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Gasless transoral robotic thyroidectomy using the DaVinci SP system: Feasibility, safety, and operative technique

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ABSTRACT

Background: Transoral robotic thyroidectomy (TORT) is an ideal method for minimally invasive thyroidectomy, as there is less flap dissection during the procedure and no postoperative scars. However, this method also has the limitation of present DaVinci system and some technical problems related to CO_2 gas insufflation that must be resolved. We investigated the feasibility and safety of gasless TORT using the latest version of the DaVinci system (SP).

Methods: From October 2018 to January 2019, we performed 10 surgeries of gasless TORT using the DaVinci SP at Yonsei University Hospital.

Results: Nine patients underwent unilateral thyroid lobectomy and one patient received total thyroidectomy. All operations were successfully completed. Nine cases had papillary thyroid carcinoma, and one had benign nodules. The mean surgical time was 177 min, and the mean hospital stay was 6.3 days. There were no reports of transient or permanent vocal cord palsy, recurrence, or mortality during the follow-up period. Temporary hypoesthesia of the chin due to mental nerve injury was observed in 3 of 10 patients, but it recovered spontaneously within 1 months in all cases.

Conclusions: Gasless TORT using the DaVinci SP system is feasible and safe for selected patients and is a potential alternative approach for scarless thyroid surgery.

Introduction

The transverse incision used in conventional thyroid surgery provides an optimal view for thyroid surgery, but it may cause a cosmetic problem after surgery because it leaves visible scarring on the anterior neck. In particular, young female patients or patients with a tendency for hypertrophic scarring might be more susceptible to these detrimental cosmetic outcomes. Therefore, various surgical techniques of remote access surgery that do not leave any visible scarring on the neck have been reported. Since Huscher et al. first reported endoscopic thyroid surgery in 1997, remote access approaches to the thyroid gland have been advanced [1]. Currently, various approaches including transaxillary, transareola, breast-chest, and retroauricular approach using an endoscope or surgical robot have been invented and performed in many institutions around the world [2–4]. However, these operative techniques cannot eliminate the neck scar completely and these remote access approaches also involve extensive tissue dissection because the thyroid gland should be approached from a distant site. Such dissection could increase operation time and postoperative pain [5].

In 2009, Wilhelm et al. reported thyroidectomy using a sublingual approach and as a possible scarless procedure [6]. However, it was not widely adopted because of its complications. Then, Anuwong et al. published a transoral vestibular approach with three incisions on the vestibule area and reported excellent cosmetic results and low morbidity [7]. Because of its excellent cosmetic results and other advantages, transoral thyroidectomy through a vestibular approach using endoscope or surgical robot has been widely adopted and performed in many institutions around the world [8–10].

Since the DaVinci surgical robot was first developed in 1999, it had been advanced into the DaVinci S and Si systems. Most recently, the 3rd generation of the DaVinci Xi system was developed and released in 2014, and has been widely used in various surgical operations. Kim et al. performed transoral thyroidectomy through a vestibular approach using the DaVinci Xi system and reported the feasibility and safety of

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transoral robotic thyroidectomy (TORT) [11]. TORT using the DaVinci Xi system has advantages in that the surgeon can perform the operation based on 3-dimensional (D) magnified visualization of the surgical site compared to the 2D view of endoscopic surgery and can use wristed instruments that can move freely at various angles within the confined working space. However, TORT using the DaVinci Xi has disadvantages that need to be improved. During access of the thyroid gland through the vestibular incision, the protruding bony structure of the mandible can interfere with instrument movement, especially when dissecting the upper pole of the thyroid gland. Even though TORT is performed using wristed instruments in the DaVinci Xi based on 3D magnified view of the surgical field, such bony anatomical obstacles may interfere with surgical procedure. Also, use of a CO_2 gas insufflation system in TORT poses a risk of fatal complication such as CO_2 embolism [12].

The recently developed flexible single-port robotic system (DaVinci SP) has two “joggle joints” in the robotic arm and endoscope, allowing more flexible movement within a confined working space. Also, as all robotic joints and the endoscope are inserted through a single arm, insertion into the long, narrow space is simplified. Recently, we successfully performed TORT using the DaVinci SP system and a self-retaining retractor system without CO_2 gas insufflation and evaluated the feasibility and safety of the procedure by analyzing the treatment outcomes of patients who received gasless TORT using DaVinci SP.

