of Auricular reconstruction is quite challenging. Since traditional method of impression registration has several issues causing distortions during impression making, time commitment and a requirement for great technological competence and very exceptional creative hand talents. [14] So, the use of intra oral scanners is being introduced in the dental field since it can produce models that accurately resemble normal auricular morphology implementing scan bodies (markers) to enhance the stitching of scanned auricles. [15,16]

The null hypothesis of this study that there is no difference in auricular morphology after being scanned with Medit IOS in comparison with the results obtained from the proface scans.

METHODOLOGY

The study involved five healthy adult male volunteers with an average age range of 30-33. The participants had similar average skin tones and both right and left intact auricles. The exclusion criteria for auricular scanning included any auricular defects or inflammatory response that could affect accurate scanning, as well as medical conditions such as epilepsy or seizure disorders that could interfere with the scanning process.

The volunteers were selected from the outpatient clinics of the prosthodontic department in the faculty of oral and dental medicine. The study followed the ethical principles outlined in the Declaration of Helsinki for research involving human volunteers and received approval from the ethics committee. [13]

In the study, written informed consent was obtained from the participants before their enrollment. They were provided with an adequate explanation of the study and the benefits they would receive from participating.During the study, all volunteers were seated on a dental chair in a supine position with full neck support to ensure stabilization of the volunteer while scanning. All the scans were performed during normal daylight illumination using luximeter (© Nipakul Buttua) to ensure the lightening protocol was equally directed to the full ear. A well-trained single operator was used to allow the equality of all scanning and being seated away from the light source to prevent any reflection that can produce any scanning artifacts. [13]

Medit i700 (Medit, seoul, korea) with tip size 22.2 x 15.9 mm, mirror angle 45-degree angle easier for scanning distant areas, and last but not least the scan area is 15 x 13 mm according to the manufacturer. [23]

It used to scan the surface topography of each auricle. Scans were performed without markers, with markers, and with scan spray. Each scanning method was done twelve times where the first and last scans were removed to eliminate any deviation errors. All scans were measured for each methodology and scanning IOS to evaluate the scanning time about feasibility of the methodology as well as its processing time to produce a scanned model. [13]

Scanned auricles were divided into the two following groups as shown in (Figure7):

Control group (CG) : Planmeca Proface (Romexis 3D imaging software)(FI-00880 HELSINKI, Finland) scans were taken for each auricle.

Medit i700 (MG): Digital ear scans were taken using Medit i700, with scans performed both with markers and without markers and Scan spray was also used in this group.

The digital intraoral scannings of the auricles were performed using three different methods: with markers and without markers, as well as with the application of scan spray. Here's a breakdown of each method:

A. Intraoral scanning of the ear with no markers:

Scanning process: In this step, an intraoral scan of the ear was performed without markers using Medit i700 intraoral scanner. The scanning process followed the same three circular movements as the ear scan with markers. (Figure 1)

The scanning process was made as explained by Ballo et al. The ear tragus was set as the starting, finishing, and reference point for the scanning. Scans were performed using IOS (Medit i700) in three circular movements with a zigzag motion. The first circle covered the tragus, antitragus, antihelix, and tragus again. The second circle covered the tragus, lobule, helix, and tragus again. The third circle focused on the rear of the ear, starting from the lobule and extending backward as shown in (Figure 2)

B. Digital intraoral scanning of the ear with markers:

Markers were created using Ivoclar composite resin (Te-Econom) ***Zurich, Switzerland*** with A3 shade with nearly 4 mm diameter circular shaped balls that were cured and bonded to the ear using 3M single bond universal. Markers' places were assessed as follows: The first marker was placed below Darwin's tubercle, the second marker at the lobule, and the last marker at the back of the lobule. These markers acted as reference points during the scanning procedure to improve the quality of the scans and allow guidance during the scanning protocol as shown in (Figure 3) and (Figure 8)

C. Intraoral scanning of the ear with scan spray(Figure 4) and (Figure 9):

Scanning process: In this method, the ear was scanned using Medit i700 scanner with scan spray applied to the auricles. The scanning process followed the same three circular movements as the previous scans.

