Investigation

The greater palatine nerve and artery both supply the maxillary teeth

An anatomic and radiologic study

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Joe Iwanaga, DDS, PhD; Yohei Takeshita, DDS, PhD; Muralidharan Anbalagan, PhD; Binghao Zou, MS; Taku Toriumi, DDS, PhD; Yuki Kunisada, DDS, PhD; Soichiro Ibaragi, DDS, PhD; R. Shane Tubbs, PhD

ABSTRACT

Background. It is generally accepted that the greater palatine nerve and artery supply the palatal mucosa, gingiva, and glands, but not the bone or tooth adjacent to those tissues. When the bony palate is observed closely, multiple small foramina are seen on the palatal surface of the alveolar process. The authors hypothesized that the greater palatine nerve and artery might supply the maxillary teeth via the foramina on the palatal surface of the alveolar process and the superior alveolar nerve and artery. The authors aimed to investigate the palatal innervation and blood supply of the maxillary teeth.

Methods. Eight cadaveric maxillae containing most teeth or alveolar sockets were selected. The mean age at the time of death was 82.4 years. The samples were examined with colored water injection, latex injection, microcomputed tomography with contrast dye, gross anatomic dissection, and histologic observation.

Results. Through both injection studies and microcomputed tomographic analysis, the authors found that the small foramina on and around the greater palatine groove connected to the alveolar process and tooth sockets. The small foramina in the greater palatine and incisive canal also continued inside the alveolar process and the tooth sockets.

Conclusions. The alveolar branches of the greater palatine nerve and artery as well as the nasopalatine nerve and sphenopalatine artery supply maxillary teeth, alveolar bone, and periodontal tissue via the palatal alveolar foramina with superior alveolar nerves and arteries.

Practical Implications. This knowledge is essential for dentists when administering local anesthetic to the maxillary teeth and performing an osteotomy. Anatomic and dental textbooks should be updated with this new knowledge for better patient care.

Key Words. Maxillary teeth; dental pulp; anatomy; nerve block; root canal treatment; cadaver.

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It is believed that anatomy, one of the oldest basic science disciplines, is well-investigated and fully understood, as it is the fundamental knowledge in medicine and dentistry. Anatomy in dentistry has been updated frequently, even in 2024.[1] However, viewpoints about the facial artery in general medicine and dentistry are different.[2,3] Anatomy in dentistry often appeared to be developed by dentists, often without the help of an anatomist.[4] Therefore, some incorrect descriptions have been accepted in dentistry but not in general medicine, for example, the course of the buccal nerve in the oral cavity.[5]

In endodontic treatment of the maxillary teeth, the superior alveolar nerves, which run through the posterior, lateral, and anterior walls of the maxillary sinus to reach the maxillary teeth, need to be blocked. Many endodontists empirically believe that local buccal anesthesia, including superior alveolar nerve blocks and buccal infiltration anesthesia, is insufficient to anesthetize the maxillary molars. However, according to anatomy textbooks, the superior alveolar nerves are supposed to innervate the maxillary teeth.[6,7] When coronal sections of the maxillary region are observed

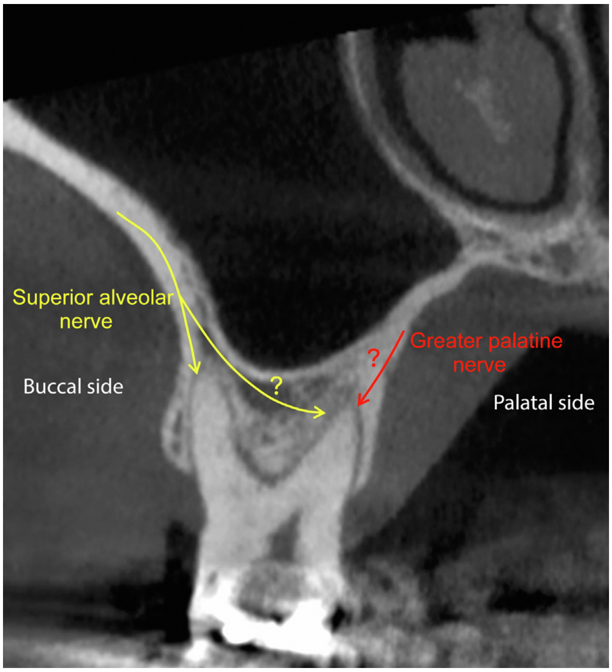

Figure 1. A coronal section of the maxillary first molar. The superior alveolar nerve runs close to the buccal root, but far from the palatal root. However, the greater palatine nerve is near the palatal root.

carefully, the palatal roots of the maxillary teeth are close to the palatal surface of the alveolar process of the maxilla, which is also adjacent to the course of the greater palatine nerve and vessels, but far from the buccal surface of the alveolar process, where the superior alveolar nerves and vessels travel (Figure 1).

One of the postoperative complications of maxillary osteotomy is sensory disturbance of the maxillary teeth, as the osteotomy line traverses the superior alveolar nerves. However, most patients do not appear to have complications in the long term.[8-10] This raises the question: Is there an alternative supply for the maxillary teeth, although there are some reports on regeneration of the superior alveolar nerves?