Materials and methods

Patients

We retrospectively reviewed the medical records of nine patients who underwent gasless TORT using the DaVinci SP system at Severance Hospital from November 2018 to January 2019. This retrospective study was approved by the Institutional Review Board of Yonsei University. Only patients older than 18 years of age were included in this study. Benign thyroid nodule or papillary thyroid carcinoma < 4 cm without extrathyroidal extension and lateral lymph node metastasis on preoperative ultrasound were indicated for transoral thyroidectomy. There were three male patients and six female patients whose age ranged from 35 to 64 years, with a mean age of 46.3 years. A total of nine patients underwent thyroid lobectomy, one of whom underwent repeat completion thyroidectomy due to adverse pathologic features on examination after the first operation. And one patient received total thyoidectomy. Therefore, we performed 10 surgeries of gasless TORT using the DaVinci SP during the study period (Table 1).

Configuration of the DaVinci SP system

Like the DaVinci Xi system, the DaVinci SP system consists of a patient cart, surgical console, and imaging cart, but the SP system is more suitable for narrow-access surgery because it is a flexible, single-port system. Three multi-jointed instruments and a full-wristed 3-D HD camera are inserted through a 25 mm single cannula. The EndoWrist SP instrument used in the SP system has two more degrees of freedom than the instruments used in the previous Xi system, allowing more precise surgical control. Also, DaVinci SP system enables the insertion of all robotic arms through single cannula, and it also provides excellent external and internal ranges of motion. The surgeon can control the fully articulating instruments on a console similar to that of the DaVinci Xi system and can also adjust the axis and location of the endoscope through a navigation system without the aid of bedside assistant (Fig. 1).

Table 1
Clinical information of all patients.

No.	Sex	Age	Preoperative Dx	Operation	Pathology
1	F	35	Thyroid nodule	Lt. lobectomy	Adenomatous hyperplasia
2	M	54	Thyroid ca.	Lt. lobectomy	Papillary ca.
3	M	54	Thyroid ca.	Rt. lobectomy	Papillary ca.
4	M	48	Thyroid ca.	Lt. lobectomy	Papillary ca.
5	F	64	Thyroid ca.	Rt. lobectomy	Papillary ca.
6	F	42	Thyroid ca.	Rt. lobectomy	Papillary ca.
7	F	30	Thyroid ca.	Rt. lobectomy	Papillary ca.
8	M	48	Thyroid ca.	Total lobectomy	Papillary ca.
9	F	58	Thyroid ca.	Rt. thyroidectomy	Papillary ca.
10	F	30	Thyroid ca.	Rt. lobectomy	Papillary ca.

Dx: diagnosis, ca: carcinoma, Lt: left, Rt: right.

Appropriate settings and preparation of the DaVinci SP system for gasless TORT

The patient was placed in a supine position without a shoulder roll. After a 2.5 cm mucosal incision was made in the vestibular area, dissection was first performed using electrocautery, and the skin flap was elevated along the subperiosteal plane using monoplolar cautery. Because the mentral nerve comes from the mental foramen outside the premolar area, care should be taken not to exceed the premolar area when lifting the periosteal flap (Fig. 2). After dissection, a specially designed self-retractor system was inserted to maintain the lifted skin flap (Fig. 3). If necessary, an additional incision could be made 1 cm lateral to the vestibular incision for insertion of a suction tube or other endoscopic instruments controlled by a bedside assistant. The patient cart of the DaVinci SP system was placed perpendicular to the surgical bed, and the cannula was fixed 10 cm from the oral cavity. An endoscope and two robotic arms were mounted on a single-arm system and inserted through a vestibular incision. The endoscope was placed first in the middle, while the two robotic arms were inserted on both sides of the endoscope. During the operation, Maryland forceps and monopolar scissors were attached to the left and right robotic arms, respectively (Fig. 4).

Operative techniques

Gasless TORT using Da Vinci SP proceeded as follows. After oral intubation, the patient was placed in supine position without a shoulder roll. A 2.5-cm horizontal mucosal incision was made at the oral vestibular area. Dissection was started using monopolar cautery, mandible was identified, and skin flap was elevated along the subperiosteal planes around the mentum area of the mandible, not exceeding the premolar area. Then, skin flap was elevated from this area to the lower neck using monopolar cautery as well as standard surgical instruments and dissector under naked eye. The lifted skin flap was maintained using a specially designed, self-retaining retractor system (Fig. 3). After the patient cart was placed perpendicular to the surgical bed, cannula was fixed 10 cm from the incision site. An endoscope was attached to the upper side of single arm, and Maryland forceps and scissors were attached to the left- and right-side port, respectively.

