Anatomic feasibility of a modified 3-distal site anesthesia injection method for impacted mandibular third molar extraction using cone-beam computed tomography

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Background: Various injection methods have been used to improve the success rate of inferior alveolar nerve (IAN) block and reduce the pain and complications. But these methods also have their advantages and disadvantages. A modified 3-distal site anesthesia injection method proposed in 2015 was used clinically with satisfactory results at some dental clinics in China. This study aimed to determine the feasibility of this modified 3-distal site anesthesia injection method for extraction of an impacted mandibular third molar from an anatomical point of view.

Methods: Three-dimensional (3D) reconstruction and analysis of the mandibles was performed using cone-beam computed tomography (CBCT) scanning to measure the simulated needle insertion depth, infiltration distance, and other important parameters. These parameters were compared with an actual depth of 20 mm and a theoretic infiltration distance of 10 mm. The main parameters were compared between males and females.

Results: Sixty-three CBCT datasets were imported into Simplant OMS software for 3D reconstruction. The left simulated insertion depth did not differ from 20 mm, while right insertion depth was >20 mm ($P<0.05$). The bilateral infiltration distances were <10 mm ($P<0.05$) and articaine blocked the IAN. The widths of the mandibular rami were greater than the syringe length (21 mm), thus it was not possible for the syringe to reach the distal edge of the mandible. There was no difference in the simulated needle insertion depth and infiltration distance between the left and right ($P>0.05$). The bilateral simulated insertion depths, infiltration distances, widths of the mandibular rami, and height of the left mandibular foramen in females were less than in males ($P<0.05$), while there was no difference in the height of the right mandibular foramen and bilateral insertion angles ($P>0.05$).

Conclusions: The modified 3-distal site anesthesia injection method was shown to block the IAN based on anatomic evidence derived from 3D analysis on the measurements by CBCT.

Keywords: Anesthesia injection; cone-beam computed tomography (CBCT); distal insertion site; inferior alveolar nerve (IAN)

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Introduction

The extraction of impacted mandibular third molars is the conventional therapeutic approach for prevention of wisdom tooth pericoronitis, interstitial infections, odontogenic cysts and tumors, caries, and pulpitis involving adjacent teeth (1). However, many patients forego treatment due to fear of pain during tooth extraction, and some patients still experience pain even when they have received local sublingual anesthesia with drugs demonstrated with different anesthetic effects (2,3). Therefore, there is a need for an appropriate method to establish an inferior alveolar nerve (IAN) block which will minimize pain during an extraction. Since the first successful operation in 1884, the conventional IAN block anesthesia method has been widely used in the extraction surgery of impacted mandibular third molars (4,5). The main advantages of injection anesthesia to establish an IAN block are that the anatomic landmarks are easily identified for novices, the existing osseous end site is helpful to determine the location of the injection site, and the scope of anesthesia is broad with a single injection (6). However, the conventional anesthesia method also has disadvantages. The pain can be intense when the needle is inserted into the periosteum or retracted from soft tissue. In addition, anesthetics may be injected into the pterygoid muscle and vessels, and the needle might exceed the mandibular notch to puncture vessels, which would increase the risk of severe complications, such as lock jaw, hematoma, temporal bell paralysis, syncope, temporary blindness, and ophthalmoplegia (4,5,7). In recent years, a variety of injection methods have been described in the literature, all of which intended to improve the success rate of IAN block and avoid complications, although all have advantages and disadvantages (8,9). Gow-Gates mandibular nerve conduction anesthesia is reported to have a success rate up to 93% in a recent report (10). But this method has a long onset and a vague injection site location that is difficult to determine (7,11). The Vazirani-Akinosi technique can be used in patients with a small mouth opening, but the injection site is also difficult to identify, and the onset of pulpal anesthesia is slower than IAN block (12,13).

In the 1980s, Geng reported that a 3-distal site anesthesia injection technique (mesiobuccal, lingual, and distal insertion sites) improved the effect of IAN block anesthesia and reduced pain (14). Based on the Geng's study (14), a modified 3-distal site anesthesia injection method described by Luo in 2015 (15) has been applied with a good effect in clinical work at some hospitals providing oral healthcare in China. Compared with the traditional anesthesia injection method, the modified 3-distal site anesthesia injection method not only reduces the operation difficulty of the operator, but also greatly reduces the trauma and complications of the patient after tooth extraction. This method has great practical guiding significance for relevant clinicians.