Friedman and Hochman[11] illustrated the anterior and middle superior alveolar (AMSA) nerve block as if the AMSA nerves are the terminal branches of the infraorbital nerve. Their depiction was just a superposition of the anatomy of the nasopalatine nerve (in the nasal septum) and superior alveolar nerves on the same image, which provided incorrect anatomic knowledge.[12] On the basis of that incorrect illustration, they proposed the AMSA nerve block. According to Velasco and Soto,[13] the success rate of the AMSA nerve block with a conventional syringe was 66% for the second premolar, 40% for the first premolar, 60% for the canine, 23.3% for the lateral incisor, and 16.7% for the central incisor. The AMSA nerve block was considered disadvantageous for clinical application because of its unpredictable anesthetic success. Anatomically, the AMSA nerve block has a high chance of failure, as no superior alveolar nerves are running on the palate and innervate the maxillary teeth. However, there was still some chance of success for the AMSA block. We concluded this outcome might be due to the infiltration anesthesia effect,[12] as no known nerve trunk innervates the teeth from the palate.

It is generally accepted that the greater palatine nerve and artery supply the palatal mucosa, gingiva, and glands but not the bone or tooth adjacent to those tissues.[6] When the bony palate is observed closely, multiple small foramina (with no specific names) are often seen on the palatal surface of the alveolar process. We hypothesized that the greater palatine nerve and artery might supply the maxillary teeth via the foramina on the palatal surface of the alveolar process and the superior alveolar nerves and arteries. This distance to the palatal roots could be more accessible than the buccal surface, where the superior alveolar nerve and artery run. We investigated the palatal innervation and blood supply of the maxillary teeth to add anatomic evidence to the anecdotal knowledge on the necessity of supplemental palatal injection for maxillary endodontic treatment and maxillary osteotomy.

ABBREVIATION KEY

AMSA: Anterior and middle superior alveolar.
GPA: Greater palatine artery.
GPN: Greater palatine nerve.
μCT: Microcomputed tomography.
ROI: Region of interest.

Figure 2. Multiple small foramina (arrows) are observed on the palatal surface of the alveolar process. They do not have specific names.

METHODS

Maxillae, which still contained most of the teeth or alveolar sockets, were selected. Thirteen sides from 8 cadaveric dry maxillae were used; 3 were from male cadavers and 5 were from female cadavers. Mean age at death was 82.4 years (range, 69-92 years). The samples were examined using 5 different methods.

Colored water injection to the small foramina on the palate

Colored water injection to the small foramina on the palate was used on 10 sides. Small foramina on the palatal surface (especially on the groove for the greater palatine artery or on the alveolar process) were identified (Figure 2). Before the injections, the teeth were removed from the alveolar process using extraction forceps to see the colored water inside the alveolar sockets. Water mixed with a purple surgical skin marker was injected into the foramina using a dental local anesthetic syringe with a 31-gauge needle. The injection was continued until the outflow of the colored water was observed.

Latex injection into the tooth sockets

After the colored water injection, latex was injected into the center of the alveolar socket of each tooth (from the central incisor to the third molar) on 10 sides. Once the alveolar socket was filled with latex, small foramina on the palate were observed to see whether any latex came out. After the latex was fixed in 48 hours, the palatal cortical plate around the latex was drilled away to trace the pathway of the latex.

Microcomputed tomography (μCT)

μCT was used on 1 side (from a 90-year-old male cadaver). Iohexol contrast dye (Omnipaque, GE HealthCare) was injected into the small foramina on the palate. Images were obtained using an μCT system (Quantum GX2 Micro CT, PerkinElmer). The exposure volume was set at 36-mm diameter and 36-mm height. Computed tomography was obtained with a voxel size of 0.144 mm. The images were collected at 90 kV and 88 μA. The axial images were transmitted in the digital imaging and communication in medicine format, and 2-dimensional images of the maxilla were then reconstructed using a digital imaging and communication in medicine viewer (OsiriX, Pixmeo SARL).[14] The images were analyzed using ImageJ software (National Institutes of Health). The area of the maxilla only in each slice was extracted by means of surrounding it with the region of interest (ROI) tool (Figure 3A). Histogram equalization was applied to the ROI using 8-bit depth (256 gray levels, with 0 representing black and 255 representing white) (Figure 3B). To distinguish the contrast dye, pixel values ranging from 0 through 255 were distributed within the ROI (Figure 3C). The region containing the contrast dye was selected and enclosed by the ROI (the area outlined with a yellow line in Figure 3C). The histogram of pixel values within the ROI revealed that the pixel values corresponding to the contrast dye used in our study ranged from 55 through 99 (Figure 3B). Each image was binarized, with the gray value range of the contrast area