Firstly, the median raphe of strap muscle was confirmed and dissected using monopolar cautery to expose the underlying thyroid gland. Then, strap muscle was separated from the lateral border of thyroid gland, and the middle thyroid vein was ligated using bipolar cautery (Fig. 5). Next, isthmus region was cut using monopolar cautery of the scissors, and the median portion of thyroid gland was partially dissected from the trachea. The upper pole of thyroid gland was grasped with Maryland forceps and retracted in superior-medial direction to identify and preserve superior parathyroid gland. Fibrotic tissue in the lateral portion of cricothyroid joint was carefully dissected to identify the recurrent laryngeal nerve, followed by dissection along the direction of the nerve. Thyroid gland was then dissected from the trachea at Berry's ligament site, and thyroid lobectomy was completed. Upon completion, commercial hemostat material was applied to the surgical site, and no drain was inserted (Supplement Video).

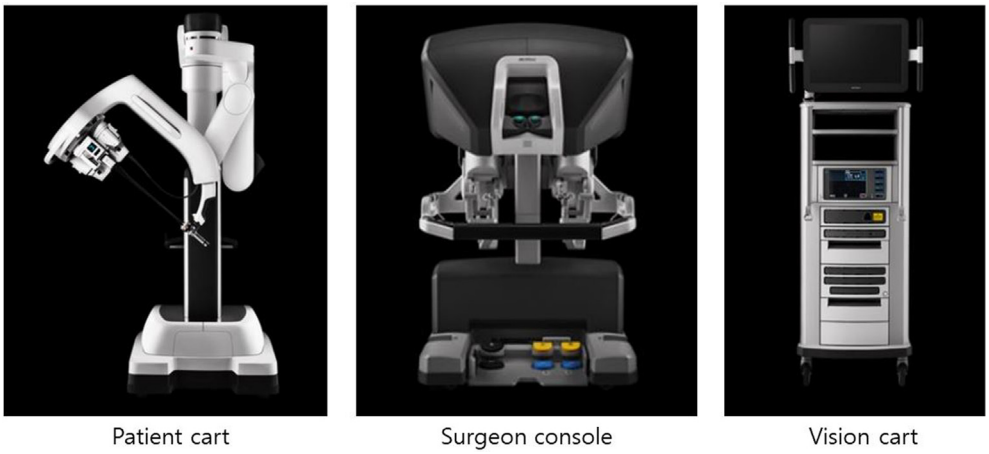


Fig. 1. Configuration of the DaVinci SP system. DaVinci SP system consists of patient cart, surgeon console, and vision cart.

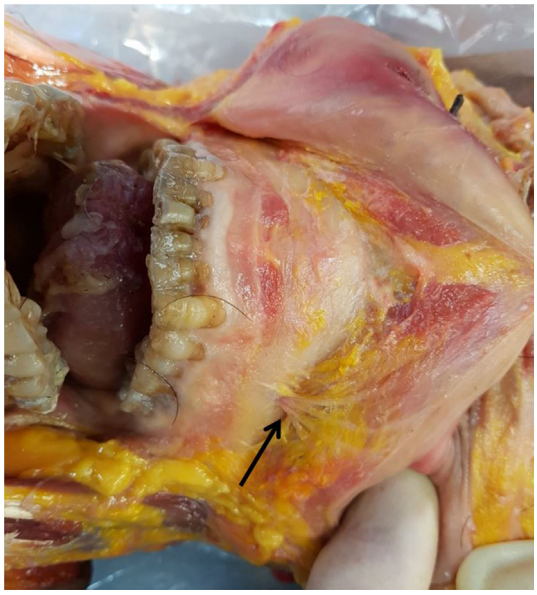
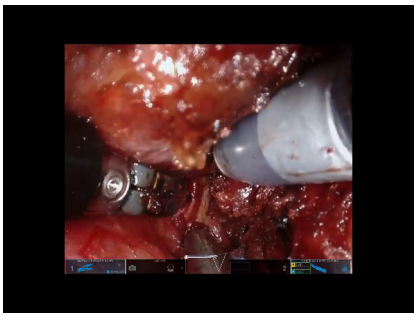


Fig. 2. The anatomy of mental nerve. The nerve emerges at the mental foramen in the mandible, and divides beneath the depressor anguli oris muscle into three branches. One descends to the skin of the chin. Two ascend to the skin and mucous membrane of the lower lip.