In this study, by comparing the main parameters obtained by 3D reconstruction from cone-beam computed tomography (CBCT) scanning, the anatomic feasibility and application of a modified 3-distal site anesthesia injection method for extraction of an impacted mandibular third molar was explored to confirm its further application feasibilities among more populations. We present the following article in accordance with the MDAR reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-3161/rc).

Methods

Participants

Sixty-three volunteers with impacted mandibular third molars who were admitted to the Department of Stomatology at Beijing Tsinghua Changgung Hospital between January 2015 and December 2018 were enrolled in the current study. The inclusion criteria included the following: (I) 18–29 years of age with bilateral impacted mandibular third molars; and (II) good health with no contraindications for tooth extraction and no history of anesthetic allergies, cardio-cerebrovascular disease, or bisphosphonate use. The exclusion criteria were as follows: (I) no tooth loss, severe tooth wear, or malocclusion; and (II) no apparent difference in the morphology and anatomic location of the bilateral impacted mandibular third molars. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Beijing Tsinghua Changgung Hospital (No. 20160330-06) and informed consent was signed by all volunteers.

Modified 3-distal site anesthesia injection method

The modified 3-distal site anesthesia injection method included the mesiobuccal, lingual, and distal insertion sites (*Figure 1*). Articaine (4%) with 1:100,000 epinephrine was used as an anesthetic, and 0.3–0.4 mL of the anesthetic was injected by a syringe needle (0.3×21 mm) into the

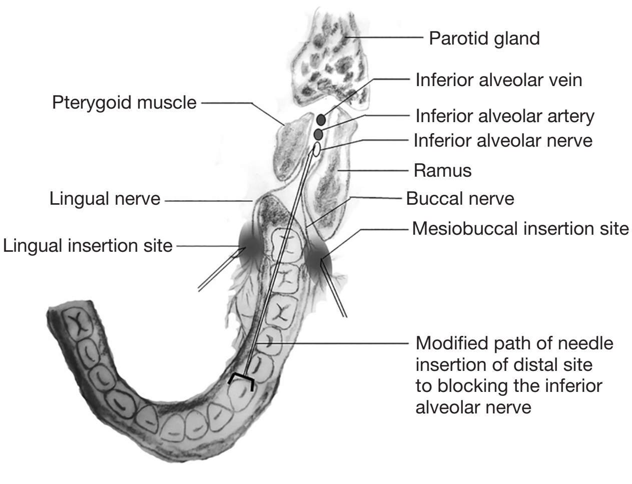

Figure 1 The schematic diagram of modified 3-distal site anesthesia injection method. Anesthetic was injected by a syringe needle into the periosteum of the mesiobuccal and lingual insertion sites to anesthetize the corresponding gums and mucosa, respectively. At the distal site of the impacted mandibular third molar, a needle was inserted and slipped inward for 20 mm after contacting the bone surface. When the needle touched the end and blood could not be withdrawn, anesthetic was injected to block the IAN. IAN, inferior alveolar nerve.

periosteum of the mesiobuccal and lingual insertion sites to anesthetize the corresponding gums and mucosa, respectively. The distal site was the key to the success of the modified anesthesia method by blocking the IAN. Briefly, the syringe was placed on the same side of the third molar and parallel to the occlusal plane, forming an angle of 35–45° to the midline. The needle was inserted at the distal site of the impacted mandibular third molar and slipped inward for 20 mm after contacting the bone surface. When blood could not be withdrawn, 0.9–1.1 mL of anesthetic was injected to block the IAN.

CBCT examination

A CBCT examination was performed before extraction of the bilateral impacted mandibular third molars. The scans were taken with SCANORA 3Dx (Nahkelantie 160, Tuusula, Finland), which was operated at 100 Kv and 2–4 mA, with slice thickness of 0.25 mm, a voxel size of 0.25 mm, a spatial resolution of 0.25 mm, and a field of view (FOV) of 160×80 mm. During scanning, the anode rotation was 360°, the X-ray irradiation time was approximately 13 seconds, and the reconstruction time was approximately 1 minute.