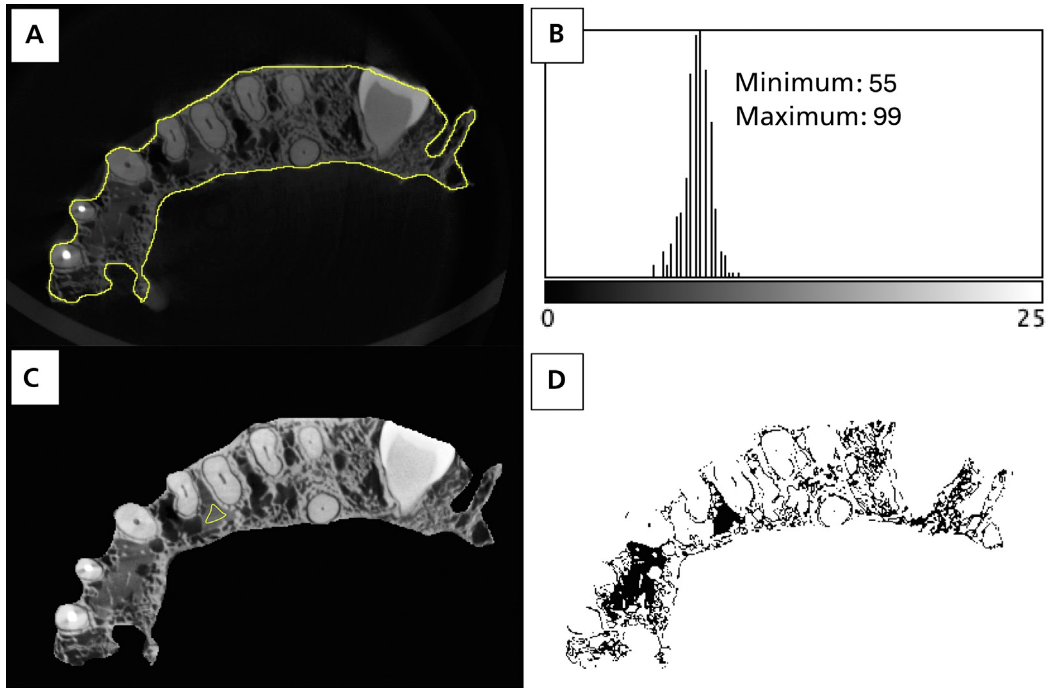

Figure 3. Axial images were analyzed with ImageJ software (National Institutes of Health). **A.** Only the area of the maxilla in each slice was extracted by means of surrounding it with the region of interest (ROI) (within yellow line). **B.** Histogram equalization was applied to the ROI using 8-bit depth (256 gray levels, with 0 representing black and 255 representing white). To distinguish the contrast dye, pixel values ranging from 0 through 255 were distributed within the ROI. The region containing the contrast dye was selected and enclosed by the ROI (area outlined with yellow line in **C**). The histogram of pixel values within the ROI revealed that the pixel values corresponding to the contrast dye used in this study ranged from 55 through 99. **C.** Each image was binarized, with the gray value range of the contrast area (55-99) displayed in black. **D.** All other pixel values are shown in white.

(55-99) displayed in black and all other pixel values shown in white (Figure 3D). The binarized images from different axial planes were observed to see where the contrast dye reached. A board-certified oral and maxillofacial radiologist (Y.T.) performed all imaging analyses.

Gross anatomic dissection of the cadaveric specimen

Gross anatomic dissection of the cadaveric specimen was used on 1 side (left palate from an 85-year-old female cadaver). The greater palatine nerve and artery running on the palatal surface (on the groove for the greater palatine artery or on the alveolar process) and their branches that entered the bone were dissected and preserved using a surgical microscope (OPMI CS NC31, Carl Zeiss). The medial branches were removed for better visualization.

Histologic observation of the cadaveric specimen

Histologic observation of the cadaveric specimen was used on 1 side (right side from 83-year-old female cadaver). The molar region of a cadaveric maxilla was cut into coronal sections at 8-mm intervals using a bone saw without dissection. The tissue was then embedded in paraffin. A microtome was used to make 5-μm slices stained with Masson trichrome. The small foramina on the palatal surface of the maxilla and associated nerves and vessels were examined using a light microscope.

Every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomic research.[15]

RESULTS

Injection study

Colored water injection to the small foramina on and around the greater palatine groove went into the ipsilateral alveolar sockets on all sides (Figure 4A). Latex injected into the tooth sockets came out from the small foramina on the palate (Figure 4B). Other than the small foramina on the palate, the latex was observed in the small foramina in the incisive canal and greater palatine canal

