Local anesthesia is described as the loss of sensation in a defined region of the body caused by the depression of excitation in nerve endings or inhibition of conduction in peripheral nerves.\(^1\) Deposition of the local anesthetics very close to the nerve is necessary to allow for optimal diffusion of the solution, ultimately achieving profound anesthesia.\(^2\) Pain control using local anesthetics is an important element when performing invasive dental and oral procedures, with numerous traditional, advanced, and auxiliary techniques described in the literature.\(^1\)–\(^3\)

Blocking the maxillary division (V2) of the trigeminal nerve provides anesthesia for the maxillary teeth, periodontium, palatal mucosa, maxillary sinus, parts of the nasal cavity, upper cheek and lip, and lower eyelid.\(^2,4\)–\(^9\) This approach is generally considered when an entire quadrant of teeth and/or associated structures are involved.\(^5\)–\(^10\) It is also particularly useful for large procedures, as it can significantly reduce the amount of local anesthetics and number of injections while providing a more profound anesthesia compared with multiple local infiltrations in the maxilla.\(^4\)–\(^10\) Furthermore, maxillary nerve blocks can be used for the treatment of painful conditions such as migraines, facial pain, cluster headaches, and trigeminal neuralgia.\(^4,11\)–\(^13\)

The most effective approach to anesthetize the maxillary branch is intraorally via the greater palatine canal (GPC).\(^2,8\) The GPC approach to the maxillary nerve block was first described by Nevin in 1917, but was later modified by Silverman, and Wong and Sved.\(^6\)–\(^10\),\(^14\)–\(^16\) To administer the local anesthetics, the greater palatine foramen (GPF) must first be located by palpating the soft depression on the posterior part of the hard palate at the junction of the horizontal palate and the vertical alveolar bone, usually distal to the maxillary second molar.\(^2,5\)–\(^8\) The needle is inserted into the GPF through the palatal mucosa, and 0.1 to 0.3 mL of the local anesthetics is injected after negative aspiration to anesthetize the area.\(^2,5\)–\(^16\) The GPC can then be gently negotiated using a long needle advanced slowly along the canal at 45 to 60 degrees to the occlusal plane, to a depth of approximately 30 mm.\(^2,5,6,10\) Aspiration must be performed at multiple stages along the course of the canal prior to dispensing the content of the cartridge to avoid intravascular or nasopharyngeal injection.\(^2,16\)
Maxillary nerve block via the GPC is contraindicated in the presence of acute infection in the GPF area, which may spread into the pterygopalatine fossa as a result. Difficulty locating the GPF and negotiating the GPC are also considered contraindications of the approach. Although the GPC approach is effective and efficient, a number of complications have been associated with it. The most notable complications reported with varying rates of occurrence include diplopia, epistaxis, intravascular injection, neural injury, anesthesia of orbital nerves, broken needle, and failure of anesthesia. Absence of anesthesia is a frequently encountered problem; this is the result of significant anatomical variability, which can make it difficult to localize the GPF and negotiate the GPC. Different types of image guidance such as x-ray fluoroscopy, ultrasonography, and computed tomography (CT) have been used with various nerve block techniques in order to ensure accurate needle placement and the achievement of the desired anesthetic effect.

In implant dentistry, the use of three-dimensional (3D) imaging and virtual implant planning has allowed for the presurgical determination of the most appropriate implant position relative to the planned prosthesis while avoiding vital anatomical structures. Subsequently, the virtual implant position can be transferred to the surgical field through the use of computer-aided design/computer-assisted manufacturing (CAD/CAM) surgical guides with reasonable accuracy, improving the overall patient experience and reducing morbidity. With further advancement of CAD/CAM technologies, planning software, and rapid prototyping, clinicians have been able to expand their use beyond guided implant placement to include procedures such as local anesthetics administration and outlining the access for lateral approach sinus augmentation.

The following case describes the guided surgical placement of two implants, one of which required a simultaneous indirect sinus elevation. The CAD/CAM implant surgical guide was modified to include a channel to direct the local anesthesia needle for administration of maxillary nerve block via the GPC.

**CASE REPORT AND TECHNIQUE**

**Case Presentation**

A female patient aged 67 years with a noncontributory medical history presented to Harvard School of Dental Medicine. The patient was partially edentulous in both the maxillary and mandibular arches and was interested in implant rehabilitation. Apart from the third molars, the patient was missing her maxillary right second premolar, right first and second molars, left first and second premolars, left first molar, mandibular right second premolar, and right first and second molars (Fig 1). The patient was planned for implant-supported restorations for the replacement of the maxillary right second premolar and first molar, maxillary left first premolar and first molar (second premolar was omitted due to space restrictions), and mandibular right second premolar and first molar. Of these planned implants, the maxillary right first molar and left second premolar implants were planned for a simultaneous indirect sinus elevation. The mandibular right second premolar and first molar were planned with a simultaneous guided bone regeneration (GBR) procedure. The patient opted to have the procedures done by quadrant beginning with the maxillary left quadrant. Therefore, the remainder of this case report will focus on the treatment provided to that quadrant only.

