



# Computed tomography-guided 3D printed patient-specific regional anesthesia

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Classic anesthetic techniques for the inferior alveolar nerve, lingual nerve, and long buccal nerve blockade are achieved by estimating the intended location for anesthetic deposition based on palpation, inspection, and subsequent correlation for oral anatomical structures. The present article utilizes computed tomography (CT) data to 3D print a guide for repeatable and accurate deposition of a local anesthetic at the ideal location. This technical report aims to anatomically define the ideal location for local anesthetic deposition. This process has the potential to reduce patient discomfort, risk of nerve damage, and failed mandibular anesthesia, as well as to reduce the total anesthetic dose. Lastly, as robotic-based interventions improve, this provides the initial framework for robot-guided regional anesthesia administration in the oral cavity.

**Keywords:** Guided Regional Anesthesia; Local Anesthesia; 3D Printing.



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## BACKGROUND

Mandibular regional anesthesia is a common technique used to facilitate dental and oral surgical procedures. However, failures are common, occurring in about 20-25% of attempts with the standard IAN block technique [1]. Variations of the IAN block, such as the Gow-Gates and Akinosi blocks, are shown to be more reliable than the traditional Halstead IAN block, with the Akinosi block demonstrating the highest anesthetic success at 95.71% [2]. However, disadvantages may include a longer time of onset and lower comfort level [2].

The ideal location for the deposition of the local anesthetic for mandibular nerve blockade has not been defined. Most sources recommend deposition “as close

to the nerve as possible” without penetrating the nerve [3,4]. In the standard IAN block, the clinician uses surface landmarks to estimate the position of the mandibular foramen, which, if located correctly, will correlate with the entrance of the nerve into the mandibular ramus. Other techniques similarly utilize surface landmarks to estimate the location of the mandibular nerve in an attempt to deposit the local anesthetic solution in close proximity to allow diffusion into the nerve. These blind approaches, while successful in many instances, are inherently imprecise, as evidenced by a relatively high failure rate.

The reported height of the mandibular foramen above the mandibular occlusal plane ranges from 3.8 to 10 mm, and the relative position of palpable landmarks to estimate the location of the mandibular foramen can vary considerably in different age groups, ethnicities, and

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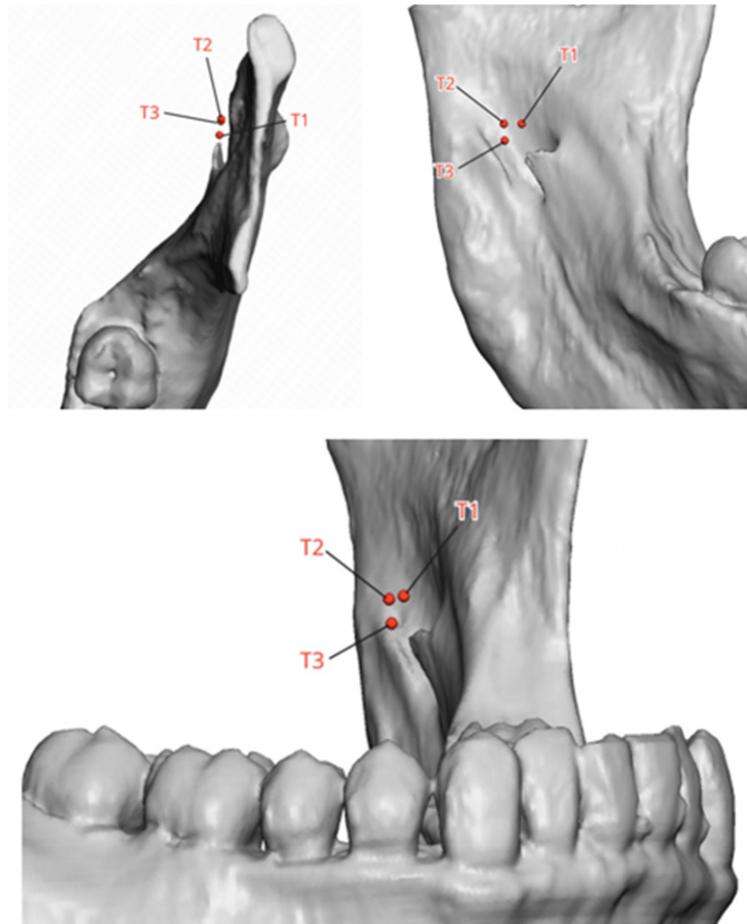


