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Computer guided Inferior Alveolar Nerve Block by a modified customized 3D-printed surgical guide: A proof of Concept

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Abstract: Background: Inferior alveolar nerve block (IANB) is essential for many surgical and endodontic procedures. It requires accurate needle placement due to its high failure rate. **Purpose:** The article was undertaken to assess the location of the targeted mandibular foramen and to present a proof of concept (PoC) of a novel customized modified surgical guide for blocking the inferior alveolar nerve. **Materials and Methods:** The location of this foramen was determined in 360 mandibular rami in 180 cone-beam computed tomography scans of the mandible from the premolar region of the opposite side. A novel customized 3D-printed implant surgical guide was modified after determining the suitable IANB needle direction on 3D images generated from digital dental model images and cone-beam computed tomography (CBCT) scans for 8 lower posterior implant cases. **Results:** The distance from the IANB targeted foramen to the premolar region of the opposite side could be measured in all CBCT scans and showed many variations. The CBCT-based analysis of the mandibular foramen location could be fused with digital dental images for the modification of the new device for IANB. The concept of determining the path of needle insertion for the design and fabrication of a modified 3D-printed surgical guide for IANB was found to be feasible. **Conclusions:** The location of the mandibular foramen could be determined in CBCT scans with its variations. A proof of concept (PoC) of a new customized device for IANB computer guided accurate needle penetration could be presented. The new modified 3D-printed guide may offer the advantages of more accurate IANB injection with an exact three-dimensional determination of the path of needle insertion.
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Keywords: Computer guided anesthesia; novel guide; customized surgical guide; modified guide; Inferior alveolar nerve block; CBCT; 3D printing; mandibular foramen.

1. Introduction

Successful local anesthetic techniques are the most important prerequisite for many oral procedures such as dental extraction, dental implant placement, oral surgical procedures, trauma management, removal of pathological lesions, and root canal treatment. Local anesthesia is more difficult in the mandible than in the maxilla. Conventional inferior alveolar nerve block (IANB) for pain control of patients showed only 80-85% success rate. Anatomical variations and technical errors are from the causes that jeopardize the success of IANB. Various alternatives have been devised to manage IANB failures.[1] Forward or backward needle tip penetration Penetrating the needle tip forward or backward excessively beyond the target location is not uncommon.[2] Anatomical variations of IAN, can cause local anesthesia failure.[3-6]

Alternatives for conventional IANB failure include repeat injection, buccal infiltration, intraligamentary injection, intraosseous anesthesia, intrapulpal injection, Akinosi block, and Gow Gates mandibular block.[7,8] Repeat injection has been described as the first option and may be successful in pain control in some patients. Kanna et al. reported 32% rate of success in repeated IANB.[8] This low success rate of repeated injections at the same site may cause many complications such as post-injection pain, tissue trauma, and trismus. The computer-assisted intraosseous injection (CAIOI) was used as an alternative to conventional IANBI for surgical interventions in the mandible like mandibular third molar surgery.[10] The position of the mandibular foramen was studied using CBCT images. IANB-based location of mandibular lingula was more successful.[11] It was previously hypothesized that ultrasound-guided IAN block may be feasible and could be used in humans.[12]

Cone beam computed tomography (CBCT) was used for studying different bone structures.[13] The position of the mandibular foramen (MF) was studied by many investigators.[14,15] CBCT images were used for evaluating the anatomical location and relations of the mandibular foramen. This foramen showed individual variations in its location. It was found to be located higher in the skeletal class III malocclusion patients than others.[14] A radio-anatomical study analyzed the position of the mandibular foramen using CBCT examination to guide IANB needle insertion. The horizontal and vertical positions of MF differed significantly according to age.[15]

The purpose of conducting this work was to assess the location of the targeted foramen in IANB and to present a proof of concept (PoC) of a novel device for inferior alveolar nerve block computer guided needle insertion in posterior mandibular implant placement. A design of 3D-printed implant drilling guide was modified after determining the appropriate IANB injection sites on 3D images. These images were a combination of CBCT file and digital images of dental models. Thus, the customized 3D-printed guide may offer the advantages of more accurate IANB injection to overcome improper needle placement.

