Anatomical study of gasless transoral thyroidectomy and clinical application

Hun-Mu Yang[1] · Kang-Jae Shin[2] · Junwon Min[3] · Seung Hoon Woo[4]

Abstract

Background Transoral thyroidectomy is becoming a preferred technique because it has the advantage of not leaving a scar after surgery. However, it is not yet standard because of the anatomic nerve complexity of this oral cavity and difficulty of approach. The aim of this study was to determine the safety zone of a gasless transoral thyroidectomy approach using an anatomical study and to evaluate the efficacy of this approach on clinical application.

Methods Phase 1, twenty unilateral specimens from fresh cadavers underwent staining by the modified Sihler's method to identify nerves around the oral vestibules. Then, the safety zone of the transoral thyroidectomy approach was proposed. Phase 2, a comparative analysis of the clinical outcomes of gasless transoral thyroidectomy through the safety zone versus transcutaneous thyroidectomy approach.

Results In phase 1, numerous inferior labial branches diverged from the mental nerve and were distributed across the lower lip. In most cases, the most lateral branch reached almost to the corner of the mouth, whereas a nerve-free area was present at the medial region of the lower lip. The suggested safety zone was presented as a trapezoid shape. In phase 2, there were no significant differences in age, mass size, or complications between the two groups. However, the operation time in the transoral thyroidectomy group was longer than in the transcutaneous group ($p = 0.001$).

Conclusions Based on the anatomical study, we suggested a safety zone for the gasless transoral thyroidectomy. On application of this safety zone, gasless transoral thyroidectomy is a safe and feasible procedure.

Keywords Thyroid · Anatomy · Scar · Nerve · Thyroidectomy · Surgery · Complication

Thyroid cancer, one of the most common cancers in women, is steadily increasing in frequency, and large numbers of patients are diagnosed at a young age [1–4]. Most patients who undergo thyroidectomy have an excellent oncologic prognosis. Traditional open thyroidectomy provides direct exposure, allowing surgery to be performed safely and quickly with minimal morbidity. However, this procedure leaves a scar on the anterior neck. Some scars heal well and blend with skin creases, but others may heal with hypertrophy. These visible healing and scarring processes are unpleasant and stressful for patients, especially young women [2, 5].

As a result, a variety of surgical techniques have been developed to minimize neck scars or to shift the scar to an area that can be covered with clothes. Moreover, several endoscopic approaches have been introduced, including the transaxillary and postauricular approaches. The advantages of these techniques are improved cosmetic results and surgical views with greater magnification [6]. However, these approaches still create scars that are often extensive and invasive, involving wide-ranging subcutaneous dissection of the chest and neck. They also do not correspond well to

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minimally invasive surgery, which is currently a major issue in surgery [7].

Natural orifice translumenal endoscopic surgery (NOTES) has recently been developed as a new surgical technique [8]. With this approach, an endoscope is passed through a natural orifice (e.g., oral cavity) into an internal organ (e.g., the thyroid). Only a mucosal incision (i.e., not a skin incision) is required. Transoral thyroidectomy was introduced as a type of NOTES, and a few trials of transoral thyroidectomy have been reported [1, 2, 5, 7–11]. The most popular approach has been to use a 3-port technique with CO_2 insufflation via the vestibular approach, which allows even large specimens to be removed through the incision site with cutting up or crushing the specimen [1, 5]. However, this approach carries the risk of damage to the mental nerve as well as CO_2 gas-related complications (e.g., CO_2 embolism). In addition, this approach could use only three devices (because this approach has only three ports), it was difficult to use another device or surgical retraction.

The aim of this study was to determine the safety zone for a gasless transoral thyroidectomy approach using an anatomical study, and to evaluate the efficacy of this approach on clinical application.

Materials and methods

Phase 1: anatomic study

All procedures were performed in accordance with the Declaration of Helsinki. Twenty unilateral specimens were obtained from ten fresh cadavers (seven males and three females; mean age, 75.2 years) that were legally donated to the Surgical Anatomy Education Centre, Yonsei University College of Medicine, and were approved for dissection of the head and neck region by this institution. One bilateral specimen (female, 68 years old) was stained by the modified Sihler's method, by which the muscle became transparent and the nerve darkly stained, following the protocol described in our previous study [12].

One of the authors (HY) made an incision on a line along the lowermost position of the mandibular buccal vestibule (IL; Fig. 1). The intermediate zone of the lower lip at the canine region was pinched by forceps and stretched anteriorly so that it was a distance of 3 cm from the IL (Fig. 1). The most medial branch of the mental nerve (mMN) beneath the labial mucosa was examined; the landmarks and reference lines are shown in Supplemental Table 1 and Fig. 1. The 3D coordinates of the location points of the mMN and the landmarks were determined by a 3D digitizer (MicroScribe G2X; Immersion Corp., San Jose, CA, USA) (Fig. 1B). Topographic items related to the mMN were calculated from these stereotactic locations (Table 1; Fig. 2).

Phase 2: clinical study

Study design

This study was designed as a prospective observational study.