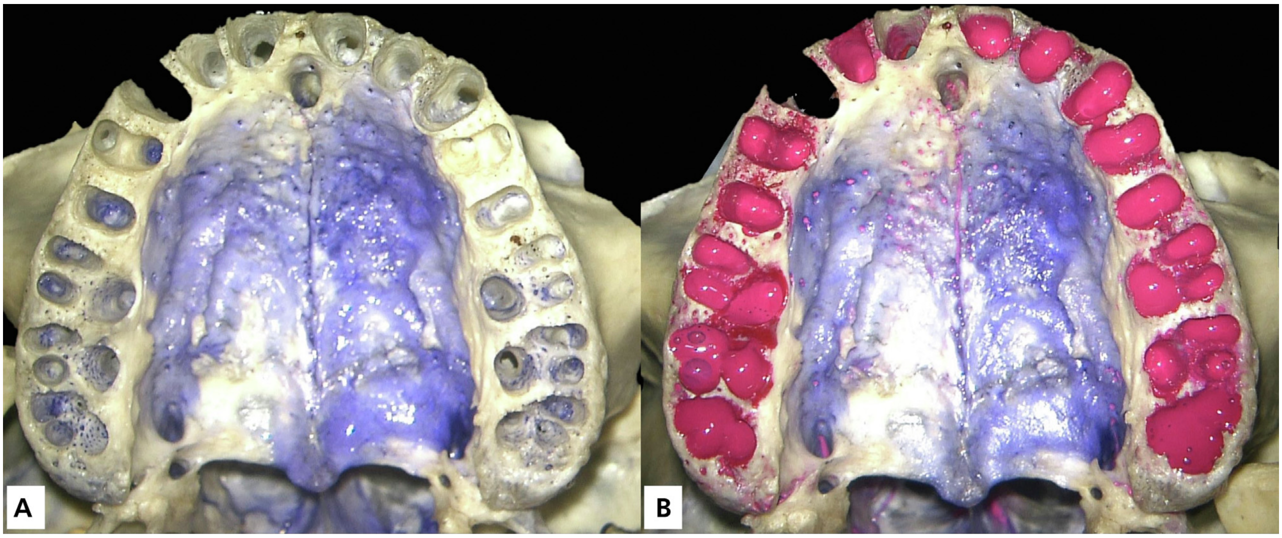

Figure 4. Palate after injection procedures. **A.** Colored water injection into the small foramina went into the ipsilateral tooth sockets from the central incisor to the third molar on all sides. **B.** Latex injected into the tooth sockets came out from the small foramina on the palate.

(eFigure 1, available online at the end of this article). This suggested communication between the alveolar sockets and the small foramina on and around the greater palatine groove and communication between the alveolar sockets and incisive canal and greater palatine canal. This indicated that the nasopalatine nerve and sphenopalatine artery supply the maxillary teeth (most likely the anterior teeth), and the greater palatine nerve and artery in the greater palatine canal supply the maxillary teeth (most likely the molars).

After removal of the palatal wall of the tooth sockets, it was observed that the latex in the socket connected to the greater palatine groove via 1 thick bundle of the latex from the apex (bottom of the socket) and thin bundles running inside the trabeculae (Figure 5). This indicated that the greater palatine neurovascular bundles supply the alveolar bone, periodontal tissue, and apex of root by means of the branches via the greater palatine groove. Findings from injection were consistent on all 10 sides.

μCT analysis

μCT images revealed that the contrast dye injected into the small foramina on the palate reached the periodontal region in most of the palatal area of the maxillary alveolar process in the incisor, premolar, molars, and greater palatine canal (Figure 6).

Gross anatomic dissection

The greater palatine nerve and artery and their branches traveling the palatal surface (on the groove for the greater palatine artery and on the alveolar process) were confirmed to enter the bone. This occurred via small foramina for the greater palatine nerve branch, greater palatine artery branch, or both (Figure 7). There were also many other smaller branches that needed to be removed during dissection.

Histologic observations

On coronal sections in the first molar area, the contents of small foramina were confirmed to contain a small nerve and artery (Figure 8).

DISCUSSION

It is generally accepted that the innervation and blood supply for the maxillary teeth are solely from the superior alveolar nerves and arteries. However, the results of our study showed the alveolar branches of the greater palatine nerve and artery also supply the maxillary teeth via small foramina in the palate, groove, and even in the greater palatine canal, which we refer to as palatal alveolar foramina. Visualization of the incisive canal with latex also proved its connection to the maxillary teeth. This shows that the branches of the nasopalatine nerve and sphenopalatine artery supply the

