

## Anthropometric Analysis of Maxillofacial Foramina in Skulls of Human Populations: The Use of 3D Laser Scanning

Dr. Ibrahim A. Alayan\*

BDS, PhD. Department of Oral and Maxillofacial Surgery, Zliten Dental School, Al-Asmarya Islamic University, Zliten, Libya

### Original Research Article

#### \*Corresponding author

Dr. Ibrahim A. Alayan

#### Article History

Received: 04.02.2018

Accepted: 15.02.2018

Published: 28.02.2018

#### DOI:

10.36347/sjams.2018.v06i02.026



**Abstract:** Various methods have been used for analysis of maxillofacial foramina in skulls of human population. The use of 3D laser scanning method have increased in recent years and become more popular. The reasons behind this popularity are of the superior advantages over other scanning methods. This article discusses the detailed use of 3D laser scanning method and highlight important aspects to consider when used.

**Keywords:** Anthropology; Scanning; 3D Laser.

### INTRODUCTION

The supraorbital, infraorbital, mental and mandibular foramina are important anatomical structures representing the origins and terminations of the nerve plexus canals. Accurate knowledge of their positions is strategically important for diagnostic and clinical procedures such as the administration of regional anesthesia, performance of periapical surgery, surgical extractions, endodontics, implant placement and osteotomy. Reported anatomical positions have been inconsistent with standard anatomy and radiology textbooks which often contain conflicting statements regarding their positions [1].

The supraorbital, infraorbital, mental and inferior alveolar nerves emerge through the supraorbital, infraorbital, mental and mandibular foramina respectively and supply the cutaneous area of the maxillofacial region.

The most common anesthetic methods used in this area, for procedures such as closure of facial wounds, biopsies, scar revisions, and cosmetic cutaneous surgeries, are nerve blocks. Effective and accurate anesthesia will be achieved only when the operator has a good and accurate knowledge of the positions of exits of the nerves supplying these areas [2].

However, it is important to have a method of quickly and accurately predicting the location of the foramina. Many studies have already delineated the location of these foramina in relation to bony.

The aim of the article is to discuss the detailed use of 3D laser scanning method and highlight important aspects to consider when used, which would provide clinicians with suitable modifications in technique to accommodate these variations.

### Scanning Method Using 3D Laser Scanning

The FastSCAN is a handheld scanner (FastSCAN SCORPION™) (



Fig). With a simple sweep of the FastSCAN wand, instant real time 3D images and databases can be created.

FastSCAN instantly acquires three dimensional surface images when the handheld laser

scanning wand is swept over an object. FastSCAN works by projecting a fan of laser light on the object while two cameras triangulate the 3D position of the laser to record cross-sectional depth profiles. The object's image is transferred to a laptop screen [3].

FastSCAN SCORPION™ has two cameras, allowing for more detailed scans in fewer sweeps. While scanning an object, the dual cameras on the SCORPION wand view the laser from either side to record surface profiles of the object.

An embedded FASTRAK® unit in the FastSCAN, used to determine position and orientation, allows the computer to reconstruct the full three-

dimensional surface of the object in real time. The 3D data can then be exported to a host of popular 3D modelling graphic, and computer-aided design (CAD) programs, or used within the FastSCAN software.

FastSCAN is loaded with advanced features to help realize absolute precision for every scan. The system works with virtually any PC, and the software offers a full array of functions including image resizing and point of view shifting. To enable ascertaining how much data has been collected, the software incorporates a point cloud view. Moreover, raw data points, from sweeps, can be selected and deleted. The software also offers numerous scan processing features such as fine smoothing, which you can use prior to exporting the scan. Captured data is clearly displayed on screen.



Fig-1: FastSCAN Scorpion ([http://polhemus.com/?page=Scanning\\_Fastscan](http://polhemus.com/?page=Scanning_Fastscan))

A computerized 3D modelling system (FreeForm Modelling Plus™, SensAble Technologies) was used for the computerized skull measurements in the current study. The Freeform Modelling software was installed.