Ethics

Approval for this study was gained from the Institutional Review Board, and the guidelines of the Declaration of Helsinki were adhered to.

Patients

Patients who suffered from neck discomfort due to a thyroid mass from January 2014 to December 2016 were recruited. Of the 67 patients initially enrolled (aged over 20 years old), three individuals failed to meet the eligibility criteria (one had signs of inflammation on preoperative neck computed tomography (CT) and the other had a history of neck surgery) and were excluded from the study. Patients were assigned a particular procedure through the allocation of a random number (32 patients/group). However, one patient refused to undergo transoral thyroidectomy. Thus, gasless transoral thyroidectomy was performed on 31 patients while transcutaneous thyroidectomy was performed on 33 patients (Fig. 3). All patients were required to give their informed consent after the advantages and disadvantages of each procedure, as well as the possibility of converting from the transoral approach to the transcutaneous approach during the transoral thyroidectomy procedure, had been explained. After thyroidectomy, each patient underwent regular check-ups, with clinical examinations (with laryngoscopy) for more than 1 year and ultrasonography twice a year. Two patients in the transcutaneous group were lost to follow-up. Finally, 31 patients in each group were analyzed.

The inclusion criteria were as follows: thyroid mass (> 4 cm), and diagnosis of a benign thyroid mass by physical examination, neck CT, and aspiration fine-needle biopsy. The exclusion criteria were an abscess or inflammation suspected by preoperative tests, a history of head and neck malignancy, or a history of surgery.

Outcomes

The primary outcome was to identify the safety zone of the transoral thyroidectomy approach based on an anatomical study. The secondary outcome was to evaluate the safety,
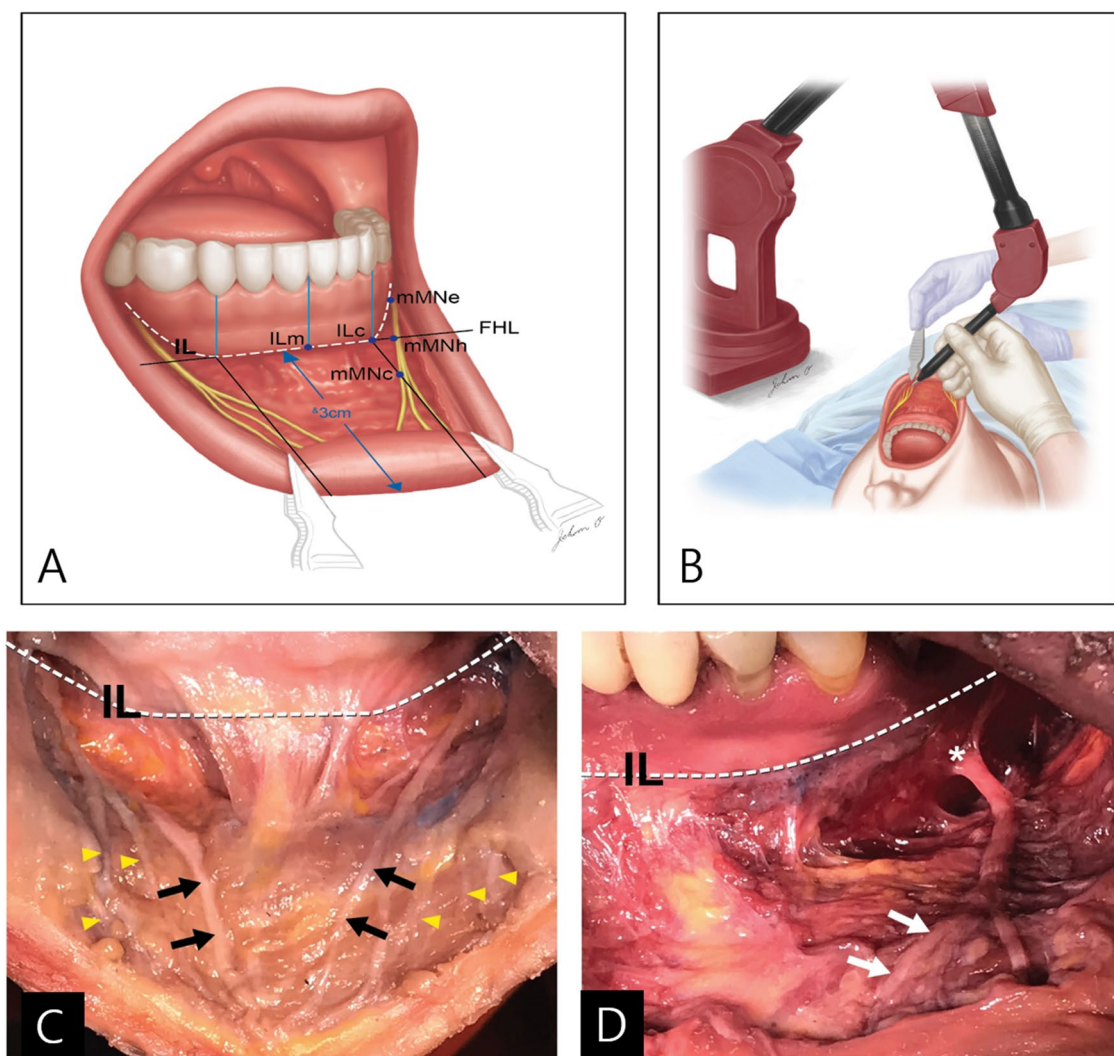
Fig. 1 Topographic examination of the most medial branch of the mental nerve. The locations of the five points (**A**) were determined by means of a 3D digitizer (**B**). The abbreviations of the five examined points and reference lines (IL, FHL, ILm, ILc, mMNc, mMNh, and mMNe) are given in Supplemental Table. The lips were stretched anteriorly to a distance of 3 cm from the intermediate zone to the IL (dashed red line). In the present study (**C**), the most medial branch of the mental nerve (mMN, black arrows) was examined after minimal dissection without exposure of the mental foramen. In D, after muscle detachment around the mental foramen (*), a course of the mMN (white arrows) was deviated laterally and the proceeding angle was increased. The arrowheads (yellow) indicate the lateral branches of the mental nerve. The incision (IL, dashed white lines) was made along the lowermost position of the mandibular buccal vestibule. The lips were stretched anteriorly to provide a 3-cm distance from the intermediate zone to the IL (in A, the midpoint of the lip was also stretched to enable the photograph to be taken) (Color figure online)