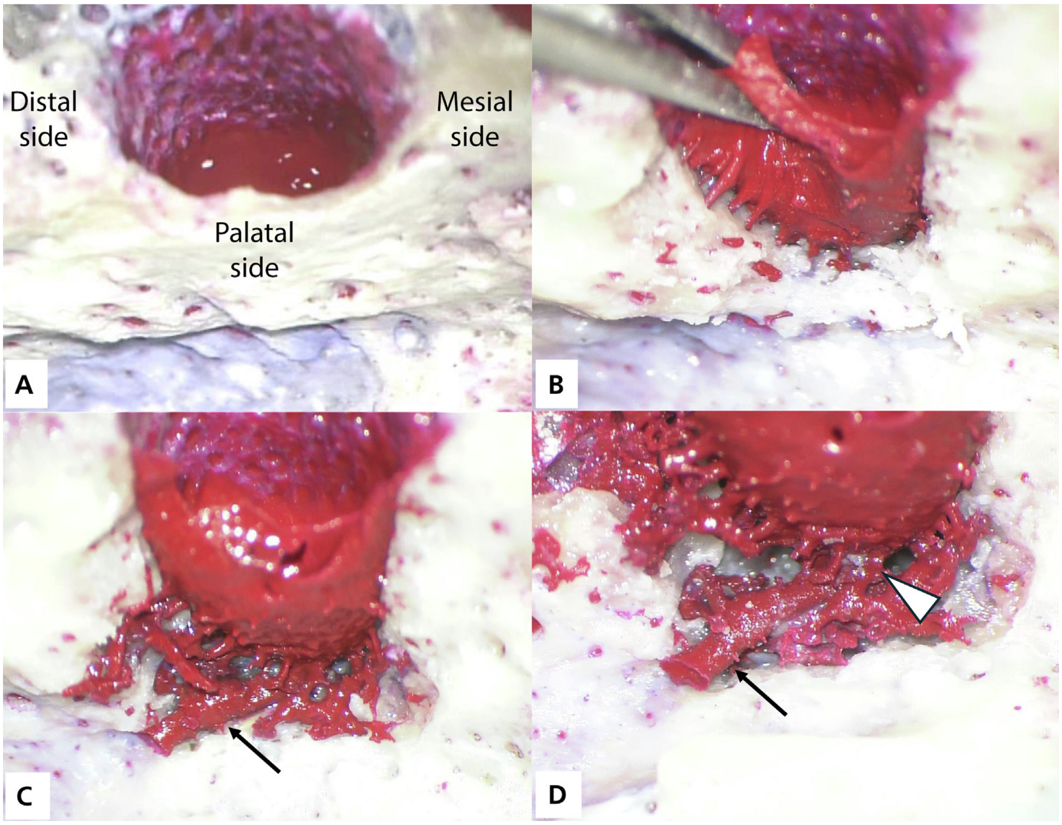

Figure 5. Latex injection shows a connection between the tooth socket (right maxillary first molar) and the greater palatine groove. **A.** Before removal of the wall. **B.** After partial removal of the palatal wall of the socket, thin bundles of the latex were seen traveling inside the trabeculae. **C.** After total removal of the palatal wall of the socket, it was found that thin bundles of the latex going inside the trabeculae connected to small foramina on the palatal surface of the palatal wall of the socket. The thick bundle of latex (arrow) was also at the bottom of the socket connected to the greater palatine groove. **D.** Latex in the socket was reflected to see the origin of the thick bundle of the latex (arrow) at the bottom of the socket, which was found to be connected to the apex of the socket (arrowhead).

maxillary teeth. Our results answer many clinical questions raised in previous studies[11,12] and from clinical practice.

Palatal infiltration anesthesia for pulpectomy of the maxillary molars

The posterior superior alveolar nerve needs to be blocked for root canal treatment (pulpectomy) of the maxillary molars. In many textbooks, it is shown that the middle superior alveolar nerve innervates the mesiobuccal root of the first molar, and this is the reason infiltrated anesthesia needs to be added for the treatment of the first molar after posterior superior alveolar nerve blockade.[7,16-20] In fact, the middle superior alveolar nerve is often absent. Although the buccal innervation of the maxillary teeth (superior dental plexus) is not simple,[21,22] the superior alveolar nerves are the only nerves that need to be anesthetized via posterior alveolar nerve blockade or infiltration anesthesia for the maxillary molars. However, endodontists occasionally encounter maxillary molars that require additional palatal infiltration anesthesia to numb the teeth. This could be due to the palatal innervation of the greater palatine nerve branches, as we found in our study.

Postoperative maxillary osteotomy and fracture sensory disturbance

The osteotomy might devitalize all of the maxillary teeth, as the Le Fort osteotomy line traverses all of the superior alveolar nerves and arteries. Based on an animal histologic study, many teeth are still vital or will be vital postoperatively.[10] According to Browne and colleagues,[10] 1 week after surgery, degenerative changes in the pulps were observed in the incisor, premolars, and molars. All of the pulps, except 1 molar, appeared healthy 2 weeks after surgery. Other authors investigated the prevalence of necrosis and dental pulp changes after osteotomy. Results of clinical studies in patients after segmental maxillary osteotomy showed that from 6% through 43% of teeth were