Video 1.

Results

Ability to perform gasless TORT using the DaVinci SP

After creating a working space through the oral vestibular incision, two 6-mm-sized instruments and an endoscope were inserted through the single incision. Positioning the cannula approximately 10 cm from the oral cavity allows both the first and second joggle joints of the robotic arm to be deployed within the working space. During the operation, the surgeon controlled two robotic arms and the assistant inserted and manipulated a suction device or a Maryland forceps through an endoscopic trocar inserted into the lateral side of the vestibular incision. In all patients, the operation was completed successfully using two robotic arms and one endoscopic instrument controlled by a bedside assistant. The mean operation time was 177 min, and the average time required to set DaVinci SP system was 47 min.

Advantages of DaVinci SP system in performing gasless TORT

The advantages of gasless TORT using the DaVinci SP are as follows. After making an incision in the oral vestibular mucosa, a skin flap was elevated using monopolar cautery and standard surgical instruments from the mandible area to the lower neck area. Then a self-retaining retractor was inserted through the incision, and the remaining portion of the skin flap was elevated using the robotic instruments of the DaVinci SP. Unlike TORT with DaVinci Xi system and CO_2 gas insufflation, our procedure does not require endoscopic equipment to create a working space. Also, in gasless TORT using the DaVinci SP, CO2 gas insufflation is also not required to maintain a working space during the operation. The protruding anterior edge of the mandible could act as an obstacle to entry of the instruments when approaching the thyroid gland through the vestibular incision. However, the DaVinci SP system's robotic arm and endoscope have a “joggle joint” and so can pass over the bony mandible. Compared to the previous Xi system, the SP has 2 degrees of freedom in the motion range of robotic arms, so it is easier to carry out work in a limited working space. And a transaxillary port is unnecessary in gasless TORT using the DaVinci SP because the surgical assistant can insert a suction or endoscopic instrument through the vestibular incision site. Although lateral port could be made for inserting suction or other endoscopic instrument controlled by the assistant, those instruments were inserted through a single vestibular incision site in our technique, not making a separate lateral incision. Also, as the endoscope of the DaVinci SP system is surrounded by an insulator, the risk of thermal damage to the surrounding tissue is extremely low, unlike with the previous Xi system.

Since DaVinci SP system does not provide an advanced energy device, such as a harmonic instrument, it is necessary to perform hemostasis by only using a monopolar or bipolar cautery during operation. As harmonic devices can be used for tissue dissection simultaneously with the ligation of vessels, it make the surgeon perform the operation easily and quickly. However, in TORT using DaVinci SP, we should ligate the blood vessels and resect the tissue separately. It takes more time to do this, and requires more experience to get