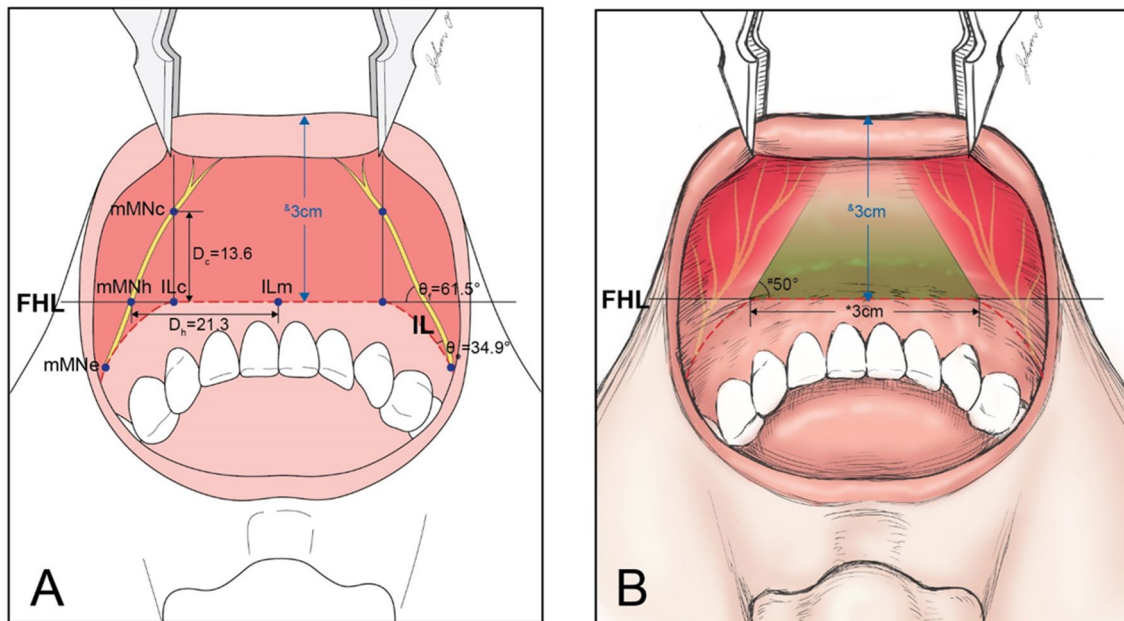**Table 1** Location and topography of the most medial branch of the mental nerve (mMN)

Topographic items[a]	Definition[b]	Value[a,c] (statistical majority[d])
Canine sagittal distance (D_c)	The distance between the mMNc and the ILc	13.6 ± 3.4 mm (> 1 cm in 90%)
Front horizontal distance (D_h)	The distance between the mMNh and the ILm	21.3 ± 3.3 mm (> 1.5 cm in all cases)
Front angle of the mMN (θ_f)	An angle between the mMNh-mMNc line and the FHL	61.5 ± 6.7 (> 50° in 95%)
Emerging angle of the mMN (θ_e)	An angle between the mMNe-mMNh line and mMNe-ILc line	34.9 ± 8.0 (> 30° in 90%)

[a]The measurement items and their values are illustrated in Fig. 3A along with their abbreviations