3D measurement and analysis

The CBCT examination data were imported into Simplant OMS software (Materialise Dental NV, Mechelen, Belgium) to create a 3D reconstruction. The key sites (*Figure 2A,2B*), lines (*Figure 2C*), and planes (*Figure 2D*) of the needle insertion simulated path at the distal site in the sagittal, coronal, and transverse views are depicted in *Figure 2*. Descriptions of the sites, lines, and planes, as well as the main parameters, are listed in *Tables 1,2*. The key sites, lines, planes, as well as the main parameters were identified and measured by a group including surgeons and radiologists in Beijing Tsinghua Changgung Hospital. Moreover, the panel, which comprised members who had experience of more than 15 years, was fixed to maintain intra/inter-observer agreement.

During injection at the distal site, the needle was inserted from the insertion site [point LRamusAnt (left) and point RRamusAnt (right)] to the bone surface. The thickness of soft tissue (StThickness) is the distance between the stop plate and needle tip. Point LRamusAnt is the most anterior point of the left ramus on the occlusal plane and the contact point for the simulated insertion at the bone surface. Point LRamusCon is the convex point of the left ramus on the occlusal plane, and point LInEnd is the left end site of the simulated insertion. The 3 points located on the occlusal plane are the intersection of the occlusal plane and mandibular ramus in different coronal views. The line, LRamusAnt-LInEnd (distance between the LRamusAnt and LInEnd), is the left simulated insertion path of the distal site, and the left simulated needle insertion depth (LSNIDepth) is the sum of LRamusAnt-LInEnd and the left soft tissue thickness (LStThickness). Point LMnF is the left mandibular foramen and the line, LMnF-LInEnd (distance between the LMnF and LInEnd), is the required distance for the anesthetic to infiltrate from the insertion end site. The height of the left mandibular foramen (HeightLMnF) is the perpendicular height between LMnF and the occlusal plane. Point LRamusPost is the most posterior point of the left ramus on the occlusal plane and the line, LRamusAP (distance between the LRamusAnt and the LRamusPost), is the width of the left mandibular ramus. The left insertion angle (LInAngle) is the angle between the LAngularline and the line of midpoint between the mesial incisal tips of both mandibular central incisors (IM) (IMline).

A schematic diagram of the left infiltration distance is shown in *Figure 3*. Points LInEnd and RInEnd were the theoretical bilateral insertion end sites. The line,