**Implant Planning and Surgical Guide Fabrication**

A maxillary complete-arch cone beam computed tomography (CBCT) scan was exposed at 120 kV, 5 mA with a voxel size of 0.3 mm (i-CAT, Imaging Sciences International). The CBCT Digital Imaging in Medicine (DICOM) files were imported into the implant planning software, CodagnostiX (Dental Wings). Using the segmentation function of the planning software, the bones and teeth were isolated, and scatter was removed from the 3D images (Fig 2a).

Digital diagnostic scans of both the maxillary and mandibular arches were made and articulated directly using an intraoral scanner (iTero Element 2, Align Technology), then exported as Standard Tessellation
Language (STL) files. The STL files were imported into the planning software and registered onto the CBCT scan using the maxillary dentition as a reference (Fig 2b). Copies of the STL files were imported into 3D sculpting based computer-aided design (CAD) software (Meshmixer, Autodesk), on which a diagnostic wax-up was done. The diagnostic wax-up was then registered onto the CBCT scan as previously described (Fig 2c). Based on the prosthetic requirements provided by the diagnostic wax-up, implants were planned for the first premolar (Standard Plus RN 4.1 × 10 mm, Institut Straumann) and the first molar (Standard Plus WN 4.8 × 8 mm, Institut Straumann) (Fig 3).

The left GPF and GPC were identified on the axial, coronal, and sagittal views of the CBCT (Fig 4). A 28-mm virtual marker (Template Fixation Pin, Institut Straumann) was planned to enter from the GPF to the pterygopalatine fossa, traversing the GPC (Fig 5). A customized guide sleeve was designed for this marker to have a length of 2 mm and an outer diameter of 2.5 mm. The marker was then moved along its axis until the guide sleeve rested above the palatal mucosa (Fig 6).

After finalization of the position of the implants and the fixation pin, a surgical guide was designed in the planning software. The customized guide sleeve presented a channel directed toward the GPF through

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**Fig 2** (a) Postsegmentation 3D rendering of maxillary complete-arch CBCT scan. (b) Digital diagnostic scans registered onto CBCT scan. (c) Digital wax-up registered onto CBCT scan.

**Fig 3** (a) First premolar virtual implant planning. (b) First molar virtual implant planning.

**Fig 4** (a) Left GPF (circled) identified on the axial view of the CBCT. (b) Left GPF (arrow) identified on the coronal view of the CBCT. (c) Dashed line outlining the GPC on the sagittal view of the CBCT.
which the needle can be inserted for maxillary nerve block anesthesia (Fig 7a). The guide was then exported as an STL file, which was sent to a commercial dental laboratory for fabrication by means of 3D printing (Fig 7b).

**Surgical Procedure**

The surgical guide was seated in the patient’s mouth. Seating was confirmed through the designed inspection windows. A long 27-guage needle (Monoject, Covidien) bent to 30 degrees from the hub was introduced into the channel penetrating the palatal mucosa, inserted through GPF, and negotiated along the GPC. To avoid injection into a vessel, aspiration was performed several times during the insertion until the hub was 2 to 3 mm away from the guide (Fig 8). 1.8 mL of 2% lidocaine HCL with epinephrine 1:50,000 was administered after negative aspiration, and the surgical guide was removed. Shortly thereafter, the patient reported numbness across the left side of the maxillary arch, midface, upper lip, and nose. Blanching of the palatal mucosa was noted as well.

After confirming adequate anesthesia, a full-thickness mucoperiosteal flap was reflected. The surgical guide was reseated; the osteotomy for each implant was prepared according to the planning and the guided surgery protocol. The indirect sinus elevation was performed using osteotomes and grafted using xenograft bone substitute (Bio-Oss, Geistlich). Both implants were placed, primary stability was achieved, and the implants were covered with healing abutments (Fig 9).
The mucoperiosteal flap was reapproximated passively and sutured in place for primary closure. Postoperative and hygiene instructions were given, and medication prescribed. The patient was seen for follow-up after 10 days; the patient did not report any significant issues or complaints. Clinical examination revealed normal healing with no signs of infection.

**DISCUSSION**

Due to the invasiveness and complexity of the procedures performed, which included the elevation of a full-thickness mucoperiosteal flap, sinus floor elevation, and the placement of two implants, a maxillary nerve block was deemed the most suitable local anesthesia approach. A single 1.8-ml carpule provided profound anesthesia lasting for the entire duration of the procedure. The modification made to the CAD/CAM implant surgical guide allowed for a more controlled needle insertion and navigation, reducing the risk of anesthesia failure and associated risks.