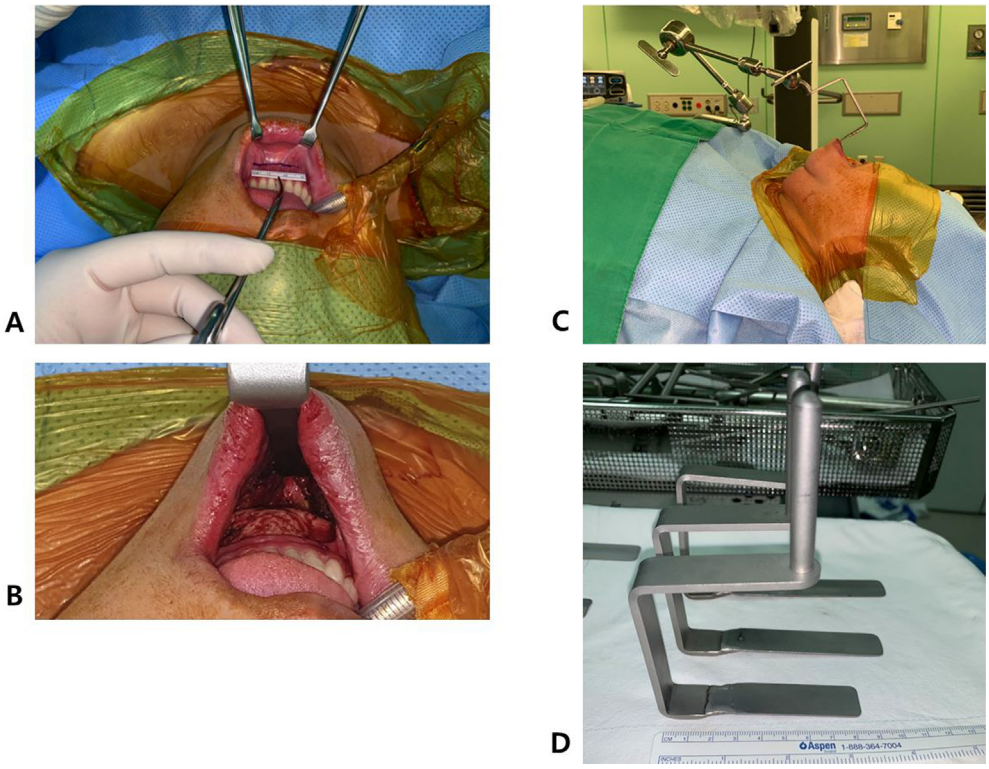


Fig. 3. Patient position, vestibular incision, and insertion of the self-retaining retractor system. (A) 3 cm sized incision was designed at the vestibular area. (B) Skin flap was elevated along the subperiosteal plane. (C) Self-retractor was inserted to maintain the working space. (D) Various sized self-retractor designed for TORT.

accustomed to such operative technique.

Compared to transoral thyroidectomy through vestibular approach, a 3-cm incision was made on the oral vestibular area to enable the removal of larger thyroid specimens without division or morselization. However, in cases of malignant tumor, specimens should be retracted within specimen bags to prevent seeding of malignant cells.

Treatment outcomes

All patients underwent gasless TORT using the DaVinci SP system and successfully completed the operation. There was no case in which the operation was converted to open surgery due to severe bleeding or technical issues. Nine patients underwent unilateral thyroid lobectomy and one patient received total thyroidectomy. On permanent pathologic examination, nine cases had papillary thyroid carcinoma, and one had benign nodules. The mean surgical time was 177 min, and the mean hospital stay was 6.3 days. Compared with thyroidectomy using the previous Xi system, there was no significant difference in amount of bleeding and hospital stay. However, the total operation time of gasless TORT was longer than for other thyroid surgery but can be decreased with experience. In the final case herein, the operation was completed within 80 min.

Perioperative complications and blood loss

Postoperative complications were investigated in all patients. No

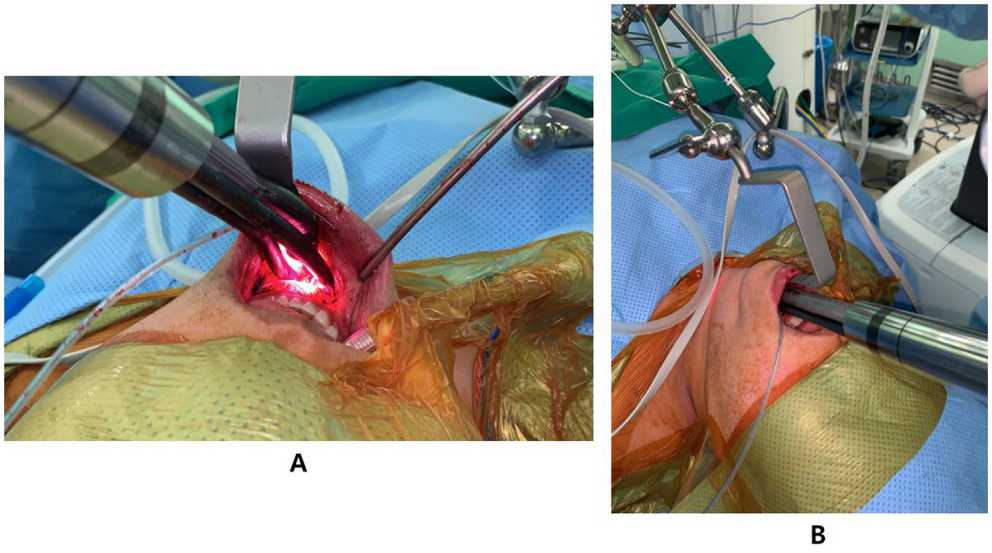


Fig. 4. Proper settings and preparation of gasless TORT using the DaVinci SP. Two robotic arms and one endoscopic arm were inserted through a single vestibular incision site. Additional lateral port was not necessary to insert a suction or endoscopic instrument controlled by the assistant. Small sized L-tube was inserted through a single vestibular incision for suctioning fumes during the procedure.