2. Materials and Methods

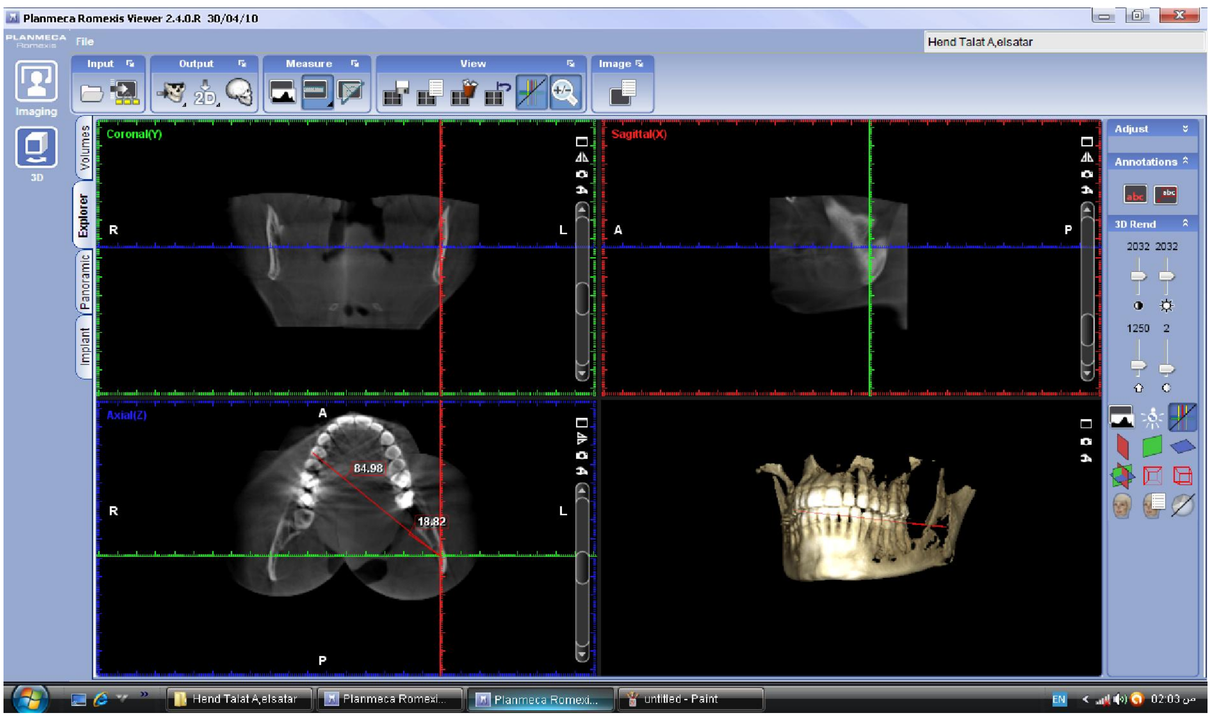

Fig. (1): The location of the mandibular foramen is determined in different planes (coronal, sagittal, and axial) of CBCT scans to measure the path of the needle from the premolar region.

The protocol of the present work was submitted to and approved by the Faculty of Dentistry Ethics Committee of the University of Mansoura in Egypt (with a code number A14010720). The location of the mandibular foramen was measured in 360 mandibular rami in 180 cone-beam computed tomography scans of the mandible from the premolar region of the opposite side. The tools of a CBCT computer program (Planmeca Romexis Viewer, Planmeca, Italy) were used to draw measuring line along the occlusal plane in 180 scans (Fig. 1). The location of the targeted mandibular foramen in the inner aspect of the left mandiblular ramus was determined first on the coronal plane by moving the side bar of the view. The sagittal plane is then moved to view the same foraminal location in that side. The intersection between corresponding lines of these planes (green-colored line for the coronal plane and red-colored line for perpendicular sagittal plane) on the axial plane is considered as the position of the mandibular foramen in this plane. The side bar of the axial plane is moved to the level of the lower premolars. The ruler tool of the program was used to draw a measuring line between the point of intersection of the green and red lines on the axial plane and the midpoint of the buccal surface of the lower premolars. If the patient is edentulous, the location of the mental foramen is chosen instead of the buccal surface of lower premolars. Data were collected from both sides giving 360 readings and evaluated.