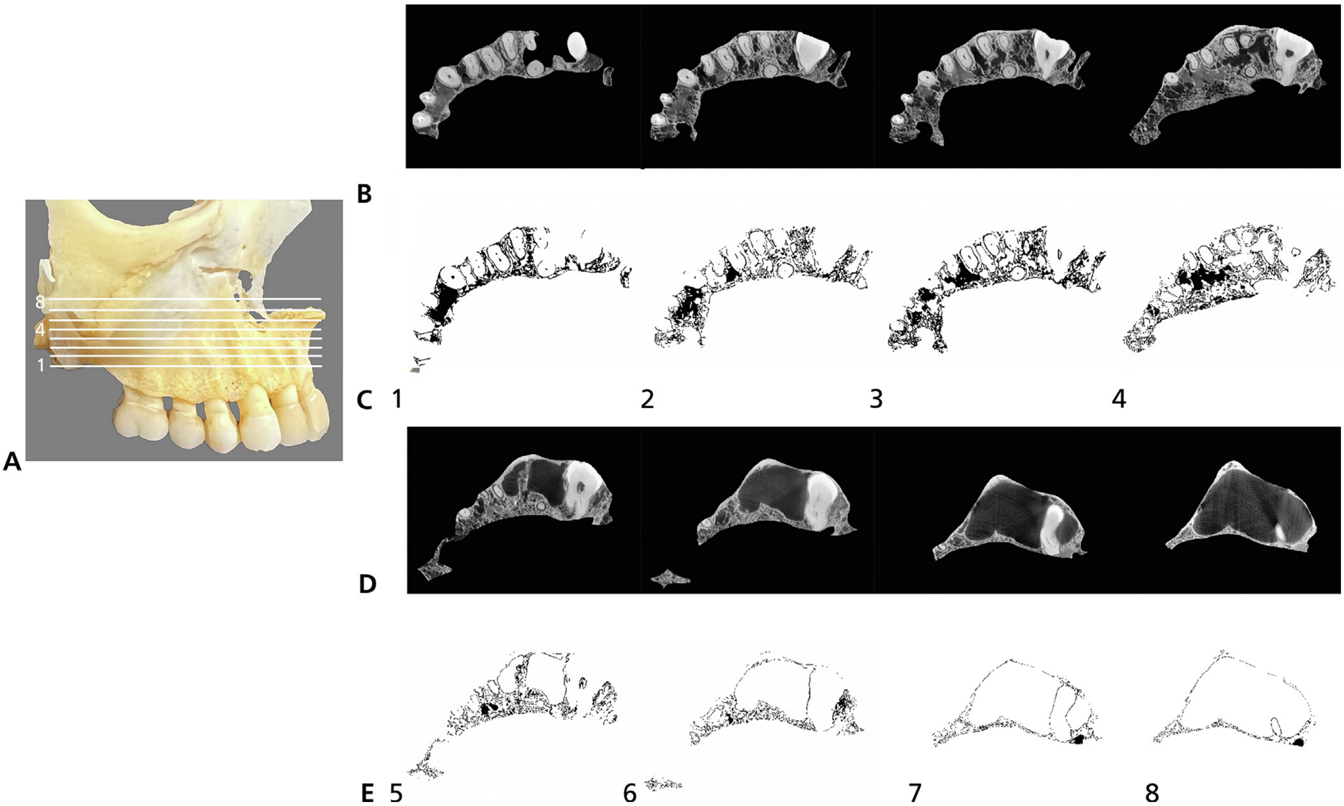

Figure 6. Microcomputed tomographic images revealed that the contrast dye injected into the small foramina on the palate reached the periodontal region. **A.** Lines correspond to images 1 through 8 in parts **C** and **E**. Images **B** and **C**, as well as **D** and **E**, depict the same planes, respectively. Binarized contrast was observed in most of the palatal region and some in the buccal region in the maxilla (ie, incisors, premolars, molars, and greater palatine canal). The gray value of the contrast area (**B, D**) is shown as a black area in the binarized images (**C, E**).

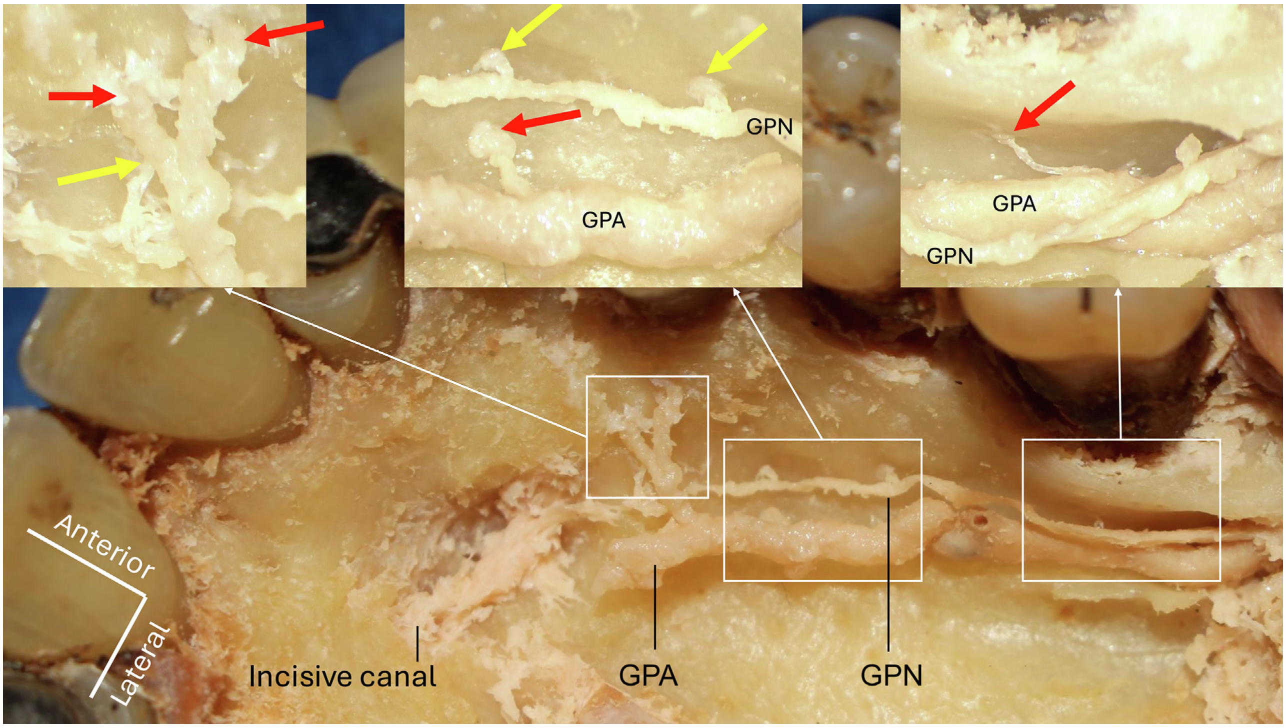

Figure 7. Left palate of 85-year-old female cadaver. The greater palatine nerve (GPN) and greater palatine artery (GPA) give way to small branches into the small foramina (red arrows indicate the GPA branch; yellow arrows indicate the GPN branch).