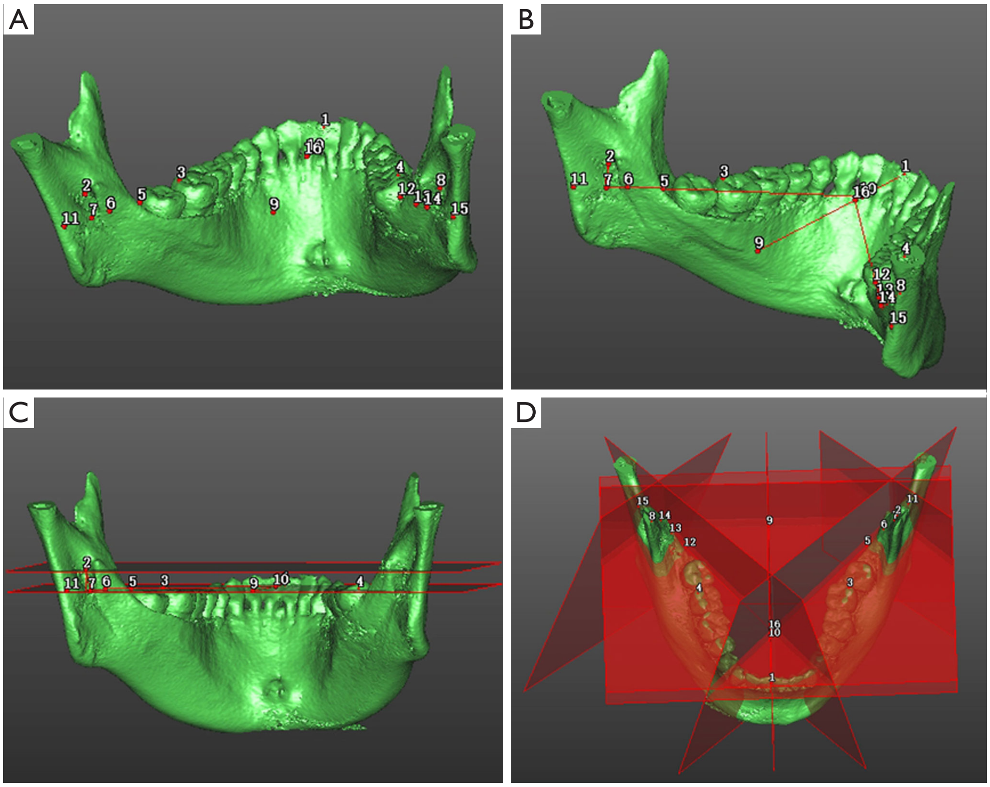

Figure 2 The points, lines, and surfaces based on 3D measurements. (A) Points 1–16 are set according to the sequence from IM to RIntersection; (B) setting lines; (C) planes in coronal view; (D) planes in transverse view. IM, midpoint between the mesial incisal tips of both mandibular central incisors.

LMnF-LInEnd, was the theoretical minimum distance for the anesthetic to infiltrate. There was a left difference (LDifference) between the actual depth of needle insertion (20 mm) and the line length (LRamusAnt-LInEnd). The LDifference and LMnF-LInEnd were set as the right-angle sides of a triangle, and the length of the hypotenuse was the left actual distance for the anesthetic to infiltrate (LWAnesthetic). Thus, the following formula was obtained: (I) the left simulation needle insertion depth, LSNIDepth=LRamusAnt-LInEnd+LStThickness; (II) the difference between the left simulation and actual needle insertion depth, LDifference = |LSNIDepth-20mm|, and (III) the left actual infiltration distance: $\text{LWAnesthetic} = \sqrt{a^2 + b^2}$, where a is the LMnFLInEnd and b is the LDifference. The right parameters were measured and analyzed in the same way. Previous studies have confirmed that a good anesthetic effect could be achieved when the distance between the injection end site and the IAN main branch was <10 mm (16,17).

Statistical analysis

Statistical analysis was performed using SPSS 21.0 released by IBM (https://www-01.ibm.com/support/docview.wss?uid=swg21476197). The comparison of the simulated needle insertion depth and the actual depth (20 mm) was analyzed using a bilateral *t*-test. The comparison of the actual infiltration distance and 10 mm was analyzed by a single *t*-test. Age, gender, and bilateral mandible main parameter differences were analyzed by an independent samples *t*-test. P<0.05 was considered a significant difference.

Results

General information

The 63 volunteers (30 males and 33 females) with a mean age (standard deviation) of 25.38±3.22 years (range, 18–29 years) successfully underwent extraction of impacted mandibular

Table 1 Description of key points, lines, and planes in 3D images

Name		Description
Points	IM	Midpoint between the mesial incisal tips of both mandibular central incisors
	LMnF	Left mandibular foramen
	37DBC	Distobuccal cusp tip of the left mandibular second molar
	47DBC	Distobuccal cusp tip of the right mandibular second molar
	LRamusAnt	Most anterior point of the left ramus on the occlusal plane
	LRamusCon	Convex point of the left ramus on the occlusal plane
	LInEnd	Intersection of occlusal plane with LRamusAC vertical plane and LMnF vertical plane
	RMnF	Right mandibular foramen
	IMLineE	Intersection of IM line and MnF coronal plane
	LIntersection	Intersection of occlusal plane with LRamusAC vertical plane and IMLine vertical plane
	LRamusPost	Most posterior point of the left ramus on the occlusal plane
	RRamusAnt	Most anterior point of the right ramus on the occlusal plane
	RRamusCon	Convex point of the left ramus on the occlusal plane
	RInEnd	Intersection of occlusal plane and RRamusAC vertical plane and RMnF vertical plane
	RRamusPost	Most posterior point of the right ramus on the occlusal plane
	RIntersection	Intersection of occlusal plane with RRamusAC vertical plane and IMLine vertical plane
Lines	LRamusAC	Line between LRamusAnt and LRamusCon
	LRamusMP	Line through LMnf and normal to LRamusAC
	LP	Line through LMnF and normal to occlusal plane
	IMline	Line through IM and normal to LRamusAC vertical plane
	LAngularline	Line through LRamusAnt and LIntersection
	RRamusAC	Line between Reft RRamusAnt and RRamusCon
	RRamusMP	Line through point RMnf and normal to RRamusAC
	RP	Line through RMnF and normal to occlusal plane
	RAngularline	Line through RRamusAnt and RIntersection
Planes	Occlusal plane	Plane defined by IM, 37DBC, and 47DBC
	MnF plane	Plane through LMnF, RMnF, and parallel to the occlusal plane
	MnF coronal plane	Plane through both MnFs and normal to the occlusal plane
	LRamusAC vertical plane	Plane through LRamusAnt and LRamusCon and normal to occlusal plane
	IMLine vertical plane	Plane through IM and IMLineE and normal to occlusal plane
	RRamusAC vertical plane	Plane through RRamusAnt and RRamusCon and normal to occlusal plane
	LMnF vertical plane	Plane through LMnF and normal to occlusal plane and LRamusAC vertical plane
	RMnF vertical plane	Plane through RMnF and normal to occlusal plane and RRamusAC vertical plane