Eight patients seeking bilateral posterior mandibular implants were chosen for the study and informed about the procedures and informed consent were signed. Digital datasets of the patient's mandible were used to detect the path of needle insertion, for the design of a modified guide frame with syringe rests in the desired location. The guide and its syringe rests are three-dimensionally (3D) printed.

2.1. Image Acquisition:

Dual scan technique was used to obtain a 3D images of patient boney architecture, soft tissue and teeth. A CBCT scan (Veraview, JMorita Inc., Japan) of the mandible and another CBCT scan was done to obtain STL file of the cast.

2.2. Segmentation:

DICOM files of the patient and cast CBCT were loaded into BlueSky Plan software (Bluesky bio Inc.) and then a process of segmentation was done to obtain STL of the bone surface and the cast surface.

2.3. Registration:

Common points between the cast STL and the CBCT of the patient were used to superimpose the cast to the segmented jaw.

2.4. Modified Guide Fabrication:

The implant surgical guide was designed (Fig. 2). Dummy implants of 3 mm in diameter and 30 mm in length were placed and rotated to be horizontal and parallel to the occlusal plane, then were again rotated to be directed from the mandibular foramen to the premolar on the contralateral side (fig. 3).

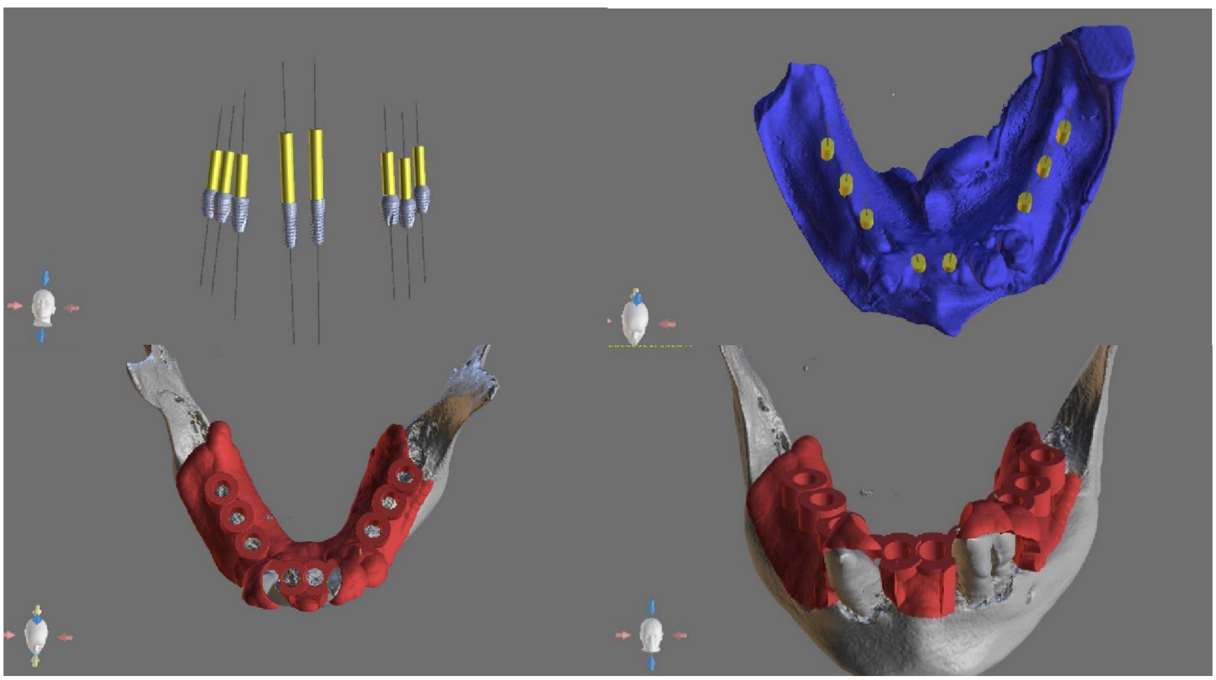

Fig. (2): The implant surgical guide was designed after adjusting angulations and positions of **implants.**