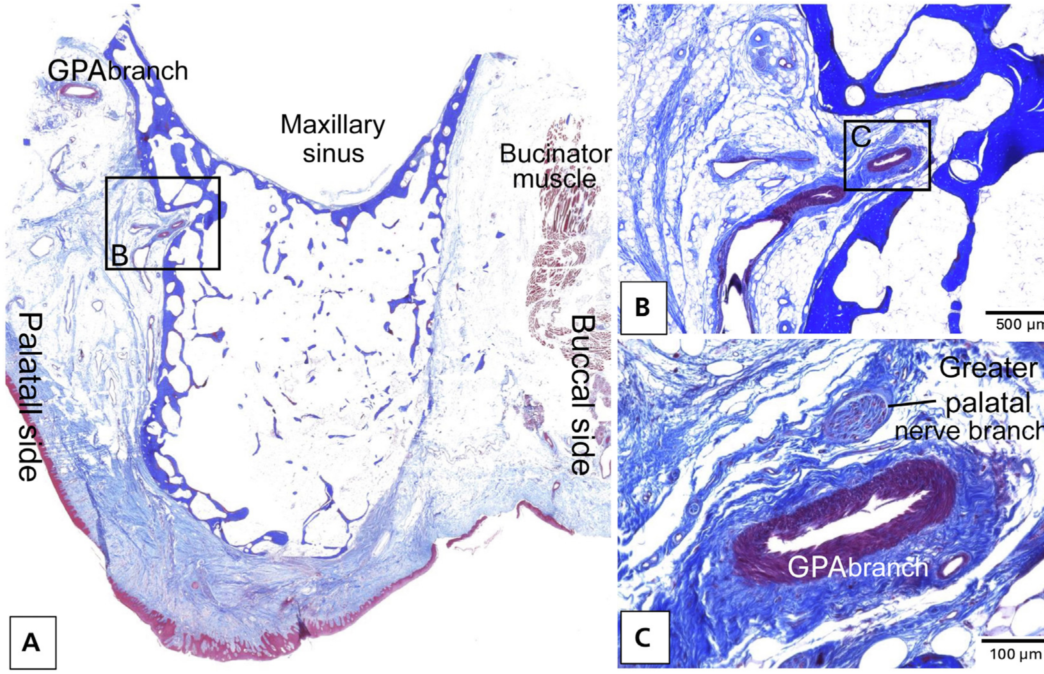

Figure 8. Coronal section of the alveolar process of the maxilla using Masson trichrome staining, magnification ×10 (**A**), ×40 (**B**), and ×200 (**C**). A greater palatine nerve branch and greater palatine artery (GPA) branch were confirmed to travel within and outside the small foramen on the palatal side of the alveolar process.

nonresponsive to electrical stimulation.[8,9,23-25] Browne and colleagues[10] studied rhesus monkeys and found 31% of the examined teeth exhibited cell degeneration and 16% were necrotic. Other investigators reporting animal studies of dogs and monkeys had varied outcomes, for example, all vital pulps, nonhistologic abnormalities, mild changes, and progressive fibrosis.[26,27]

The blood and nerve supply for the maxillary teeth is supposed to be from the superior alveolar nerves and arteries only. Once the Le Fort osteotomy is performed, the nerves and arteries running inside the maxillary sinus wall (ie, anterior, lateral, and posterior) are cut. The chance for vital pulp should be due to accessory route via the alveolar mucosa, gingiva, and periosteum to the bone; regeneration; and alternative supply from another sources.

The nasopalatine nerve and sphenopalatine artery are cut during osteotomy, but the greater palatine nerve and artery in the greater palatine canal are still intact, which can be an alternative supply to the maxillary teeth.

AMSA nerve block and palatal approach anterior alveolar nerve block

Iwanaga and Tubbs[12] noted that the AMSA and palatal approach anterior alveolar blocks were developed on the basis of incorrect anatomy. The AMSA block procedure provides anesthesia on the palate far from the superior alveolar nerve. Depending on the tooth, the AMSA block can still work with a success rate of 16.7% through 66%.[13] We hypothesized that this most likely comes from the infiltration anesthesia effect in the previous report.[12] Cetkovic and colleagues[28] investigated nutrient foramina on the palate using μCT, but did not discuss the origin (trunk) of the palatal branches or terminology. On the basis of our study, we speculated that the AMSA block targets the trunk or branches of the greater palatine nerve that palatally innervates the maxillary teeth. The low success rate might be because the superior alveolar nerves are still considered the main supply.

Friedman and Hochman[4] proposed the palatal approach to anterior alveolar block. As this block targets the incisive canal, the nasopalatine nerve is supposed to be blocked, not the anterior superior alveolar nerve. The results of our study revealed why the palatal approach anterior alveolar block (nasopalatine nerve block) could anesthetize the anterior maxillary teeth.

CONCLUSIONS

The greater palatine nerve and artery as well as the nasopalatine nerve and sphenopalatine artery supply maxillary teeth, alveolar bone, and periodontal tissue via the palatal alveolar foramina with superior alveolar nerves and arteries (eFigure 2). Dentists and oral surgeons should be aware of this when they administer local anesthetic to perform maxillary osteotomies. Authors of anatomic and dental textbooks should consider the results of our study when describing the neural and vascular blood supply to the maxillary teeth to improve patient care. ■

DISCLOSURE

None of the authors reported any disclosures.

SUPPLEMENTAL DATA

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Dr. Iwanaga is a professor, Department of Neurosurgery and Department of Neurology, Clinical Neuroscience Research Center, and Department of Structural and Cellular Biology, School of Medicine, Tulane University, New Orleans, LA, a professor, Department of Neurosurgery and Ochsner Neuroscience Institute, Ochsner Health System, New Orleans, LA, a visiting professor, Dental and Oral Medical Center, School of Medicine, Kurume University, Kurume, Fukuoka, Japan, and a visiting professor, Division of Gross and Clinical Anatomy, Department of Anatomy, School of Medicine, Kurume University, Kurume, Fukuoka, Japan. Address correspondence to Dr. Iwanaga, Department of Neurosurgery, Clinical Neuroscience Research Center, School of Medicine, Tulane University, 131 S Robertson St, Suite 1300, New Orleans, LA 70112, email iwanagajoeca@gmail.com.