IM, midpoint between the mesial incisal tips of both mandibular central incisors.

Table 2 Description of main parameters

Name	Description
LRamusAnt-LInEnd	Distance between the LRamusAnt and LInEnd
LMnF-LInEnd	Distance between the LMnF and LInEnd
HeightLMnF	Perpendicular height between LMnF and the occlusal plane
LRamusAP	Distance between the LRamusAnt and LRamusPost
LInAngle	Angle between the LAngularline and IMline
RRamusAnt-RInEnd	Distance between the RRamusAnt and RInEnd
RMnF-RInEnd	Distance between the RMnF and RInEnd
HeightRMnF	Perpendicular height between RMnF and the occlusal plane
RRamusAP	Distance between the RRamusAnt and RRamusPost
LInAngle	Angle between the RAngularline and IMline

third molars after a CBCT examination. The mean age of the 30 males was 25.73±2.97 years (range, 20–29 years), and for the 33 females, it was 25.06±3.45 years (range, 18–29 years). There was no difference in age between the genders (P>0.05).

Comparison of measured distances and angles

The measurements of distances and angles described in 3D measurements and analysis are shown in *Table 3*. The LSNIDepth was 20.49±2.20 mm, which was not significantly different from the actual depth of 20 mm (P>0.05). The RSNIDepth was 21.17±2.75 mm, which was significantly >20 mm (P<0.05). The LWAnesthetic and RWAnesthetic were 4.45±1.62 and 4.67±2.15 mm, respectively, which were significantly <10 mm (P<0.05). Thus, articaine blocked the IAN from the injection end site. The LRamusAP and RRamusAP were 30.38±3.59 and 31.31±3.13 mm, respectively, which were longer than the syringe length (21 mm), thus it was not possible for the syringe to reach the distal edge of the mandible. The LInAngle and RInAngle were 40.60±6.81° and 41.28±4.91°, and the HeightLMnF and HeightRMnF were 3.50±1.71 and 3.55±1.73 mm, respectively. There was no difference in the simulated needle insertion depth and actual infiltration distance between the left and right (P>0.05).

Comparison of the main parameters between genders

The comparison of main parameters between males and females is shown in *Table 3*. The LSNIDepth and RSNIDepth, LWAnesthetic and RWAnesthetic, and LRamusAP and RRamusAP in females were significantly less than males (P<0.05). The HeightLMnF in females was 3.04±1.12 mm, which was significantly less than males (P<0.05), while the HeightRMnF was not significantly different between the genders (P>0.05). In addition, there was no significant difference between the LInAngle and RInAngle (P>0.05).

Discussion

Anatomic variation is the main factor leading to conventional IAN block anesthesia failure (6), while oral surgeon proficiency, patient psychological factors, a small mouth opening, and tooth loss also contribute to injection anesthesia failure (6,8). Anatomic variation may be a source of neuropathic and referred pain (18). During modern dental treatment, the patient's operative posture changes from an early upright sitting posture to a flat-lying posture, and the anatomic key sites rotate and move with the rotational movement of the head, which is also a reason for failure of the conventional method (6). Thus, familiarity with the anatomic characteristics of the IAN is a critical factor influencing anesthesia success.