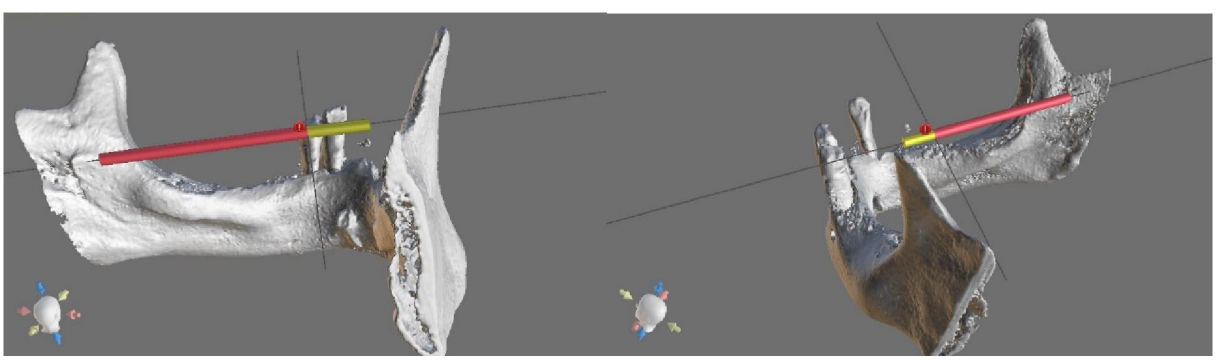

Fig. (3): Dummy implants of 3 mm in diameter and 30 mm in length were placed and rotated to be directed from the mandibular foramen to the premolar on the contralateral side.

A guide tube of 10 mm diameter was added to each implant on each side. Offset of the guide tubes were then adjusted so that the guide tubes be located on the buccal and lingual side. The guide tubes were designed to act as syringe rests on a line that resemble the passage of needle in direct IANB technique. The guide tubes were then stitched to the surgical guide in MeshMixer software (AutoDesk Inc.) (fig. 4).

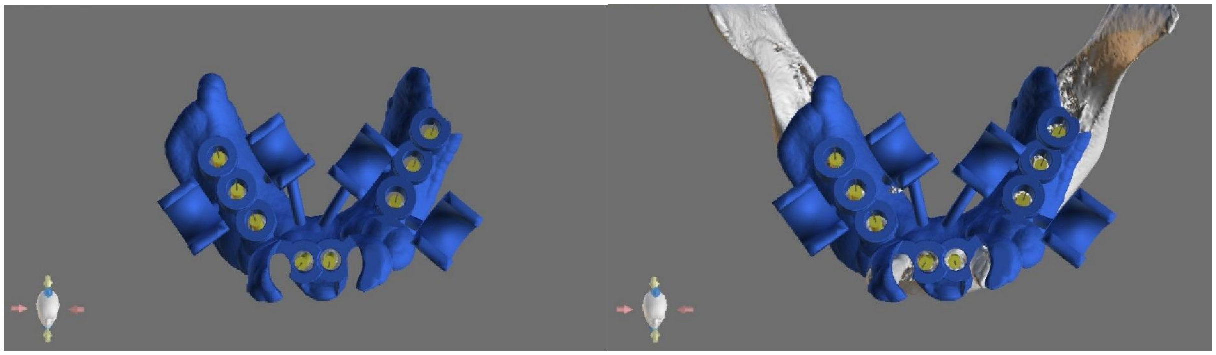

Fig. (4): The guide tubes were designed to act as syringe rests on a line that resemble the passage of needle in direct IANB technique and were stitched to the surgical guide in MeshMixer software in the buccal and lingual sides.

A mandibular surgical guide was designed for each patient. After locating the mandibular foramen using Blue sky computer program. Two syringe rests were added to the design of the surgical guide in the right and left premolar regions. In each side, a buccal rest was designed above and opposite to the lower first premolar and a lingual rest opposite to the second premolar. The buccal and lingual rests were designed on a line that resemble the passage of needle in direct IANB technique. The surgical guides were printed using a 3D printer (fig. 5).

Fig. (5): The surgical guides were printed using a 3D printer.

Guided IANB anesthesia were used for implant placement in one side while a standard IANB technique was followed on the contralateral side. The incidence, duration, potency, and any complications of anesthesia were recorded. Subjective and objective signs and symptoms of anesthesia were also recorded. Profoundness was recorded by asking the patients. Evaluation of recorded data was done.