[b]The abbreviation definitions of the landmarks (IL, ILm, ILc, mMN, mMNc, mMNh, and mMNe) are presented in Table 1
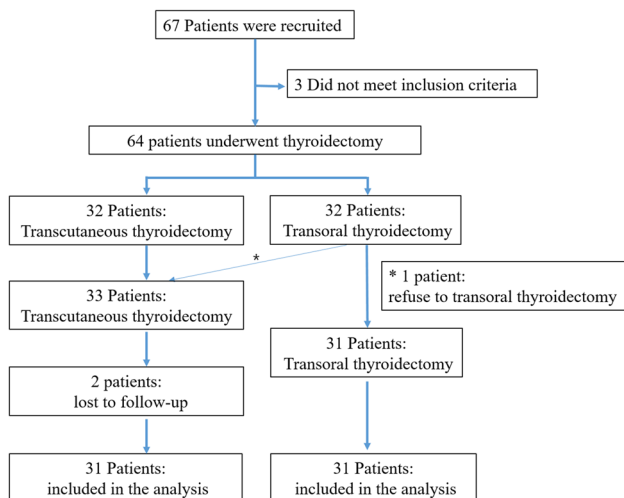
[c]The values are presented as 'average ± standard deviation'

[d]A safety area suggested by the statistical majority of the measurement items is illustrated in Fig. 3B

Fig. 2 Topography of the most medial branch of the mental nerve (**A**) and its safety and danger areas (**B**). In B, the safety zone is shown as a green trapezoid and the danger zone as reddish areas. The abbreviations of the noted points and lines (IL, FHL, ILm, ILc, mMNc, mMNh, and mMNe) are given in Supplemental Table. The abbrevia-

tions of the four topographic items (D_c, D_h, θ_h, and θ_e) are presented in Table 1. [#]The θ_h was > 50° in 95% of patients. *All mMN were more than 1.5 cm horizontally distant from the ILm. [&]The lips were stretched anteriorly to provide a 3-cm distance from the intermediate zone to the IL (dashed red lines) (Color figure online)

were used to compare the two groups by using SPSS 12.0 for Windows (SPSS Inc., Chicago, IL, USA). A p value < 0.05 was considered to indicate statistical significance.

Surgical technique (transoral thyroidectomy)

With the patient under general anesthesia through transnasal intubation, the lower lip was pulled with a retractor and a curvilinear incision 4–5 cm in length was made through the mucosa in the vestibule (Fig. 4A—C). According to the safety zone, the curvilinear incision was made between the canines, 10–15 mm away from the attached gingiva, and in an anteromedial direction at an angle of about 40° to the horizontal plane of the lower lip. This curvilinear incision with its lateral aspects parallel to the lower lateral branch of the mental nerve was created to expose the mandibular symphysis (Fig. 4D).

The mucosal flap was dissected to expose the surface of the mentalis muscle. The mentalis muscle was then divided close to the alveolar bone ridge, thus creating a stepwise incision. Later, during wound closure, the mentalis muscle required full reattachment to avoid a drooping chin. Using an electric scalpel, the flap of the lower lip and chin was separated from the surface of the mandibular bone from the medial to the lateral direction. A vestibule flap was elevated with a retractor to expose the layer of submental muscle and, eventually, the suprahyoid muscles in the anterior neck. A

Fig. 3 Patient enrollment

efficacy, and complications of gasless transoral thyroidectomy through the safety zone.
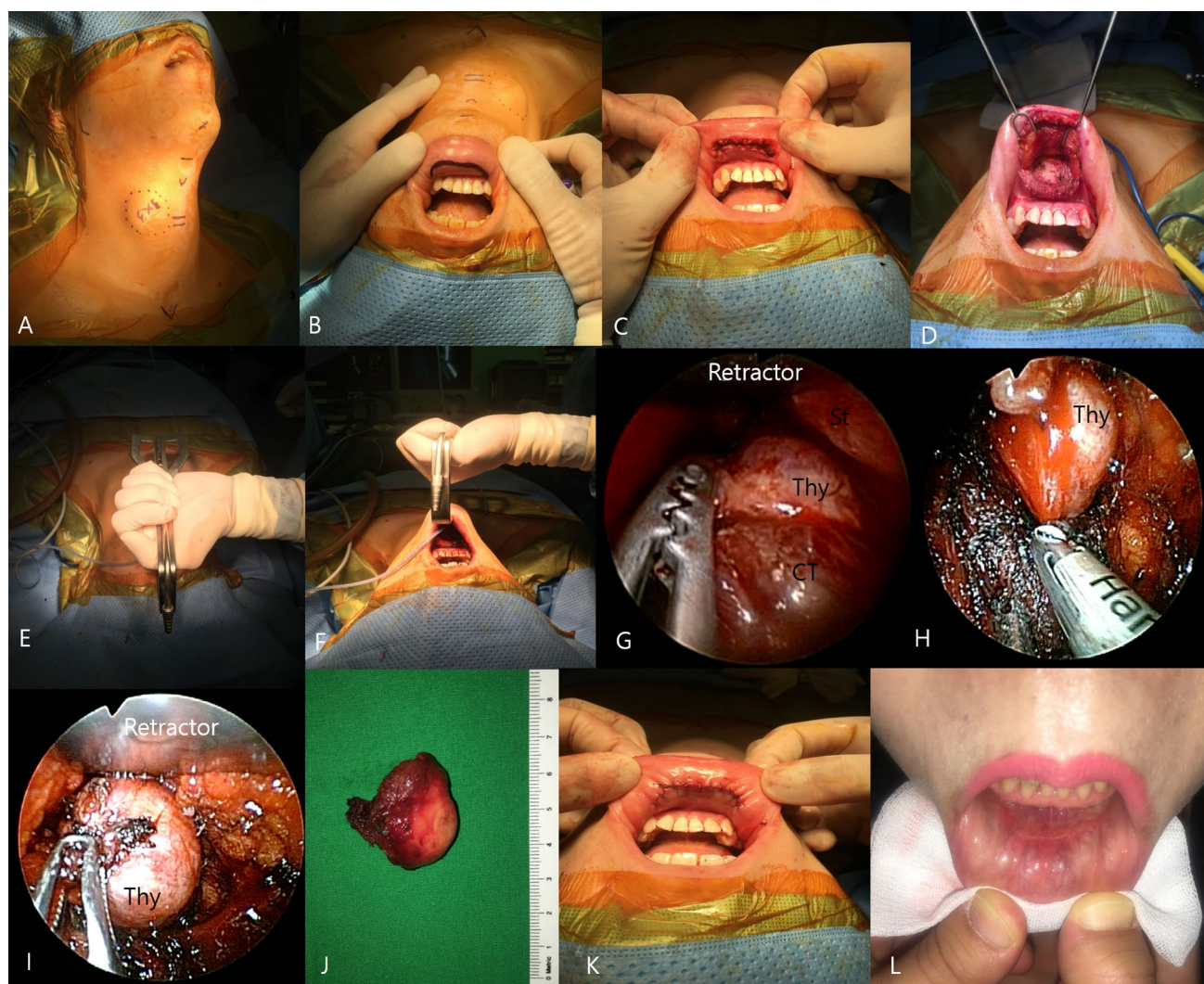
Statistical analysis