Dr. Takeshita is an assistant professor, Department of Oral and Maxillofacial Radiology, Faculty of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, Japan.

Dr. Anbalagan is an assistant professor, Department of Structural and Cellular Biology, School of Medicine, Tulane University, New Orleans, LA.

Mr. Zou is an assistant professor, Department of Structural and Cellular Biology, School of Medicine, Tulane University, New Orleans, LA.

Dr. Toriumi is an associate professor, Department of Anatomy, School of Life Dentistry at Niigata, The Nippon Dental University, Niigata, Japan.

Dr. Kunisada is an assistant professor, Department of Oral and Maxillofacial Surgery, Faculty of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, Japan.

Dr. Ibaragi is a professor, Department of Oral and Maxillofacial Surgery, Faculty of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, Japan.

Dr. Tubbs is a professor, Department of Neurosurgery, Department of Neurology, and Department of Structural and Cellular Biology, School of Medicine, Tulane University New Orleans, LA, a professor, Department of Neurosurgery and Ochsner Neuroscience Institute, Ochsner Health System, New Orleans, LA, a professor, Department of Anatomical Sciences, St. George's University, St. George's, Grenada, a professor, Department of Surgery, School of Medicine, Tulane University, New Orleans, LA, and a professor, University of Queensland, Brisbane, Australia.

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ORCID Numbers. Joe Iwanaga: https://orcid.org/0000-0002-8502-7952; Yohei Takeshita: https://orcid.org/0000-0002-9345-5797; Muralidharan Anbalagan: https://orcid.org/0000-0001-5797-7558; Taku Toriumi: https://orcid.org/0009-0004-0275-425X; Yuki Kunisada: https://orcid.org/0000-0001-6356-0740; Soichiro Ibaragi: https://orcid.org/0000-0003-2897-1231. For information regarding ORCID numbers, go to http://orcid.org.

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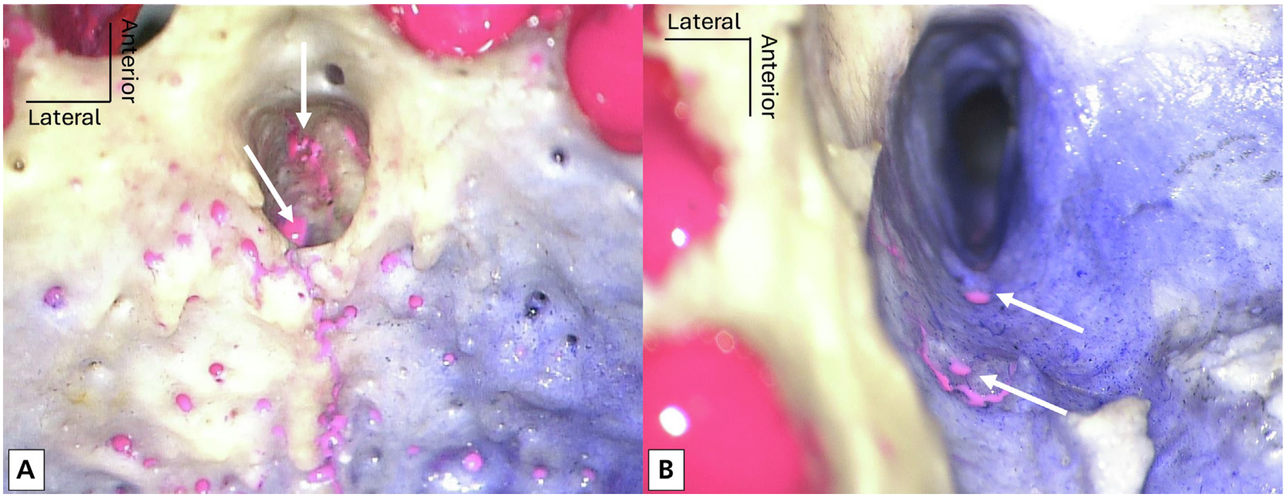
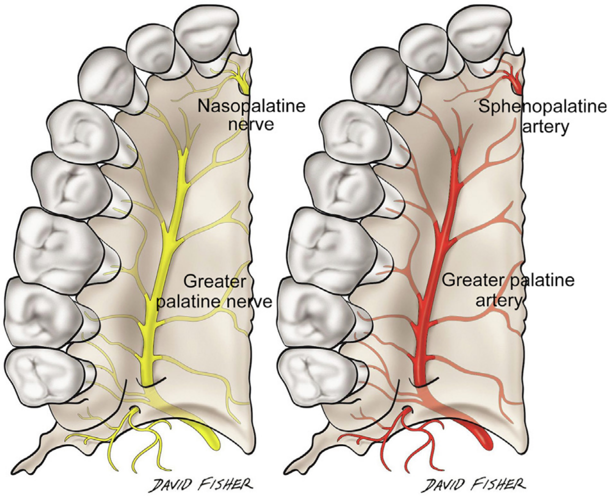


eFigure 1. **A:** Magnified view (×8) of latex in the small foramina (arrows) inside the incisive canal. **B:** Magnified view (×10) of latex in the small foramina (arrows) inside the greater palatine canal.



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