3. Results

Of the 180 patients, 112 were female and 68 were male. The average age was 35.17 years. The distance determined by the measuring tool of the program between the targeted foramen and the lower premolar region of the opposite side showed many variations. 360 readings were grouped according to age and gender. The mean of this imaginary distance was 83.33 mm. The results showed many variations among age groups (Figure 6 and figure 7) and between male and female cases. Data of these groups will be published in a separate paper for more discussion and evaluation. The only needed result of this work was the feasibility of measuring this distance. Many measurements could be elicited from the scans as the length of needle penetration.

The CBCT-based analysis of mandibular foramen could be fused with digital dental images for the modification of the novel device for IANB in all the cases. The concept of determining the anatomical location of mandibular foramen for the design and fabrication of a modified 3D-printed surgical guide for IANB was found to be feasible. A proof of concept (PoC) of a novel device for inferior alveolar nerve block computer guided needle insertion could be presented. A new 3D-printed implant drilling guide was modified after determining the expected needle path. Digital images for dental models in lower posterior implant cases were taken. These images were used with CBCT scans to generate 3D images on a specific computer program. Surgical implant guides were then designed and modified for IANB. Thus, the customized 3D-printed guide may offer the advantages of more accurate IANB injection. The modified guide could be tested in the patient mouth (fig. 8). This is a pilot study for further testing of the device.

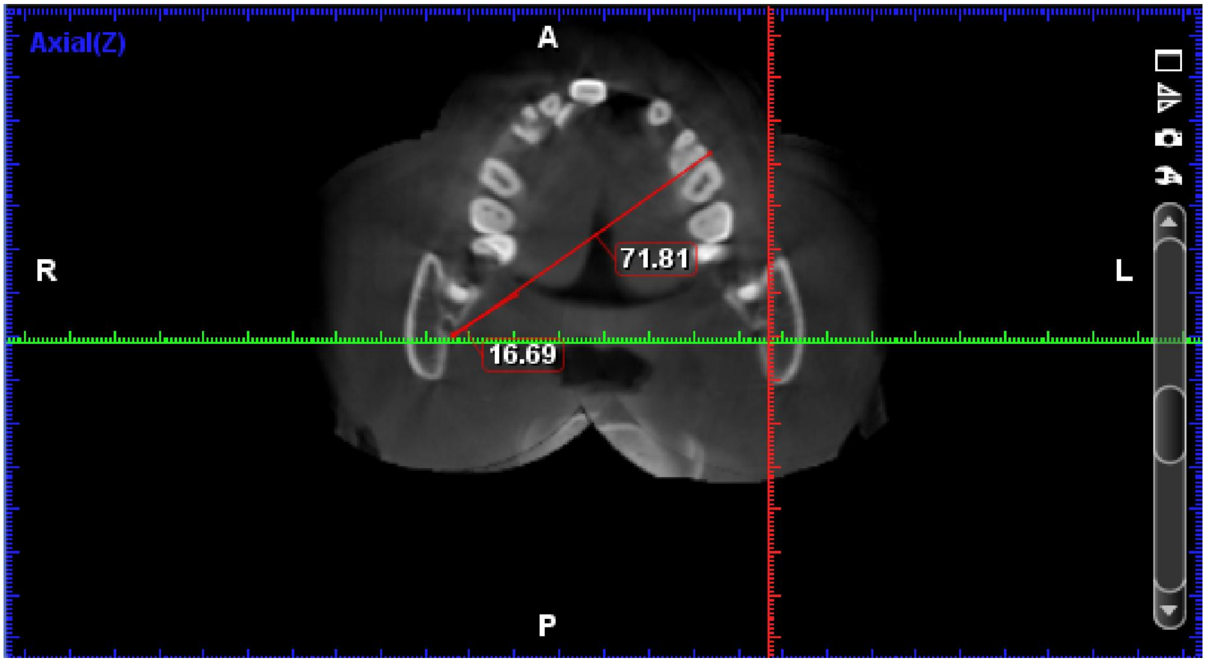

Fig. (6): The measurement tool of the program showing the distance from the premolar region of the opposite side to the targeted foramen in children (shorter than in adults).