Acquisition and Evaluation

The 3d auricular models were assessed for the area of interest and any excess data was eliminated to reduce file size. Exporting the file: The scanned files were exported in a Standard Tessellation Language (STL) file format. The STL file of was used to superimpose their positions on the ear. Using free-form designing software (Blender software), points were selected using Geomagic control X (3D Systems, Rock Hill, SC, USA) and Cloudcompare (Cloudcompare, Paris, France)Then, a best-fit alignment algorithm was used to register the planmeca proface on the reference data, followed by a 3D surface comparison using three test groups. The total 3D deviation was recorded for all the scans.

Using the heat map Seven points were selected to be tested to identify the accuracy of different point deviation among the three test groups on being compared to the reference model as shown in (Figure 5) and (Figure 6)

Figure 1 shows scan of right auricle without markers

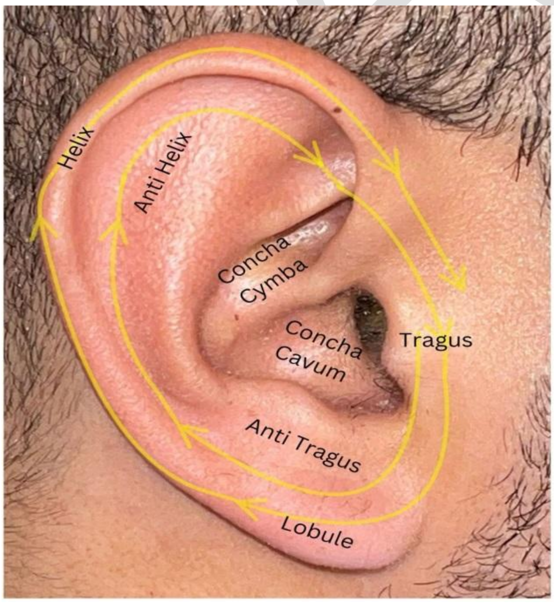

Figure 2 shows the scanning pattern used

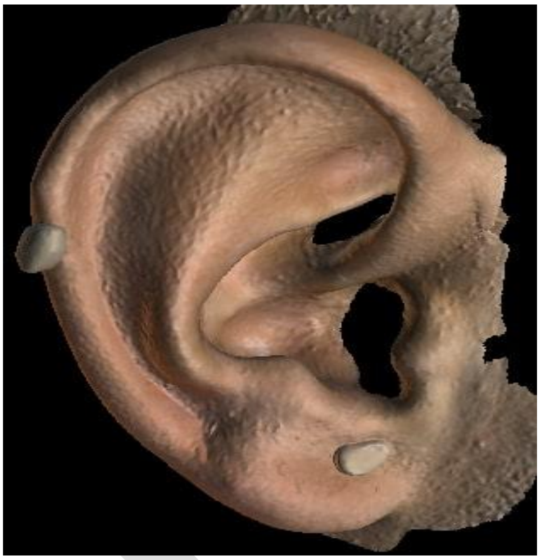

Figure 3 shows the scan for the right auricle with resin markers.

Figure 4 shows the real picture for the right auricle with scan spray

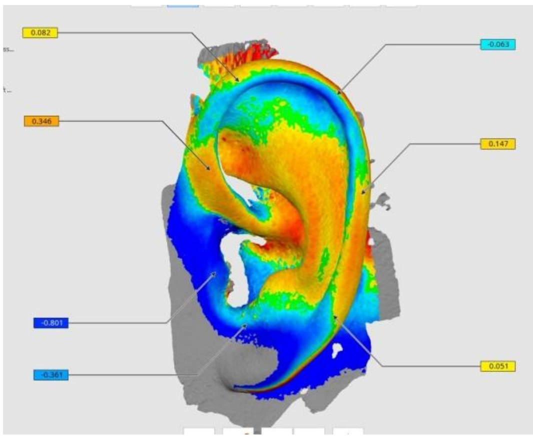

Figure 5 shows the heat map and point deviation for the super imposition of the scan resulting from IOS and Proface face scan (without markers)