Fig. 1. Target sites T1, T2, T3

craniofacial disease [3-9]. Further, variations in sensory innervation to the mandibular teeth, for example, from branches of the mylohyoid nerve, undoubtedly confound this effort in a subset of patients [10,11]. Communications can occur between the lingual nerve and mylohyoid nerve, which can possibly contribute sensory components through a lingual foramen [12]. Without the ability to determine accessory innervation as the cause of failed injection in real-time, the scenario usually results in repeated attempts using similar techniques, increasing volumes of local anesthetic administered, and perhaps never achieving sufficient anesthesia.

If reliable localization of the anesthetic needle in relation to the inferior alveolar nerve could be ensured, the ability to troubleshoot a failed nerve block would be greatly enhanced. Specifically, if profound saturation of the nerve at its entrance to the mandibular foramen fails to provide

pulpal anesthesia, suspicion of accessory innervation would be warranted rather than a technical error or variant in the patient's mandibular anatomy. This would allow for a more systematic approach to address anesthetic failure while avoiding unnecessary deposition of larger volumes of local anesthetic and the associated risk of adverse events caused by diffusion outside of the target area.

## TECHNIQUE DESCRIPTION

Patients requiring regional anesthesia for surgical intervention require a preoperative computed tomography (CT) scan with a resolution of at least 0.5 mm as well as scanned or shipped accurate maxillary and mandibular impressions. A point 3 mm medial and 6 mm superior