Topographic items were rendered from the 3D coordinates by means of a 3D digitizer running a program using R 3.3.2 [13]. Independent-samples t tests and Mann–Whitney tests

Fig. 4 Surgical incision for transoral endoscopic thyroidectomy. **A** With the patient under general anesthesia, **B** the lower lip was pulled and a 4.0-cm-long crescent-shaped incision was made through the mucosa in the vestibule. **C** The incision was made 10–15 mm away from the attached gingiva in a curvilinear fashion. To save the mental nerve, the incision proceeded in an anteromedial direction at an angle of about 40° to the horizontal plane of the lower lip. **D** Using an electric scalpel, the flap of the lower lip and chin was separated from the surface of the mandibular bone. **E**, **F** After creating a space in the subplatysmal layer of the anterior neck, the flap was lifted up by a self-retractor (KIM's retractor) and fixed above the patient's neck. **G** Anterior neck was lift up by a self-retractor without CO_2 insufflation and created an effective working space (Thy, thyroid; St, strap muscle; CT, cricothyroid muscle; Retractor, KIM's retractor). **H** Thyroid was dissected from the trachea and ligated using the Harmonic scalpel. **I** The thyroid was removed through the incision site. **J** 3×3 cm size thyroid mass was removed. **K** The oral surgical wound was closed using running 4.0 absorbable sutures. **L** One month later, the operation wound was clear

subsequent space was created beneath the subplatysmal layer passing the mandibular. Great care was taken to avoid stripping the lingual periosteum, since lingual soft-tissue attachment to the bone is needed to preserve the blood supply.

After creating a space beneath the subplatysmal layer in the anterior neck, the subplatysmal flap was lifted by a self-retractor (the KIM's retractor) and fixed above the patient's neck (Fig. 4E, F). This anterior neck-lifting method without CO_2 insufflation creates an effective working space and provides an excellent field of view (Fig. 4G). When adequate

access was obtained, a videoscope (Olympus, Tokyo, Japan) was inserted for amplification and illumination. Strap muscles were divided by cutting at the midline and an anchoring suture was placed percutaneously to retract the strap muscle laterally.

After these procedures, the thyroid isthmus was transected with a harmonic scalpel (Johnson & Johnson Medical, Cincinnati, OH, USA) after blunt dissection of the thyroid gland from the trachea. Then, the thyroid upper pole was easily dissected from the trachea with an endoscopic dissector (Aesculap, Inc.,

Center Valley, PA, USA) and ligated with the harmonic scalpel. After that, the lateral portion of the thyroid was dissected from the strap muscle using a peanut dissector (a cotton ball was grasped by the endoscopic dissector) and the middle thyroid vein was ligated as close to the thyroid as possible.

The upper pole and lateral portion of the gland were lifted up, and the recurrent laryngeal nerve (RLN) could be easily identified because its insertion into the larynx lies downwards, parallel to the trachea in the tracheoesophageal groove. After the RLN had been identified and saved, the inferior thyroid vessel was identified and dissected. Finally, the thyroid gland was dissected and the RLN was left intact.