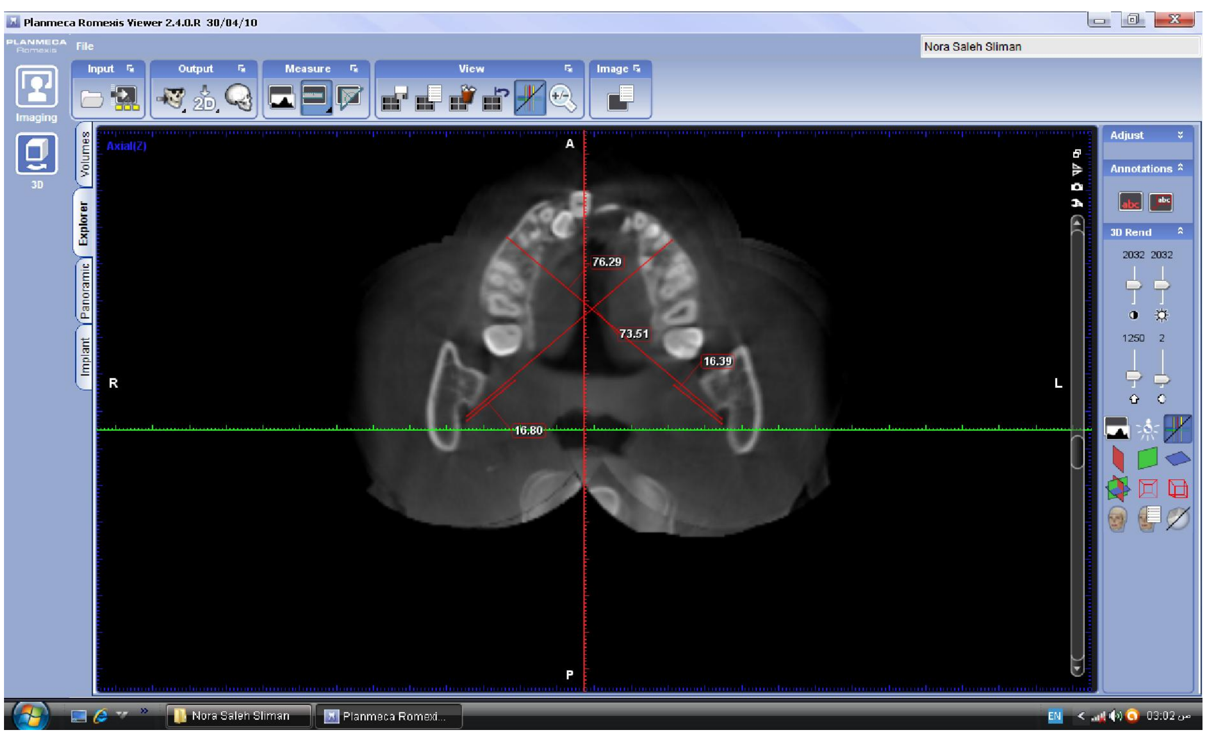

Fig. (7): The location of the mandibular foramen showed some differences between the right and left sides.

Fig. (8): The modified guide was tested in the patient mouth.

4. Discussion:

Block anesthesia is mainly used in the mandible. The increased bone density and the inaccessible IAN precludes the use of infiltration anesthetic techniques. Successful IANB requires accurate needle insertion toward the targeted foramen as possible. Anatomical variations and technical errors jeopardize the success of IANB. To overcome the problem of anatomical variations many visualization techniques were used. Visualization techniques of IAN included panoramic examinations, CBCT, CT, endoscopic visualization, MRI, and ultrasonography.[16] This report refers to the use of CBCT technique for localization of the mandibular foramen.

There is a need to establish a well-defined profile for the anatomical characteristics of mandibular foramen location in CBCT. The location of the mandibular foramen could be determined in CBCT scans with wide variations. This could be considered when planning for computer guided inferior alveolar nerve block to overcome anesthesia failure. The buccal surfaces of the lower premolars was chosen as the reference point in this study because it is a fixed point that could be seen in the patient mouth in the path of needle insertion.