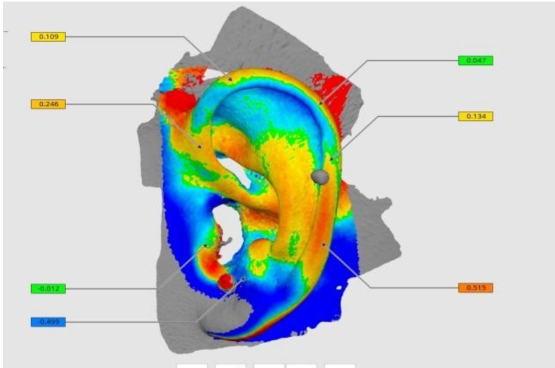

Figure 6 shows the heat map and point deviation resulting from the super imposition the scan resulting from IOS and Proface face scan (with markers)

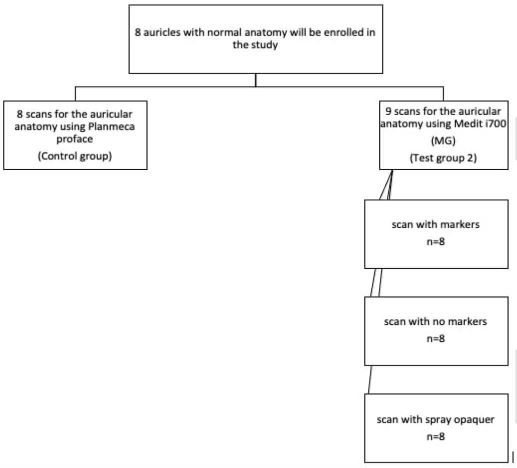

Figure 7 shows an illustrated diagram to the methodology.

Figure 8 shows real picture for the right ear with markers in place

Figure 9 shows right ear with scan spray.

RESULTS

For statistical analysis, The Shapiro-Wilk test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation. (Table 1) shows the RMS of the right ear using different techniques of scanning (without, with markers and with scan spray) showing no significant difference between the three techniques in scanning the right ear. In (Table 2) we also compared between three different techniques in scanning the left ear showing no significant difference in results among the different techniques. (Table 3) shows a comparison between the right and left auricles using different techniques regarding the RMS of each technique, showing no significant difference between the first two techniques (with and without markers) on both wight and left ear , on the other hand there is a significant difference between the right and left ear in using the scan

spray. (Table 4) in this table we are comparing the point deviation in seven different points of the auricle using the same IOS but with different techniques on the same auricle and we got points (1,2,4,5,7) shows significant difference between scanning with markers and scanning without marker. while points number (1,2,3,4,6) shows significant difference between scanning without markers and scanning with scan spray. Points (1,2,4,5) show no significant difference between scanning with markers and scan spray.

Table (1): Comparison between the three studied markers according to RMS (n = 10)

RMS	Scan without markers	Scan with markers	Scans with scan spray	F	P
Right ear					
Min. – Max.	0.52 – 0.76	0.41 – 0.77	0.56 – 0.72	1.747	0.218
Mean ± SD.	0.63 ± 0.07	0.58 ± 0.10	0.64 ± 0.05		
Median	0.62	0.56	0.63		

SD: Standard deviation
F: F test (ANOVA) with repeated measures, Sig. bet. periods was done using Post Hoc Test (Bonferroni) p: p value for comparing between the studied markers

Table (2): Comparison between the three studied markers according to RMS (n = 10)

RMS	Scan without markers	Scan with markers	Scans with scan spray	F	P
Left ear					
Min. – Max.	0.59 – 0.71	0.59 – 0.71	0.63 – 0.77	3.737	0.073
Mean ± SD.	0.65 ± 0.04	0.64 ± 0.05	0.68 ± 0.04		
Median	0.65	0.63	0.68		

SD: Standard deviation
F: F test (ANOVA) with repeated measures, Sig. bet. periods was done using Post Hoc Test (Bonferroni)
p: p value for comparing between the studied tech