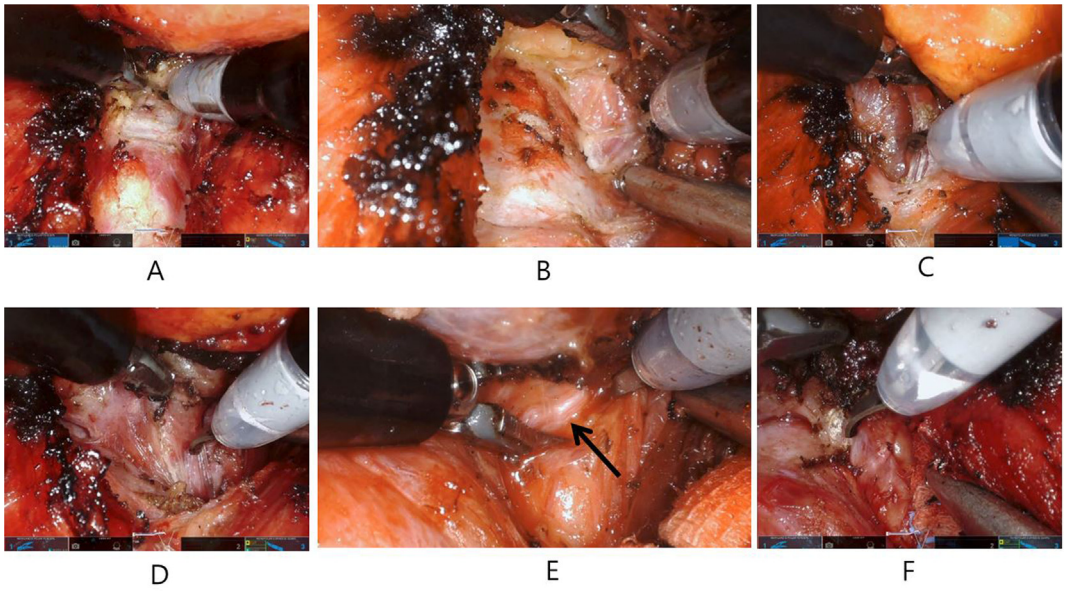


Fig. 5. Operative procedure of gasless TORT using the DaVinci SP. (A) Isthmusectomy was performed at first. (B) The avascular plane of cricothyroid space was dissected. (C) Sternothyroid muscle was dissected to expose the upper pole of the thyroid gland. (D) Superior vascular pedicle of the upper thyroid pole was ligated. E. Recurrent laryngeal nerve (Black arrow) was identified lateral to the cricothyroid joint. (F) Finally, the thyroid gland was dissected from the Berry's ligament.

vocal fold paralysis or hypoparathyroidism occurred after surgery. Although postoperative seroma was occurred in one patient, skin flap breakage and other wound problems were not observed in this study. Three patients complained of hypoesthesia in the mental area after the operation but recovered within 1 month without any treatment. The mean blood loss during operation was less than 30 ml, and there was no need for blood transfusion or conversion to open surgery due to severe bleeding.

Patient's satisfaction score

Patient satisfaction with the cosmetic results was measured on a graded scale of I (extremely satisfied), II (satisfied), III (average), IV (dissatisfied), and V (extremely dissatisfied). This subjective measure of cosmetic satisfaction was already described in our previous study [13]. All patients were satisfied with their cosmetic results (Table 2 and Fig. 6).

Discussion

During recent decades, various minimally invasive and remote access approaches have been developed in the field of thyroid surgery including transaxillary endoscopic or robotic, transareolar breast, and retroauricular robotic approaches [4,14–16]. These surgical approaches can minimize or hide visible scarring but require extensive tissue dissection to access the thyroid gland from a distant site and so are accompanied by extensive tissue damage. Also, in these surgical approaches, a small, but hidden skin incision is necessary. Due to extensive tissue damage, some of these surgical approaches involve increased postoperative pain and longer hospital stay [17,18]. As ideal minimally invasive surgery would minimize tissue damage and avoid extensive tissue resection and scarring, these remote access approaches are not truly minimally invasive.