The mandibular nerve is the largest branch of the trigeminal nerve and is divided into the buccal nerve, lingual nerve, and IAN before the mandible foramen (6,8). The extraosseous IAN is located in the pterygomandibular space between the medial pterygoid and medial mandibular ramus, where the injection end site is also located (6,8). After injection of adequate anesthetic at the end site, the IAN can be blocked by infiltration (6,8). The injection during conventional IAN block anesthesia often encounters resistance leading to an inability to reach the predetermined depth. Currently, an experienced oral surgeon can reposition the needle and direct the syringe toward the mandibular midline and the same side of the injection. After reaching the predetermined depth or bone surface, the oral surgeon feels the resistance from the medial pterygoid. If the injection is continued, muscle spasms might occur (17). To avoid this complication, a modified 3-distal site anesthesia injection method was proposed. Per the modified method,

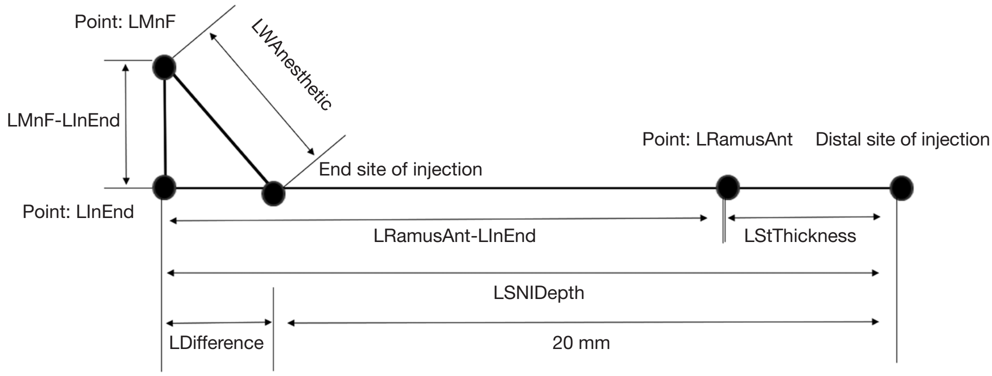

Figure 3 Schematic diagram of the left infiltration distance. Points LInEnd and RInEnd were the theoretical bilateral insertion end sites. The line, LMnF-LInEnd, was the theoretical minimum distance for the anesthetic to infiltrate. There was a left difference (LDifference) between the actual depth of needle insertion (20 mm) and the line length (LRamusAnt-LInEnd). The LDifference and LMnF-LInEnd were set as the right-angle sides of a triangle, and the length of the hypotenuse was the left actual distance for the anesthetic to infiltrate (LWAnesthetic).

Table 3 Measurements of distances and angles (distance: mm; angle: °)

Name	Total (n=63)	Female (n=33)	Male (n=30)	t	P
LRamusAnt-LInEnd	17.39±2.30	16.49±2.22	18.38±1.99	3.544	0.001
LStThickness	3.10±0.43	3.08±0.38	3.12±0.49	0.364	0.717
LSNIDepth	20.49±2.20	19.57±2.12	21.49±1.82	3.838	0.000
LMnFLInEnd	3.88±1.55	3.45±0.97	4.34±1.91	2.297	0.027
LDifference	1.81±1.03	1.74±1.27	1.89±1.35	0.454	0.651
LWAnesthetic	4.45±1.62	4.02±1.12	4.92±1.95	2.217	0.032
HeightLMnF	3.50±1.71	3.04±1.12	4.01±2.09	2.264	0.029
LRamusAP	30.38±3.59	28.45±3.16	32.50±2.78	5.378	0.000
LInAngle	40.60±6.81	39.52±6.47	41.79±7.09	1.329	0.189
RRamusAnt-RInEnd	17.97±3.02	16.65±2.37	19.42±3.03	4.061	0.000
RStThickness	3.20±0.55	3.30±0.45	3.08±0.63	1.606	0.113
RSNIDepth	21.17±2.75	19.95±2.22	22.51±2.67	4.152	0.000
RMnFRInEnd	3.85±1.68	3.49±1.08	4.24±2.10	1.756	0.086
RDifference	2.30±1.88	1.73±1.37	2.93±2.18	2.586	0.013
RWAnesthetic	4.67±2.15	4.04±1.37	5.37±2.63	2.481	0.017
HeightRMnF	3.55±1.73	3.18±1.12	3.40±2.17	0.498	0.621
RRamusAP	31.31±3.13	29.45±2.87	33.36±1.90	6.429	0.000
RInAngle	41.28±4.91	40.95±4.78	41.64±5.10	0.554	0.581

The data are expressed as mean ± standard deviation.