Geomagic Software: 3D computer modelling system (FreeForm Modelling Plus™ SensAble Technologies) with haptic feedback (Phantom Desktop™) was used in this study to import the skulls to be measured into FreeForm Plus as a stereolithography (.stl) file. The strengths of the computerized modelling method are reproducibility, time conservation and little or no damage to the original specimen.

FastSCAN software gives the user a variety of options, such as adjusting scanning resolutions, linear

measurements, customizing scan sweeps and controlling 3D views such as solid, wireframe or point and rotate, zoom, center and scale.

**Hardware:** This system utilizes PHANTOM Desktop Haptic Device (

Fig) that enable designers and modelers to use their sense of touch to model with virtual clay, just like real clay, that provides the user with a sense of touch, when manipulating digital 3D images. The PHANTOM Desktop haptic devices are true 3D interfaces with force feedback; it delivers higher fidelity, stronger forces, and lower friction. Haptic devices are used in forensic investigations, also virtual sculpting laparoscopy training etc., engaging tactile senses to shape and manipulate digitized 3D models in a non-invasive manner.

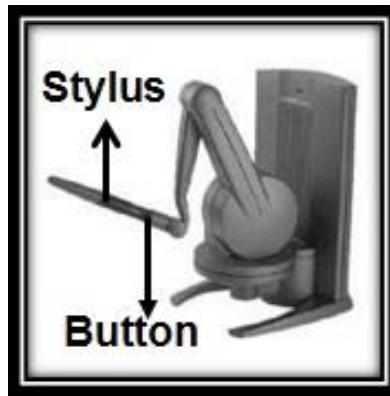


Fig-2: PHANTOM Desktop

### Laser Scanning Measurement Procedure Scanning Cranium or Mandible

The handheld laser scanner was used to digitize the complete 3D surface of either the cranium or mandible and the data were saved in industry standard formats to be used by other programs. 3D scans of either the cranium or mandible were created with a FastSCAN™ Scorpion laser surface scanner. The object was securely positioned on the translucent box. Scanning was performed in dim light. The FastSCAN™ software filters each scan.

Profile smoothing was set to “low” (option being low, medium or high), to avoid loss of detail. Wand sensitivity was set at 1.5 (from a scale of 1 (minimum sensitivity) to 6 (maximum sensitivity)) to preserve maximum obtainable detail without unwanted artefacts.

Scanning a 3D object required multiple sweeps which were “registered” while processing, and allowed amendment of small errors in scan sweep alignment [4].

A “basic surface” was generated to merge sweeps smoothly. Parameters controlling this function are available within “Generate Surface”.

“Smoothing” option controlled the extent to which each individual sweep “stitches” one into another (set at 1.0).

The “decimation” value, which affects the triangulation detail of the scan and subsequent file size, was set to 0.5. Completed scans were exported as (.stl) (stereolithography) files, and then the data was saved in industry standard formats to be used by other programs.

### Reconstructing the Scan in Freeform Modelling Plus™

The (.stl) file was imported into FreeForm Modelling Plus™. The 3D software integrated a PHANTOM™ desktop arm and a haptic feedback device that allowed the user to have a “sense of touch”. The

scan was subsequently re-designated as a FreeForm™ (.cly) file (SensAble Technologies™, 2002).

From the “File” menu, FastSCAN™ file was imported to FreeForm™, in Dynabar (F) an option available to “fill holes” in the 3D image. The “fill holes” option was selected by clicking on the down arrow at the fill Style.

Other option to “Add fine detail” could be elected by pressing the down arrow at the Clay Coarseness. In Impact as, ensures that “Clay” option was chosen. Also ensure that the “Align Voxel Grid with Model” box was ticked. Then click [Apply], preserves morphological detail, the object then was saved as .cly file.