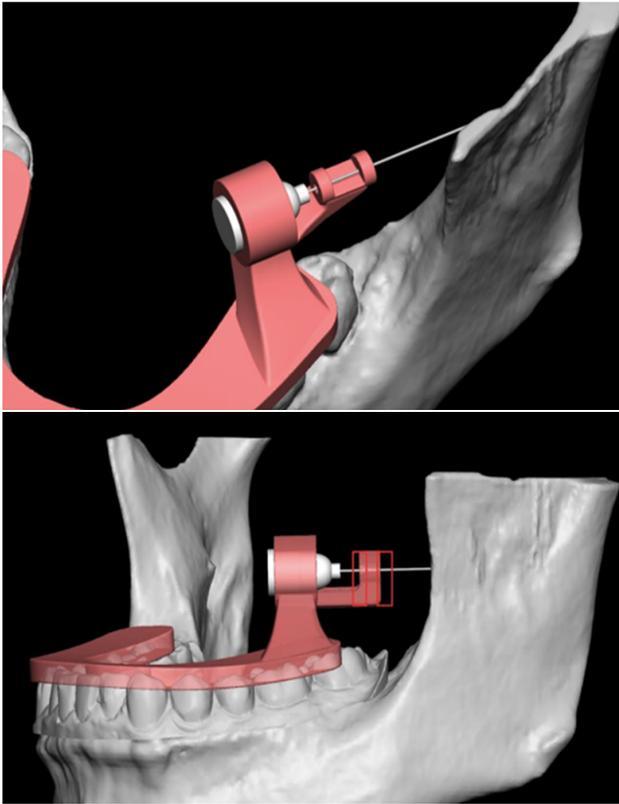


Fig. 2. 3D Rendering of guide with reconstructed model

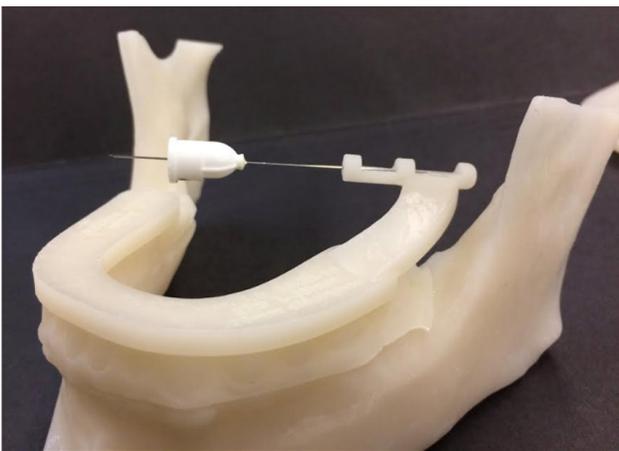


Fig. 3. 3D Printed guide with 3D printed model

to the mandibular foramen was identified at a location along the proximal aspect of the IAN, marked as T2 (Fig. 1). A patient-specific CT-based channeled, tooth-borne guide is then designed using the needle hub diameter to maintain orientation of the needle (Fig. 2). The final design is printed using a 3D printer and tested on the model (Fig. 3). Lastly, the tooth-borne guide is placed



Fig. 4. Device application and injection

in the patient's mouth, the needle is inserted into the predetermined hub depth, and the local anesthetic is injected (Fig. 4).

## DISCUSSION

Traditional techniques for administering anesthesia in the oral cavity are solely based on the rational application of average anatomical relationships among surface landmarks, bones, and nerves. Conversely, the use of image-guided anesthesia provides a framework for accurate and systematic investigations to define the ideal anatomical location for anesthetic deposition, which to date, has not been rigorously evaluated. The definition of an optimal anatomical location for needle positioning has the potential to maximize local anesthetic efficacy, thereby reducing the total anesthetic dose required. Further, image-guided anesthesia has significant potential to improve patient comfort by 1) reducing the rate of repeat injection, 2) reducing the risk of the needle penetrating the nerve, and 3) obviating the need to sound bone, thereby eliminating barb formation, a proposed mechanism for permanent paresthesia [13,14]. This

technique can also be used to investigate differences in the ideal location for anesthetic deposition in patients with varying facial/jaw morphologies (i.e., long vs. short face, class III vs. class II malocclusion), which may inform improved techniques for traditional landmark-based nerve blocks.

This method of delivering anesthetic to achieve blockade may help minimize the dose of anesthetic and epinephrine in cardiac patients. In addition, a decrease in total volume may lower the risk of unintended diffusion of the anesthetic, which has demonstrated complications such as ophthalmoplegia or visual impairment [15]. Troubleshooting failed blocks using blind approaches to locate the IAN can result in multiple needle punctures and increase anesthetic volume, which are known risk factors for deep fascial space abscess formation [15,16].

Traditional local anesthetic techniques demonstrate an unacceptably high failure rate. Several groups have attempted to apply current technologies to improve the accuracy of IAN blocks. Won and Kang demonstrated the utility of fusing cone-beam CT images with intraoral photographs to improve the standard landmark-based approach [17]. In contrast, our technique specifically allows for precise placement of the needle tip in three dimensions based on hard-tissue landmarks and a rigid guide for needle positioning. We demonstrate that this image-guided approach provides an objective, reproducible method for accurate needle placement and local anesthesia deposition. Furthermore, as robotic technology emerges within the field of regional anesthesia, this technique provides a proof-of-concept for the use of robotic-assisted anesthesia in the oral cavity.

This patient-specific guide, similar to a fully occlusal stabilization splint, could be used repeatedly for dental visits unless or until substantial changes to the occlusion occur. We propose that the currently available technology, CBCT and commercially available 3D printing devices, can be utilized to improve upon the ubiquitous, yet inherently imprecise, traditional IAN block, with implications for current clinical practice and future

research. However, without validation in a clinical study, this technique cannot be recommended for routine use in all patients. CBCT is also associated with increased radiation exposure compared to panoramic radiographs that are often obtained as the standard screening imaging in dental patients [18]. Therefore, CBCT should not be obtained solely for the fabrication of a 3D-printed anesthetic guide unless the patient has a history of failed IAN block or another compelling circumstance requiring increased precision for local anesthetic deposition. Ultimately, clinical studies are required to evaluate the utility and broader applicability of this new technique.

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**Marcus Couey:** Data curation, Formal analysis, Writing - original draft, Writing - review & editing

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