a needle was inserted from the key distal insertion site for 20 mm, then 1 mL of articaine was injected into the pterygomandibular space to block the IAN. The mandibular foramen, located at the middle of the anterior and posterior borders of the mandibular ramus, is the key site for IAN block anesthesia. Originally, the mandibular foramen is nearly at the same level of the occlusal plane. As age increases, it moves upwards, so the height between the mandibular foramen and occlusal plane also increases with the increase in age and the occurrence of tooth wear (18-21). Previous anatomic investigations involving the mandibular foramen were mainly based on cadaveric studies, and the mandible is asymmetric, thus virtual line and plane data cannot be measured correctly and directly (22). In addition, it is difficult to obtain sufficient samples without tooth loss and wear for measurement and analysis due to incomplete skeletal remains of the deceased (23). As technology updates, the location of mandibular foramen can be easily determined by CBCT (24). In the current study, the population was selected to avoid measurement error caused by age. There was no tooth loss or wear, which obviated significant changes in the distance between the mandibular foramen and the injection end site, as well as the height between the mandibular foramen and occlusal plane. Simplant OMS software can be used to perform 3D measurements and analyses of soft and hard tissues. After a CBCT examination of the maxillofacial region, the data were imported into Simplant OMS software to perform 3D reconstruction and measurement of the mandible, which makes the data more accurate and more visible (24,25).

Zhao *et al.* (26) measured and analyzed the mandible of 100 corpses and reported that the distance between the mandibular foramen and anterior border of the mandibular ramus was 17.87±0.22 mm. Based on 3D measurements, Findik *et al.* (27) found that the distance between the left mandibular foramen and the anterior border of the mandibular ramus was 15.41±2.32 mm, and the distance between the right mandibular foramen and the anterior border of the mandibular ramus was 15.27±2.28 mm. In the current study, the distance between the left mandibular foramen and the anterior border of the mandibular ramus (LRamusAnt-LInEnd) was 17.39±2.30 mm, the thickness of the soft tissue was 3.10±0.43 mm, and the distance between the right mandibular foramen and the anterior border of the mandibular ramus (RRamusAnt-RInEnd) was 17.97±3.02, with a soft tissue thickness of 3.20±0.55 mm. The distance between the left mandibular foramen and the anterior border of the mandibular ramus in the current study, although different from the results of Findik *et al.* (27), were consistent with the results of Zhao *et al.* (26). Malamed (13) recommended that the needle insertion depth should be approximately two-thirds of the needle length (31 mm), which was approximately 20 mm. Srisopark and Hatajid (28) studied IAN block anesthesia in Thais and concluded that the optimal insertion depth was 20 mm. Boonsiriseth *et al.* (29) also recommended 20 mm as the insertion depth in a new anesthesia method. In the current study, the simulated insertion depth was 20.49±2.20 mm on the left side and 21.17±2.75 mm on the right side. The left simulated insertion depth was not significantly different from 20 mm, while the right simulated insertion depth was significantly >20 mm ($P<0.05$). It should be noted that the injection was on different sides.

Compared to lidocaine, articaine has a shorter onset, longer duration, and less pain in dental application (30). Biocanin *et al.* (16) showed that the infiltration anesthesia range for 0.8 mL of 4% articaine with 1:100,000 epinephrine was 24.0–32.9 mm in a supraperiosteal injection and 12.1–22.4 mm in a periodontal injection. The distance between the insertion end site and the main branch of the IAN was 5–10 mm, and the onset was approximately 10 minutes. In the current study, the infiltration distance between the insertion end site and mandibular foramen was 4.45±1.62 mm on the left and 4.67±2.15 mm on the right, both of which were significantly <10 mm ($P<0.05$), and thus the articaine could block the IAN. As previously mentioned, a difference existed between the right simulated insertion depth and 20 mm, but the infiltration distance was significantly <10 mm, so a good anesthetic effect was also achieved on the right. Based on a 3D anatomic analysis of conventional IAN block anesthesia, Kang *et al.* (25) reported the distance between the mandible and the occlusal plane as 3.8±2.3 mm. Al-Shayyab (31) determined the distance between the mandibular foramen and the occlusal plane in adults to be 4.68±1.15 mm by analyzing CBCT measurements. In the current study, the distance from the left mandibular foramen to the occlusal plane was 3.50±1.71 mm, the corresponding distance on the right was 3.55±1.73 mm, and both distances were less than the relevant studies (25,31). In addition, the syringe should be 10 mm above the occlusal plane during the conventional anesthesia method. The modified 3-distal site anesthesia injection method positioned the needle parallel to the occlusal plane, which is clearer for identification of the key points and easier to use.