The “Object List” was displayed on the left top of the window by pressing the **o** key on the keyboard (Object List is also hidden by pressing **o** key again). The Object List shows the icons of the object and created planes.

On the “Object List”, the planes can be hidden by clicking the eye icon next to the name of each plane “open eye”, meant the piece is visible, whereas, “closed eye”, meant it is hidden.

The pieces in the Object List can be renamed to be more descriptive. The piece icon was clicked (or right-click with the mouse on the current name of the piece) (Display the Object List by pressing **o** key if it is not already open) to display the piece’s submenu, and then Rename from the menu was selected, the new name was written, and then click away of icon to finish the process.

The Side View window was also displayed by selecting Show Side View from the View menu, and then From Right of Main View was selected. It can be also displayed by pressing the F6 key function on keyboard (F).

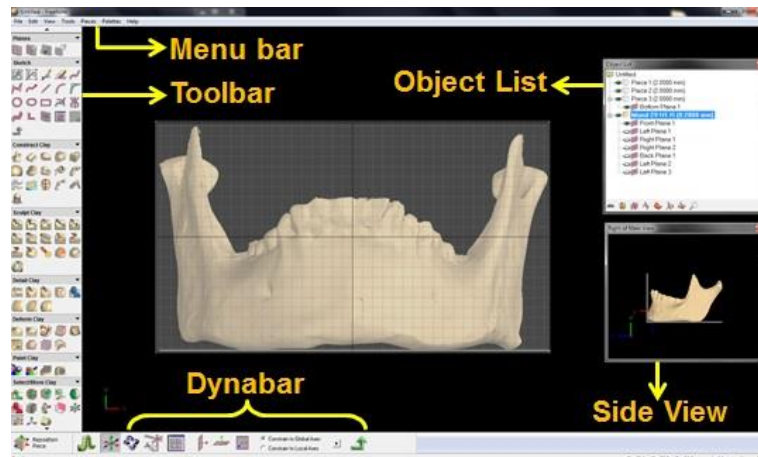


Fig-3: FreeForm™ Application Window

When unwanted artefacts were visible in the object scan, there were “cleaned” using the “Carve with Ball” and “Cut” tools, which cleaned the scan while avoiding cutting away necessary details.

The “Clay Hardness” slider in the “Sculpt Dynabar” was used to adjust the hardness of the digital clay, the hardness of the clay was changed using a slider control by clicking the cursor on the “clay hardness slider” and dragging it left for “harder” and right for “softer” clay.

Residual roughness was “cleaned” with the “smooth” tool on the sculpt clay on the toolbar. The smooth level slider was used to adjust the level of smoothing by clicking the cursor on the smooth level slider and dragging it left for “low” smoothing, and right for “fine” smoothing. The “low level” was chosen to smooth sharp edges only to avoid deleting bone or altering morphology.

For this the size of the FreeForm tools can be changed by clicking on the arrows in “spine box” next to Tool Size box or by typing a number in the Tool Size box and pressing the Enter key. The size of the “Carve with Ball” and “Smooth” tools spheres can be changed also, by pressing the plus (+) key to increase and the minus (-) key to decrease. Acquired data was saved as a (.cly) file. At this stage, the object was in the middle of the Free Form application and ready for scanning. After that, the object was moved using a combination of the PHANTOM desktop and keyboard keys. The object also was moved using the mouse as follows. To rotate the object, the left mouse button was held down while moving the mouse.

To zoom the object and its plains, **h** key can be used instead of **g** key to move the object in and out, up and down, and left and right without rotation. This prevents accidentally changing the orientation of the object during movement to zoom.

Eventually, both the size and the direction of the object were chosen. After that, the **F2** function key was pressed to return the object to the center of the FreeForm window, facing the way it did originally. The **F3** and **F4** function keys on keyboard were used to move the object to show right and left views respectively. The arrow keys on the keyboard were used to move the object quickly, precisely and easily a specific number of degrees, in any direction. Each press of the arrow key moved the object 15 degrees in one direction.