Three-dimensional implant placement using surgical guides allow operators with less experience to insert dental implants perfectly. The implant surgical guides which are computer-generated may be costly.[17] The analysis of some anatomic structures locations was used for guided IANB. The internal oblique ridge and lingula were from these structures.[10]

Clinical studies showed that IANB is associated with a high clinical failure rate in spite of using proper techniques.[18] Palti et al. 2011 described an alternative IANB technique. They used certain anatomical points in 193 mandibles as reference. A relationship between the teeth and the target foramen was established in mandibles from dry skulls to facilitate their technique.[19] However, individual anatomical variations were commonly reported. Success rate of repeat IANB was considered to be low.[8] The wide personal anatomical variations related to of the ramus and foramen position may explain this low success rate. To overcome the problem of individual anatomical variations, analysis of the anatomic locations for certain anatomical structures were used for guiding IANB. Internal oblique ridge and mandibular lingula locations were evaluated for this purpose. This was found to be useful for many endodontic procedures and surgical interventions in the lower molars area.[10]

The 3D- printed customized guides were used for needle insertion in temporomandibular joint (TMJ) arthrocentesis. The virtual computer imitated guides were found to be beneficial.[20] A previous study was conducted to increase the success rate of the IANB by developing a device for the Gow-Gates technique.[21] The reported high clinical failures of IANB may be related to the wide individual anatomical variations in the ramus position or foramen location.[22,23] The age related positional variations of the mandibular foramen were reported in many previous studies.[24-26]

Technical errors still have their effect and operator skill may affect the final outcome of IANB procedure. Accurate identification of the mandibular foramen is very important to achieve the success of IANB. CBCT makes this possible in a non-invasive manner. In our study, custom guides were used to direct the passage of needle into the pterygomandibular space for accurate and more precise IANB anesthesia. We used CBCT to determine the exact position of the targeted foramen as it is precise.

The customized 3D-printing provided solutions to specific needs in modern dentistry and allowed the manufacturing of sophisticated devices. Three-dimensional implant placement using Computer-generated surgical guides allow perfect implant insertion.[17] A customized 3D-printed guide was evaluated in temporomandibular joint arthrocentesis to achieve accurate needle placement into the superior joint space for the treatment of TMJ internal derangement.[20] In our study, modified custom guides were used to direct the passage of needle into the pterygomandibular space for accurate and more precise IANB anesthesia. This customized guide approach may allow operators with less experience to place needles expertly, thus decreases the possibility of technical errors. Evidence-based studies do not clearly discuss this before.

The study was conducted to present a new device for IANB by the modification of implant surgical guide, simplifying the procedure and enabling greater success. For this reason, a CBCT scan and a digital scan for an intraoral dental model were superimposed. A specific planning software was used. The resulting 3D-printed implant drilling guide was modified for an IANB. The present surgical guide may allow an accurate IANB injection.

This work may be the first to present a proof of concept for the possibility of modifying a 3D-printed implant surgical guide to be used also for IANB anesthesia. Thus, the customized 3D-printed guide may offer the advantages of more accurate IANB injection and could be useful in presurgical planning. However, this is a pilot study and up till now there are no conclusive data on clinical evaluation of this modified guide. The authors emphasize that further clinical investigations of this modified guide are essential for many reasons. There will be different indications other than implant surgery such as root canal treatment, traumatic injuries or endodontic surgery. Patients in need for IANB anesthesia may be dentulous or may suffer from jaw deformity or post-resection defect. The design may be further modified to meet the requirements of every case.

5. Conclusion:

In conclusion, the location of the mandibular foramen could be determined in CBCT scans with wide variations. This could be considered when planning for computer guided inferior alveolar nerve block. A proof of concept (PoC) of a new modified customized 3D-printed device for accurate IANB needle insertion was presented. The computer guided IANB injection with an accurate 3D localization of the targeted foramen before injection could be possible. On the basis of the current study, it is possible to conclude that a modified surgical guide could be designed and modified for IANB after determining the exact injection site using 3D digital image constructed from CBCT scans and digital dental model images. Adding syringe rests to the customized mandibular implant surgical guides for more accurate IANB could be important consideration in further studies. This work may be the first to present the use of computer guided IANB surgical device. Although an accurate virtual localization of the mandibular foramen is expected, further clinical testing may be needed.

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Author's Contribution:

Ass. Prof. Dr. Hamdy Marzook: concept/design, data collection, data analysis, drafting article, critical revision, final approval.

Ass. Prof. Dr. Abeer A. Elgendy: concept/design, data analysis, critical revision, final approval.

Dr. Fawzy A. Ali: concept/design, data analysis, critical revision, final approval.

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