Table (3): Comparison between right and left according to RMS

RMS	Right (n = 10)	Left (n = 10)	t	p
Scan without markers				
Min. – Max.	0.52 – 0.76	0.59 – 0.71	0.972	0.344
Mean ± SD.	0.63 ± 0.07	0.65 ± 0.04		
Median	0.62	0.65		
Scan with markers				
Min. – Max.	0.41 – 0.77	0.59 – 0.71	1.791	0.090
Mean ± SD.	0.58 ± 0.10	0.64 ± 0.05		
Median	0.56	0.63		
Scans with scan spray				
Min. – Max.	0.56 – 0.72	0.63 – 0.77	2.185*	0.042*
Mean ± SD.	0.64 ± 0.05	0.68 ± 0.04		
Median	0.63	0.68		

SD: Standard deviation t: Student t-test
p: p value for comparing between Right and Left
*: Statistically significant at $p \leq 0.05$

Table (4): Comparison between the three studied markers according to Point (n = 10)

	Scan without markers	Scan with markers	Scans with scan spray	Fr	p
Point 1 Min. – Max. Mean ± SD. Median	 -0.41 – -0.20 -0.30 ± 0.09 -0.30	 -0.51 – -0.48 -0.50 ± 0.01 -0.50	 -0.60 – -0.08 -0.33 ± 0.25 -0.32	5.0	0.082
Point 2 Min. – Max. Mean ± SD. Median	 0.02 – 0.08 0.04 ± 0.02 0.04	 0.23 – 0.53 0.39 ± 0.14 0.39	 0.15 – 0.51 0.33 ± 0.17 0.34	18.20*	<0.001*
Sig. bet. tech	p_1<0.001*,p_2=0.014*,p_3=0.074				
Point 3 Min. – Max. Mean ± SD. Median	 0.07 – 0.19 0.13 ± 0.05 0.12	 0.13 – 0.20 0.16 ± 0.02 0.15	 0.02 – 0.11 0.05 ± 0.03 0.05	15.0*	0.001*
Sig. bet. tech	p_1=1.000,p_2=0.001*,p_3=0.001*				
Point 4 Min. – Max. Mean ± SD. Median	 -0.16 – -0.03 -0.10 ± 0.05 -0.10	 0.03 – 0.65 0.23 ± 0.21 0.19	 -0.11 – 0.10 -0.01 ± 0.11 -0.01	15.0	0.001*
Sig. bet. tech	p_1=0.001*,p_2=0.001*,p_3=1.000				
Point 5 Min. – Max. Mean ± SD. Median	 -0.04 – 0.09 0.02 ± 0.06 0.02	 0.09 – 0.12 0.11 ± 0.01 0.11	 -0.08 – 0.14 0.03 ± 0.10 0.03	6.200*	0.045*
Sig. bet. tech	p_1=0.014*,p_2=0.371,p_3=0.118				
Point 6 Min. – Max. Mean ± SD. Median	 0.19 – 0.40 0.29 ± 0.09 0.28	 0.20 – 0.28 0.24 ± 0.02 0.24	 0.29 – 0.51 0.39 ± 0.10 0.39	15.0*	0.001*
Sig. bet. tech	p_1=1.000,p_2=0.001*,p_3=0.001*				
Point 7 Min. – Max. Mean ± SD. Median	 -1.40 – -0.79 -1.08 ± 0.29 -1.08	 -0.80 – -0.01 -0.39 ± 0.39 -0.37	 -1.58 – -0.43 -1.07 ± 0.53 -1.19	15.20*	0.001*
Sig. bet. tech	p_1=0.002*,p_2=0.655,p_3<0.001*				

SD: Standard deviation
Fr: Friedman test, Sig. bet. periods was done using Post Hoc Test (Dunn's)
p: p value for comparing between the studied tech
p_1: p value for comparing between Scan without markers and Scan with markers
p_2: p value for comparing between Scan without markers and Scans with scan spray
p_3: p value for comparing between Scan with markers and Scans with scan spray