Using the function or arrow keys enabled the object to be moved without change of orientation. Next, all points that represent the anatomical landmarks related to the region of supraorbital, infraorbital, mental and mandibular foramina that were used for the measurements of all distances related to the supraorbital, infraorbital, mental and mandibular foramina, were marked up using “Paint” tool.

The Paint Dynabar was displayed and the red color was selected by clicking on a well on the color palette. The Blending Level Slider was used to adjust the level of paint blend (Light blend to the left side of the slider, heavy to the right). The size of the “Paint” tool was adjusted to one that was appropriate for the landmarks, using the Diameter box in the Dynabar or the plus (+) & minus (-) keys on the keyboard to make the ball larger or smaller.

The landmarks were painted by the paint tool’s handle by lightly applying pressure while holding down the PHANTOM button, and once the point was painted, the PHANTOM button was released. By using this process, all the anatomical landmarks on the object were marked up in red.

In FreeForm Modelling Plus™ there was an option to create a new plane. A new plane was displayed on the FreeForm application. The plane was divided into small squares. The size of these squares could be increased or decreased. The “Orient Flat to

View” button was selected and the plane jumped to the front and center of the application window. The plane flattened in front of the object in a frontal view and perpendicular on the horizontal planes.

The Touch button in the Edit Plane Dynabar was selected; consequently, the plane was moved close until it was in contact with the object. The FreeForm plane also could be moved and manipulated easily in any direction and to any location demanded, using the PHANTOM device. In the Edit Plane Dynabar, Precise Movement (Shift) button could be selected or the shift key held down, while moving the tool to move and control the plane more slowly and precisely.

The plane was activated from the Object List (using the mouse to right click opposite the icon of the plane piece then the activate or edit option was selected on the submenu) or using the PHANTOM tool to activate the plane from the Object List or touch the plane with the PHANTOM cursor, when the stylus button was clicked to select the plane.

#### **Why it used**

When taking electronic caliper measurements, crania were placed on the apparatus so that contacts were made by the maxillary teeth and the mastoid processes, the occipital condyle or the external occipital protuberance on the base platform. This resulted in the “imaginary horizontal lines” being parallel to the horizontal platform but not parallel to the horizontal position of the skull. A possible way to overcoming this would be to cut the occipital condyles to make sure that all of the skulls were positioned on the mastoid processes. This could not be contemplated as this would lead to damage and destruction to the skulls, and was completely contraindicated. At all times, the integrity of the collection was maintained. To overcome this problem an alternative method of measurement was sought. (Vide infra)

In the measurement procedures, with both maxilla and mandibles, there were some limitations when the electronic caliper measurement method using the electronic caliper was used, including the following

1. The Frankfurt plane was difficult or impossible to achieve physically, though it had been used by some authors before [5,6]. It was a complicated process and the accuracy was questionable because there was no specific apparatus available to achieve the plane accurately. It was difficult to fix the cranium in a stable position at all times while taking measurements. Theoretically, it is easy to define, but it is very difficult to achieve practically.
2. The plane of the cranium had some limitations: Crania were placed on the apparatus in the standard basal position so that contacts were made by the maxillary teeth and mastoid processes or occipital condyles on the base platform.

3. Plane of Morant: This is easy to define theoretically [6], but it is difficult to achieve for all mandibles, especially for those mandibles that had a convex lower border. In these cases it was difficult to stabilize the mandible. In a few mandibles which displayed this “rocking displacement”, pins or plasticine were used to stabilize the mandible to prevent movement while taking measurements.
4. Anatomical Midline: It was difficult to obtain this precisely, especially in the cranium. It difficult to define the midline using only two points in one plane. Some authors used a silk to delineate the midline [7]. This method was tired but proved equally difficult because it was difficult to maintain the silk in a stable position while taking measurements.
5. Inferior border of mandible: It was difficult some times to measure the distance between the mental or mandibular foramina to the inferior border of the mandible, especially if the inferior border point was not in contact with the horizontal platform. Also in the case of the mandibular foramen, the most inferior point of the mandible was not at the same vertical plane as the mandibular foramen.