According to Mercuri, failure to obtain anesthesia is a common problem faced with the GPC technique for maxillary nerve block, particularly for novice clinicians.5 The inability to locate the GPF altogether is a frequent cause of anesthesia failure.5 The GPF is commonly located in the posterior part of the hard palate 3 to 4 mm anterior to the posterior border of the hard palate, at the junction of the vertical alveolar bone and the horizontal palate.2,5,8 This often corresponds to the area on the palatal mucosa distal to the maxillary second molar.5,8 However, the GPF could be located further distally and more closely related to the third molar when present rather than the second molar.8,9 As for the GPC, studies have demonstrated variability in its length, shape, and direction in the sagittal plane.7,9

The length of the canal ranges from 15 to 44 mm with a mean of 31.1 mm according to Tomaszewska et al.9 Intracanal bony exostoses, tortuous canals, and age-related canal obliteration could impede the passage of the needle through the canal and prevent proper administration of local anesthetics.5,7 CBCT analysis and a working knowledge of the anatomical landmarks and potential variations in this region are necessary, as the inability to locate the GPF and negotiate the GPC is a contraindication for this anesthetic technique.5,6,9

Sved et al studied the complications associated with maxillary nerve block anesthesia and reported diplopia of the ipsilateral eye as the most common complication associated with this anesthesia approach, with a possible occurrence rate of 35.6%.17 The patient should be reassured and informed that the diplopia is transient and is also a good indicator of profound anesthesia.17 Neural trauma can occur; however, the occurrence rate is less than 1%.17 This can be the case when patients complain of "electric shock" during needle insertion. If this occurs, the needle should not be inserted farther, and alternative anesthesia procedures should be used, as this approach may not produce profound anesthesia at this point.17 Anesthetizing the orbital nerve, although rare, can occur if the needle is too long or advanced too far along the GPC.5 Anesthetizing the orbital nerve leads to transient blindness of the ipsilateral eye; however, a consultation with the ophthalmologist is advised.5 Despite these potential complications, maxillary nerve block is considered a safe and efficient way to control pain.5,17

Image guidance methods have been used with nerve blocks to increase accuracy when landmarks are difficult to identify.11,12,19 In pain medicine, x-ray fluoroscopy is the most common form of image guidance; however, it only displays bones, which makes it suitable only for nerve blocks that depend on bony landmarks.11 Furthermore, targets such as the pterygopalatine fossa and foramen ovale may not be adequately visualized on radiographs.11,12 CT guidance is another approach used in the maxillofacial region, particularly for extraoral routes.12,19 X-ray guidance methods tend to prolong the procedure and expose patients to excessive radiation.11

Three-dimensional imaging and CAD/CAM technologies allow clinicians to align multiple data sets in order to perform a comprehensive diagnostic evaluation and implant planning.21 This makes guided implant placement surgery more efficient and accurate.22–24 To make further use of the diagnostic data available, clinicians have modified surgical implant guides to include features that aid in execution of other adjunctive procedures.20,23 Similar to this reported case, Dahiya et al have designed a modified implant surgical guide with additional guide sleeves that allow accurate administration of local anesthetics for nasopalatine and greater palatine nerve blocks.20 Although the principle behind designing the local anesthetics administration channels was the same as the one used in this case report, Dahiya et al only targeted the GPF with the virtual marker for greater palatine nerve block rather than align it with the entire length of GPC.20 Therefore, without consideration of both the location and angulation of GPC, it may not be possible to administer a maxillary nerve block anesthesia. Another example of modified implant surgical guides is described by Goodacre et al.25 In their report, they modified the guide to outline the sinus wall access for a lateral approach sinus augmentation with simultaneous implant placement.25

The local anesthetics used in this report contained a vasoconstrictor, epinephrine at a concentration of 1:50,000 as recommended by Aravena Torres et al.13 The vasoconstrictor lowers the rate of absorption and
prolongs the anesthetic action, potentially reducing the need for reinjection. The vasoconstrictor can reduce bleeding in the surgical field and can reduce submucosal bleeding in the highly vascular area of needle entry. Furthermore, the vasoconstrictor may reduce the dissemination of the solution into adjacent structures, potentially reducing complications such as diplopia and headaches. Lower concentrations of vasoconstrictor including the use of plain local anesthesia solution have also been recommended, particularly in patients with cardiovascular problems. However, lower concentrations of vasoconstrictor reduce the duration of action of the local anesthetics, which should be taken into account.

The incorporation of a channel in the surgical guide for block anesthesia delivery is a promising approach that can potentially increase the efficacy and safety of local anesthetics administration; nevertheless, it does present with some limitations. The time necessary to plan such a modification to the surgical guide is increased, although it is not done chairside and indeed has the potential to shorten the surgical procedure. In patients with limited mouth opening, it may be more difficult to maneuver the needle into the channel in such patients. Although non-negotiable canals present a contraindication for maxillary nerve block via the GPF, occasionally, if resistance is met during needle insertion due to bony exostoses or a tortuous canal, redirecting the needle tip may alleviate this issue. Despite designing the channel to be 2.5 mm in diameter to allow for some degree of repositioning if necessary, the presence of the guide can limit any further redirection and prevent the needle from reaching the required depth to produce the desired anesthetic effect.

This case demonstrates the utility of digital and CAD/CAM technology to modify a surgical guide to aid in administering a block to the maxillary branch of the trigeminal nerve. Further research and clinical trials are warranted to confirm the accuracy of local anesthetics administration and to assess whether it reduces morbidity.

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REFERENCES