The specimen was removed via the incision site without the need for cutting or crushing (Fig. 4I, J). The incision was closed after the wound was thoroughly irrigated and hemostasis achieved. Anteriorly, the mentalis muscle was reapproximated with sutures to prevent drooping of the chin. Then, the oral vestibule surgical wound was closed using running 4.0 absorbable sutures (Fig. 4K). A pressure dressing around the chin was applied for 24 h. Frequent oral gargling with 0.02% chlorhexidine was encouraged and a normal diet allowed on postoperative Day 1. Oral antibiotics were prescribed for 7 days. 1 month later, the operation wound was clear (Fig. 4L) and patients underwent follow-up observations at our outpatient clinic.

Conventional transcutaneous approach

Patients undergoing transcutaneous thyroidectomy were included in this study. Surgical procedures were performed by an experienced head and neck surgeon (SHW). Under general anesthesia, a skin incision was made along a natural skin crease overlying the neck. The incision for the face and neck mass resection was made 6 cm over the mass. After cutting through the subcutaneous tissue, a subplatysmal flap was created and elevated. Strap muscles were dissected and retracted to the lateral side from the midline during thyroid surgery without being cut.

The thyroid isthmus was dissected and transected, and an ultrasonic device was used for the dissection and division of tissue and vessels. Following dissection of the upper pole, the superior thyroid artery and vein were then divided. Then, the RLN was confirmed with certainty and the inferior thyroid artery was divided. Finally, the thyroid gland was dissected and the RLN was left intact.

Results

Phase 1: anatomic study

Numerous inferior labial branches diverged from the mental nerve and were distributed across the lower lip (Fig. 1C). In most cases, the most lateral branch reached almost to the corner of the mouth. On the other hand, the nerve-free area was situated between bilateral mMNs at the medial region of the lower lip. The location and proceeding angle of the mMN are detailed in Table 1 and Fig. 2. Modified Sihler's staining showed that a number of tiny twigs of the mental nerve were located between the mMN and the mouth corner (Fig. 5). There were also some marginal mandibular branches of the facial nerve ascending toward the lower lip.

Phase 2: clinical study

A total of 31 patients underwent gasless transoral thyroidectomy, and a further 31 patients underwent transcutaneous thyroidectomy. All thyroid masses were successfully excised via transoral thyroidectomy or transcutaneous thyroidectomy. There was no conversion from transoral thyroidectomy to the transcutaneous approach in any procedure. Patients' clinical and pathologic data are summarized in Table 2.

The transoral thyroidectomy group comprised 10 males and 21 females with a mean age of 41.3 ± 7.2 years, including 17 cases of single thyroid nodule, 13 cases of multinodular goiter, and one case of papillary microcarcinoma. All patients in this group received a lobectomy or hemithyroidectomy. The mean length of the oral vestibular incision was 45.2 ± 5.6 mm (range 40–55 mm). The median mass size was 4.82 ± 1.5 cm. The average operating time was 90.2 ± 45.7 min (range 60–110 min). Blood loss was minimal.

The transcutaneous group comprised 13 males and 18 females with a mean age of 44.2 ± 6.9 years, including 18 cases of single thyroid nodule, 12 cases of multi-nodular
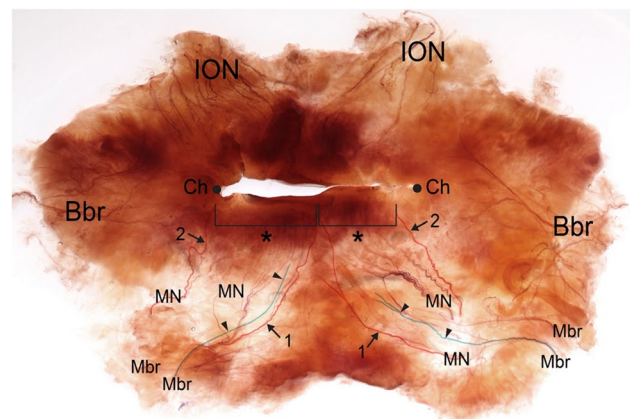
Fig. 5 Nerve distribution of the perioral region visualized by the modified Sihler's staining method. Numerous tiny twigs (*) of the mental nerve (MN) located between its most medial branch (arrows 1) and its most lateral branch (arrows 2) reaching the mouth corner (Ch). Arrowheads indicate twigs of the marginal mandibular branch (Mbr) approaching the lower lip (*ION* inferior orbital nerve, *Bbr* buccal branch of the facial nerve)

Table 2 Demographic data and surgery-related outcomes

Clinical characteristics	Transoral group ($n = 31$)	Transcutaneous group ($n = 31$)	p value
Female/male	21/10	18/13	
Age (years)	41.3 ± 7.2	44.2 ± 6.9	0.147
Tumor size (cm)	4.82 ± 1.5	5.05 ± 1.7	0.533
Operation time (min)	90.2 ± 45.7	61.2 ± 32.5	0.001
Blood loss (ml)	72.82 ± 31.18	75.59 ± 38.61	0.399
Follow-up (mos)	17.3	17.2	0.651
Thyroid disease			0.932
Single nodule	17	18	
Multi nodule	13	12	
Papillary microcarcinoma	1	1	
Complications			0.872
Total	1	2	
RLN palsy			
Transient	1	1	
Permanent	0	0	
Hypocalcemia			
Transient	0	0	
Permanent	0	0	
Infection	0	0	
Hematoma/seroma	0	1	
Mental nerve injury	0	0	

RLN recurrent laryngeal nerve

goiter, and one case of papillary microcarcinoma. All patients in this group received a lobectomy or hemithyroidectomy. The mean length of the skin incision was 51.6 ± 11.2 mm (range 50–110 mm). The median mass size was 5.05 ± 1.7 cm. The average operating time was 61.2 ± 32.5 min (range 40–84 min). Blood loss was minimal. There were no significant differences in age or mass size between the two groups. However, the operation time was longer in the transoral group compared to the transcutaneous group ($p = 0.001$).