DISCUSSION

Maxillofacial prosthetics play a crucial role in improving the quality of life for individuals with congenital or acquired defects. These prostheses serve multiple purposes, including restoring function, preserving anatomical structures after surgical treatments, and enhancing the maxillofacial appearance of patients. Digital 3D facial scanning is a rapidly advancing technology with applications in various fields, including biomedical engineering, 3D animation, and dentistry. In the context of maxillofacial rehabilitation, digital 3D facial scanning has been utilized to complete virtual patient records by providing information about the external patient profile. This technology holds great potential for improving the accuracy, efficiency, and patient experience in the fabrication of maxillofacial prosthetics. It has several potential sources of errors, such as distortion of facial soft tissues, time-consuming steps, patient discomfort during impression-making, and requiring the patient's attendance for an extended period. However, recent advancements in digitized imaging technology have revolutionized the field by providing non-contact 3D measurements of facial soft tissues and enabling the creation of 3D models. Different approaches have been successfully employed to obtain 3D data for maxillofacial soft tissues. [13]

The enhanced digital strategy improves upon the conventional process by utilizing digital impressions of the intact ear. This approach allows for better reproduction of minor details and surface texture, as well as increased patient comfort compared to the traditional workflow. By leveraging digital technology, therefore, the current study aimed to enhance the overall accuracy and efficiency of the auricular prosthesis. Digitizing an intact auricle poses challenges due to the unique characteristics of the front and rear surfaces. The front surface of the auricle contains internal undercut areas, which can make it difficult to capture a complete scan. Additionally, the rear surface should ideally be scanned simultaneously with the front surface as a single scan to ensure accuracy. One of the challenges in digitizing an intact auricle is the stitching of images captured by the intraoral scanner due to the presence of 3 axes. Unlike intraoral scanning of teeth, the extraoral soft tissues of the auricle have fewer distinct landmarks that can be used for accurate stitching. [17]

To ensure standardization and minimize potential sources of error, several measures were taken in the study where all scans were performed by the same operator. This approach eliminates potential errors that could arise from using different scanning patterns and skill levels among multiple operators. By having a consistent operator, the scanning process is standardized, reducing variability in the data. Also, all scans were conducted in the same room with ambient light because it is known that ambient lighting can have an impact on the accuracy of scanning, as variations in lighting can affect the quality and consistency of the captured images. This was done to standardize the lighting conditions during the scanning process. [17]

By conducting scans at the same time, any potential variations in lighting are controlled and standardized across all participants , aside from the light part we had an issue with scanning of flat surfaces and poorly differentiated anatomy found extra orally so The use of scanning markers and a scanning pattern based on the tragus area as a reference point helped to provide clearer reference points, aiding in the stitching of acquired data and ultimately improving the quality and accuracy of the digital impressions. [13]

The results we got from the super imposition of the scanned auricles with the IOS in comparison with results of scanned auricles with the planmeca proface showed that the presence of markers and scan spray on the poorly differentiated anatomy of the auricles and flat surfaces acted as reference points giving more anatomy.[13] Using heat map Mobile parts of the auricle show great variation in different techniques which is easily distorted during impression making or changing patient position showing significant difference in all points except for point (1) the lobule which is the most static part in contrary with Doheim et al. who stated that the most significant part was the lobule and because it was being compared to conventional impression which can cause the sagging of the lobule on compression during registration. [22] As we also got heat map for the superimposed scans giving us the better results in auricles scanned with both (markers and scan spray) than without markers. The clinical significance of using IOS (Medit i700) to produce an auricular scan showed a significant mild to moderate clinical anatomical morphology that can resemble the normal auricle. The concept of data recording of scanned auricles showed a reduced clinical significance for both total deviation as well as point deviation as selected to be < 1.5. [21]

In the study, the null hypothesis was rejected, indicating that there was a statistically significant difference in the total 3D deviation between the digital impression and Proface (Romexis 3D imaging software).

CONCLUSION

This suggests that the digital strategy proposed in the study could potentially provide more accurate auricular soft tissue data, enabling physicians to construct and deliver precise auricular prostheses.

To overcome these challenges, further research and development are needed to improve the scanning techniques and software algorithms used for digitizing intact auricles. This would enable more accurate and reliable scanning, ensuring that the front and rear surfaces are captured seamlessly as a single scan. [20]

The use of scanned auricles serves a fundamental principle in case of auricular loss which can guide during any auricular prosthetic reconstruction.

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