In order to standardize measurements by standardizing the position of either mandibles or crania on the measuring platform two types of spirit levels were used. A large spirit level was used to check the level of the horizontal platform and the pencil holder arm and to make sure that they were always in the horizontal plane. A small spirit level with a magnetic surface was attached to the electronic digital caliper, enabling the caliper ruler to be maintained in a horizontal plane or vertical plane when taking measurements.

An electronic digital caliper is easy to use, quick and simple to operate, cheap and universally available. However it has an accuracy limited by the Vernier scale. Readings are dependent on the operator ability both in terms of eyesight and the force and feel in judging when to stop closing the jaws. Caliper measurements do not follow the curvature of the skull but measure the shortest distance between the points [8].

Because of the above limitations of caliper measurements, the study was duplicated using 3D laser scanning in an effort to evaluate if this could prove to be more accurate alternative. As the 3D laser scanner was portable, it was immediately obvious that, if needed, such a method and apparatus could be taken to locations such as museums or other sites.

The results of the present study showed that the measurements by both electronic digital caliper and laser scanning were comparable. Thus for the following



reasons, laser scanning should be considered the method of choice in future studies.

Advantages of 3D laser scanner: It is relatively easy to learn how to use both the hardware and the software. It is portable and relatively inexpensive. The skull (or other items) can be positioned in a virtual horizontal position without the requirement of vertical pressure or fixation bars as in the caliper method. "Rocking" of mandibles which have a convex lower border is overcome and is no longer a problem. Subject matter (skulls) can be easily moved in any direction for ease of measurement, an example being the ability to position crania and identify the Frankfurt plane with a high degree of reproducibility. Similarly, mandibles are easily "positioned" in the Morant position. It can be used anytime anywhere to scan the skulls. The scanned skulls' data were saved and accessed remotely, either across the internet or by CD. It is easy to move the subject in any direction without any possibility of changing its orientation or direction. There are options to "zoom" in on the subject (as previously described in Method and Material Section) to make sure the planes that were used such as the Frankfurt and horizontal basal plane, were exactly in the correct position. The "occlusal line" was drawn easily without obstruction from any over eruption of molar tooth. Because it is an imaginary line it can be drawn, using the laser scanning, relative to on the occlusal surface of one molar tooth.

The following is a short list of the advantages found in practice where collecting data for this study. The distances from the mental or mandibular foramina to the inferior border of the mandible were obtained accurately even if it was not in contact with the plane because the software only allows data to be collected from the "bony surfaces". The edge of the bone can be easily recognized. Any unwanted planes can be hidden if they cause obstructions to the measurements and can be displayed again without any change or effect on the position of the subject.

In addition it allows repetition of any measurement because the subject's data have been saved in the measurement position. The points on the foramina or the anatomical landmarks could be marked on/off easily. Another very useful option is the "Orient Through Three Points" option which enables the plane to be defined by three anatomical landmarks (e.g. nasion, anterior nasal spine and external occipital protuberance/ external occipital crest). Once three landmarks are defined a plane is generated which passes through them. This allowed a more accurately defined midline plane to be generated.

There are other options such as "fill holes" and "Add fine detail" which enables defects to be appears as bone, thus allowing the measuring of distances between the infraorbital foramen and midline where it was very difficult or impossible when taking electronic caliper

reading from skulls due to the presence of the nasal aperture. There are some limitations such as the "ruler" tool which like electronic digital caliper, measures the shortest distances between points and does not follow the curvature of the subject.