The average follow-up period was 12 months for both groups. Data relating to postoperative complications are presented in Table 2. No wound problems occurred during the follow-up period. One patient in each group showed a temporary decrease in vocal cord movement (damaged RLN), although it had recovered completely within 2 months. One patient in the transcutaneous group experienced a seroma on the surgical area, which was aspirated.

Discussion

Traditional thyroid surgery requires a transcutaneous approach, which is identified as standard for thyroid surgery. However, this approach results in external scarring of the neck. Another approach is endoscopic transaxillary thyroid surgery, which moves the area of the incision from the anterior cervical area to the precordial or axillary region, an area that can be covered with clothes and has provided cosmetic benefits to patients. However, these endoscopic thyroidectomy is merely a "transition state" between open surgery and truly non-invasive surgery.

In light of this, surgeons have tried to apply NOTES to thyroid surgery. The concept of NOTES, which was recently introduced to neck surgery, is novel from the viewpoint of minimal-incision surgery (surgery via a natural orifice such as the mouth) [2, 10, 11, 14–27]. In addition, transoral thyroidectomy was introduced as a new type of thyroid surgery. Recently, Anuwong [5] reported an endoscopic thyroidectomy oral vestibular approach using a 3-port technique with CO_2 insufflation, while Woo [2] reported a transoral thyroidectomy via frenotomy approach.

However, before applying NOTES to thyroid surgery, it is essential to understand the location of the safety zone from the mouth to the thyroid because the anatomy of this area is extremely complicated. Though transoral thyroidectomy using gas and a trocar has been applied to certain patients, some authors suggest that there is a continuing concern regarding mental nerve damage and CO_2 gas-related complications [28, 29]. Thus, we performed an anatomical study by means of cadaver dissection to define the safety zone in

a gasless transoral thyroidectomy approach and its clinical application.

Herein, intact human fresh cadavers were used without any chemical treatment to reproduce the tissue rigidity and elasticity of a living object. In order to simulate a real manipulation, an intermediate zone of the lower lip was stretched anteriorly 3 cm. The mental foramen was not exposed and the adjacent tissues around the nerve were preserved to the extent possible. Then, we used a 3D digitizer instead of a conventional straight ruler to ensure accuracy.

The mental nerve is ramified as the angular medial inferior labial, lateral inferior labial, and mentum branches after passing through the mental foramen, and the medial and lateral inferior labial branches are vulnerable to surgical trauma [30]. Therefore, their most medial twig, the mMN, was chosen as an indicator of mental nerve distribution. The lower lip was consistently stretched by 3 cm to allow topographic standardization of the flexible mucosa during measurements (Fig. 2A). Based on the region where the mMN was mostly absent, the minimal safety area was conceived as a trapezoid with a base line 3 cm in length and a base angle of 50° (Fig. 2B). Unlike this nerve-free zone, our results showed that twigs of the mental nerve were situated between the mMN and the corner of the mouth. In line with this, Won et al. [31] also reported nerve twigs reaching the mouth corner. Therefore, the approach to the lateral area of the lower lip can cause injury to the mental nerve twigs.

Anatomically, there are other neurovascular structures vulnerable to surgical manipulation on the lower lip. The mentum branch of the mental nerve is situated deeply and proceeds horizontally along the lower mandibular border [30]. After an initial incision, the view of the surgical field is secured by an endoscope; therefore, a meticulous approach to the thyroid gland can be performed without damage to the mentum branch. In general, the marginal mandibular branch of the facial nerve did not exist between the mMNs of each side [31]. Some of the marginal mandibular branches reached the lateral area of the lip, and therefore an approach to the lower lip can also damage the branches. The inferior labial artery is located within the submucosal layer of the middle area between the oral commissure and the lower mandibular border [32]. Careful, and not too deep, incision can avoid vascular complications with the artery situated 4.8 mm beneath the labial mucosa [33].

Following the anatomical study, we defined the safety zone and used it in the application of transoral thyroidectomy. Because the safety zone had a trapezoidal shape in the oral vestibule, we made a curvilinear incision between the canines in the vestibule. We then created a pathway with a retractor and thus did not need to use any gas for the thyroidectomy. This approach showed that a gasless transoral approach was technically feasible and allowed us to reach the thyroid gland without any nerve damage (mental nerve or marginal mandibular branch of the facial nerve). Moreover, even large specimens could be removed through the incision site without the need for cutting or crushing.