The smaller the diameter of the needle, the less painful the injection area, thus the syringe needle in the current study was 0.3×21 mm. Because the recommended needle insertion depth was approximately 20 mm, a 21-mm long needle was inserted to the approximate end of the insertion. During this process no assistant marker was required, but the end of the injection needle needed to be within the visible range to avoid removing a broken needle. Our study also compared the main parameters of both genders and found that the bilateral simulated needle insertion depth in males was significantly greater than females ($P<0.05$). Therefore, in clinical work, replacing the long needle in males with a wider jaw and properly reducing the insertion depth in females with a shorter jaw is recommended. According to the 3D measurements, there was no statistical difference in the bilateral insertion angle between males and females, and so it is suggested a 35–45° angle with the midline is maintained during injection.

As CBCT can be used as a diagnostic test on impacted third molars in relation to the IAN, CBCT assessment is the main diagnostic tool during anaesthetization in the presurgical phase (32-34). Among the thousands of cases presented by Luo *et al.* (15), extractions of lower, middle, and high impacted wisdom teeth at mandibular level benefit a lot from CBCT preoperative assessment. Among a study with 350 patients, cortex status is statistically insignificant with age, sex, site, and angulation of impacted third molars in CBCT images. If diversion of the mandibular canal is observed and when the roots are present between canals on digital orthopantomogram, CBCT imaging is highly recommended (35). Patel *et al.* shows CBCT is better than digital panoramic radiograph or orthopantomography in evaluating the close relationship between impacted mandibular third molar root and IAN canal, which can minimize post-operative neurological complications (36). Another study highly recommends CBCT examinations to reduce the risk of mandibular nerve injury when diversion of the mandibular canal is observed on panoramic radiographs images (37). A long-term follow up study finds that additional CBCT imaging may decrease the prevalence of temporary IAN injury, but it is not superior to panoramic radiography in reducing IAN injury after third molar surgery (38). Therefore, CBCT may help decrease the risk of IAN injury. The 3D analysis based on the measurements by CBCT images in our study are valuable and helpful for clinical surgeries. However, the results among another patient group shows that the risk for complications during the surgical removal of complex lower third molars is not significantly affected by CBCT (39). Intraoperative IAN bundle exposure is not necessarily predicting simultaneous neurological damage, and is not indicating of surgery discontinuation. So, CBCT should only be applied for preoperative risk assessment, but not for risk assessment during or after the operation (39).

Age may be correlated closely with oral health. Oral cleanliness and health of the elderly were poor (40). Bad oral habits lead to caries and poor oral health in adolescents (41). Smoking plays a great role on the incidence and progression of periodontitis (42). According to previous discussion, our modified method could block the IAN and was anatomically easier to perform than conventional IAN block anesthesia. But sex may cause differences in the practical skills of the methods in our study. Different studies find that the periodontal status of the distal of second molars was significantly improved by the removal of the mandibular third molars, which also positively affects overall periodontal health (43,44). Poorer healing after the mandibular third molar extraction may be due to a history of periodontitis, preoperative deep pockets and older age (44). Age, poor oral condition may impact the healing after mandibular third molar extraction (40-44). However, this study limited the included person between 18–29 years old, the clinical data of their oral condition were not recorded in details. Further clinical researches of our methods on the population with different oral conditions should be explored for better application.

Limitations of the study

The current study was based on 3D reconstruction only, and participant selection was strictly limited to a specific age group, which reduces the application in a larger population. Further clinical surgery and research in a population with differing ages or oral conditions are needed to confirm clinical feasibility and promote the application of the modified method.

Conclusions

In conclusion, the feasibility of a modified 3-distal site anesthesia injection method was investigated in this study using 3D analysis on the measurements by CBCT. The modified method could block the IAN and was anatomically easier to perform than conventional IAN block anesthesia. In the 3D anatomy study, the optimal insertion depth was approximately 20 mm, but there were differences between the left and right sides, which should be noted during clinical injection. Also, the bilateral simulated needle insertion depth in males was significantly greater than females. Therefore, in clinical work, it is recommended the long needle be replaced in males with a wider jaw and the insertion depth in females with a shorter jaw be properly reduced.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Beijing Tsinghua Changgung Hospital (No. 20160330-06) and informed consent was signed by all volunteers.

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