#### **Why it was useful?**

The present study revealed that the 3D laser scanning method is a very useful method for craniometrics as it provides data as accurate as caliper measurements, and therefore can be recommended as an alternative measurement method. Excellent intra and inter-reliabilities were obtained with 3D laser scanning with the exceptions of four data which depend on the interpretation of the position of the occlusal line.

As well as being an excellent measuring tool, 3D laser scanning can be adapted for teaching purpose such as anatomy as it can show anatomical details in three dimensions. With respect to medical or surgical intervention, it can be of extreme value, particularly in specific areas, as it allows focusing on distinct anatomical structures such as nerves or blood vessels. Because it allows identification of the relationship between different structures, from superficial to deep, and from any angle, identification of structures that may be at risk during procedures such a dental local anesthesia can be highlighted, allowing students to practice when learning injections procedures. It is an excellent tool in the field of anthropology not only because of its measurement potential, but also in that it is portable, can be taken 'on site' and records kept and distributed, especially in situations where it would be impossible to remove and store skulls or other anatomical structures.

#### **CONCLUSION**

This work will be extended to include more populations such as Arabic and North African populations because there are only a few studies relating to these.

Geometric morphometric methods on the 3D laser scanned skulls of the four populations used in the present study will be undertaken. Geometric morphometric measurements follow the curvature of the skulls and so differ from data obtained from electric digital caliper or the ruler tool measurements which measure the shortest distances between two points.

Nowadays, unfortunately there are many incidents of reported massacres particularly in North Africa (Libya) or in Middle East (Syria). 3D laser scanning techniques provide a means of recording data from such incidents as the apparatus is relatively inexpensive, portable and allows data to be recovered and sent virtually anywhere.

The present data can be used to improve clinical local anesthetic nerve block procedures such as

the Vazirani-Akinosi closed-mouth technique and Gow-Gates method, by providing robust measurements.

3D laser scanning is used for facial anthropology and forensic facial reconstruction in the Centre for Anatomy and Human Identification, College of Life Sciences, University of Dundee. In Glasgow an interactive head and neck anatomy package was developed to enable students to dissect the head and neck “virtually” (Forgie, 2013).

I intend to attend courses on the use of 3D laser scanning in both these centers and to take the technology back to my own university where they will be put into operation in the dental school.

#### **Acknowledgment**

The author expresses his appreciation to his supervisor for support, Professor Ario Santini, and to Dr. Mohammed Aldossary for his contribution to the article preparation.

#### **REFERENCES**

1. Cutright B, Quillopa N, Schubert W. An anthropometric analysis of the key foramina for maxillofacial surgery. *Journal of oral and maxillofacial surgery*. 2003 Mar 1;61(3):354-7.
2. Gupta T. Localization of important facial foramina encountered in maxillo-facial surgery. *Clinical anatomy*. 2008 Oct 1;21(7):633-40.
3. Shwetha G, Chandra P, Anandakrishna L, Dhananjaya G, Shetty AK, Kamath PS. Validation of different diagnostic aids in detection of occlusal caries in primary molars: An in vitro study. *Journal of Indian Society of Pedodontics and Preventive Dentistry*. 2017 Oct 1;35(4):301.
4. Harrower G. A biometric study of one hundred and ten Asiatic mandibles. *Biometrika*. 1928 Dec 1:279-93.
5. Macedo VC, Cabrini RR, Faig-Leite H. Infraorbital foramen location in dry human skulls. *Braz J Morphol Sci*. 2009 Dec 1;26(1):35-8.
6. Morant GM. A first study of the Tibetan skull. *Biometrika*. 1923 Mar 1:193-260.
7. Webster RC, Gaunt JM, Hamdan US, Fuleihan NS, Giandello PR, Smith RC. Supraorbital and supratrochlear notches and foramina: anatomical variations and surgical relevance. *The Laryngoscope*. 1986 Mar 1;96(3):311-5.
8. Morant GM, Collett M, Adyanthaya NK. A biometric study of the human mandible. *Biometrika*. 1936 Jun 1;28(1/2):84-122.