Despite the excellent cosmetic result and safety, continued auditing is essential when introducing a new technique. The results of our transoral thyroidectomy approach are similar to those of transcutaneous thyroidectomy. Transient RLN injury was observed in one case in each group, but these recovered within 2 months. Transoral thyroidectomy results did not differ from those of transcutaneous thyroidectomy. The flap of the lower lip and chin can adhere to the periosteum as the wound heals. In this study, there were no healing problems in this area of the chin, and none of the patients presented with dysphagia or dysphonia during the follow-up period [34]. Therefore, all patients began oral intake the day after surgery and the drain was removed the same day. It is probable, therefore, that all patients could be discharged from the hospital one or 2 days after surgery.

Significant swelling or bleeding was not observed after gasless transoral thyroidectomy. The majority of patients in the present study were young women (80%), about half of whom were unmarried. The main advantage for patients in choosing transoral surgery is the excellent cosmetic result with no scarring and concomitant emotional benefit. Cosmetic concerns and requests are frequently demanded from young women and men. At present, the minimally invasive aspect and cosmetic advantage appear to be an important factor for such patients. Considering that the prevalence of thyroid disease is higher in young women and men, this scarless transoral thyroidectomy technique would be highly beneficial for these patients.

However, we did not recommend transoral thyroidectomy in trachea invasion or anatomic problem patients before clinical check-up. This was because this approach was just developed and requires further study, and this study was just one of many trials. However, I expect it to replace the transaxillary or BABA approach, because the transoral approach is a less invasive surgery and leads to an actually invisible scar. In our early experiment, gasless transoral thyroidectomy can replace previous thyroidectomy about 30% of the times.

In our experiment, the most time-consuming step in this procedure was the adaptation of the endoscope assistant people (usually residents) for the transoral approach. I use two hands to grasp the forceps and dissector (or harmonic scalpel), so I need at least one more hand to hold the endoscope. A resident almost always handled this endoscope, and they needed to adapt to the procedure. The assistant was changed every surgery, and sometimes even changed in the middle of surgery. Thus, much of the operation time was attributable to endoscope handle work, as handling the endoscope requires adaptation. Thus, the operation time has recently decreased as the assistants have adapted to the procedure.

In this respect, the present study has three major features. (1) We suggested a safety zone for gasless transoral thyroidectomy. This zone is precisely defined by anatomical landmarks and ensures that the thyroid gland is safely reached. The safety zone provides a reduced risk of mental nerve and marginal mandibular branch injury. (2) A working space is created by mechanical lifting without CO_2 insufflation, which provides an excellent endoscopic view during the operation (gasless methods also lack the disruption associated with smoke suction) and the avoidance of gas-related complications. Gasless methods also enable surgeons to use conventional instruments that are used in open thyroidectomy for the dissection of skin flaps or bleeding control. (3) A single large incision (no side ports) could provide a large working space and could allow the easy removal of larger specimens without the need to cut or crush them. In addition, we could use 4–5 surgical devices (not only three devices) through large working space for retraction or manipulation. Thus, this technique provides not only a no-scar endoscopic surgery but also give us a surgical variety surgical option for neck or chest disease.

This study had some limitations. First, the patients underwent follow-up for only 1 year and the number of enrolled patients were relatively small, a longer follow-up period and large sample size may be needed to evaluate the risks and benefits of the described procedure. Second, additional studies with larger sample sizes may be needed to investigate differences between various age and sex groups. It may also be necessary to improve the reliability and applicability of the data for treating and managing patients who have undergone transoral thyroidectomy. Third, infection is the primary concern with oral cavity surgery because of contaminated wounds. Thyroid surgery via the transcutaneous approach is considered a "clean" procedure and antibiotics are not indicated. However, transoral thyroid surgery is a type II clean-contaminated wound. Although the surgical field and incision site are clean, the inferior vestibule is non-sterile; hence, we used antibiotics and an oral gargle, and the drain was removed 2 days after the operation. Follow-up observations were carried out for 12 months after the operation and no complication patterns were observed. Forth, we want this surgical approach to eventually be used for malignant tumors. However, this approach was just developed, and it is necessary to confirm its safety and feasibility through a step-by-step process (from benign to malignant tumors). This trial was just for benign tumors, and our next trial will be for malignant tumors.

In conclusion, gasless transoral thyroidectomy is a potentially safe and effective method that can remove the thyroid mass with excellent cosmetic outcomes. This anatomical description is useful for surgeons who employ the vestibular approach for transoral thyroidectomy. We believe that this approach not only has a cosmetic advantage but also provides another pathway for such surgery.

Compliance with ethical standards

Disclosures Hun-Mu Yang, Kang-Jae Shin, Junwon Min, and Seung Hoon Woo have no financial or material support has been received for this work; moreover, the authors declare no financial interests in companies or other entities that could have an interest in the information contained within this study. Hun-Mu Yang, Kang-Jae Shin, Junwon Min, and Seung Hoon Woo have no conflicts of interest or financial ties to disclose.

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