In 2007, Witzel et al. performed transoral endoscopic thyroid surgery through an incision in the floor of the mouth and named it a natural orifice transluminal endoscopic surgical approach [19]. Compared with previous remote access approaches, transoral endoscopic thyroidectomy required much less tissue dissection to access the thyroid gland from the incision site, and visible scars can be completely hidden. However, it has not been widely adopted or performed due to its complications. Subsequently, several investigators modified this surgical technique by creating the small, lateral incision site in the gingivabuccal sulcus area and performing transoral thyroidectomy through a vestibular incision using endoscopes or robots [8,20,21]. Since then, this transoral vestibular approach has been adopted in many institutions because it confers a small degree of tissue damage and has the advantage of completely hiding the scar. Several authors have reported excellent treatment outcomes of a transoral endoscopic or robotic vestibular approach [10,22–24].

The transoral vestibular approach has the advantage of approaching the contralateral thyroid lobe easily because it provides a central surgical field, unlike the transaxillary or retroauricular approach. In

Table 2
Perioperative data and functional outcomes.

No.	Docking time, min	Console time, min	Estimated blood loss, ml	Hospital stay, days	Complication	Cosmetic satisfaction
1	120	188	50	8	Temporary hypoethesia	I
2	40	242	< 10	11	Temporary hypoethesia	I
3	30	178	< 10	11	None	I
4	30	276	< 10	6	Temporary hypoethesia	I
5	30	150	50	3	None	I
6	30	120	< 10	7	None	I
7	10	150	< 10	3	None	I
8	10	260	100	5	None	I
9	10	130	< 10	4	Seroma	I
10	10	80	< 10	5	None	I

Fig. 6. Postoperative photograph of two patients who underwent gasless TORT using DaVinci SP.

addition, when using a robot, it is possible to use a wristed instrument with tremor filtration and 3D magnified visualization of the surgical site, enabling surgical precision. However, it is still difficult to operate on the upper pole of the thyroid gland because the robotic appliances currently used are not flexible. Also, CO_2 gas insufflation is required to maintain the working space during the operation and it can induce fatal complication, such as CO_2 embolism. The occurrence of clinically significant CO2 embolism is rare, but it has the potential to cause fatal complications during endoscopic surgery. The most common cause is CO_2 being injected through large diameter vessels. Depending on the patient's condition and the volume and degree of CO_2 injected, the severity of symptoms varies from asymptomatic to death. Therefore, it is important to prevent the vessel injury during operation using this delicate surgical technique. On the contrary, the DaVinci SP system is a single-port flexible system and is superior to the previous Xi system in performing narrow-access surgery such as transoral robotic surgery, because it can be easily moved within a narrow, long working space [25,26]. The robotic arms and endoscope of the DaVinci SP have two "joggle joints" that support two additional degrees of freedom of the robotic arm compared to previous systems, allowing ease of movement within narrow and confined spaces. In addition, a digital zoom function is built into the endoscope, which can form an "cobra shape" to ensure various angles of view. In this study, two robotic arms and an endoscope were inserted through a 2.5 cm single vestibular incision, and the operator was able to adjust the angle and location of the endoscope to ensure proper view of all parts of the thyroid gland. Using the two flexible robotic arms, the upper and lower poles of the thyroid gland could be handled without any difficulty.

In our study, the transoral vestibular approach using the DaVinci SP system without a gas insufflation required much time for docking and had a long operation time. However, with experience, we confirmed that docking time and overall operating time decreased. Finally, the console time could be reduced to 60 min. Although there are Maryland forceps, scissors, and prograsp forceps available for the DaVinci SP system, no harmonic scalpel is available for ligating vessels. Therefore, there is a disadvantage of using only bipolar or monopolar cautery for vascular ligation. Therefore, careful attention is needed to prevent postoperative bleeding and a clip applier of robotic arm could be used if neccessary. Although we used only bipolar cautery for ligation of the blood vessels in this study, there was no serious bleeding during or after surgery. In some patients, temporal hypesthesia was observed in the mentum area, but all of them recovered within 3 months without any treatment. Complications such as vocal fold paralysis and skin flap breakage did not occur. In addition, oral diet could be started from the day after surgery, there was no surgical site infection, and the average hospital stay was 3.3 days.

Conclusion

Based on the results of our study, we confirmed that gasless TORT using the DaVinci SP system was feasible and safe. Because CO_2 gas insufflation is not used in our procedure, there is no possibility of related fatal complications such as CO_2 embolism. Additionally, as a suction device or endoscopic instruments can be inserted through the lateral port, a transaxillary port is not required, unlike TORT using the DaVinci Xi. Due to the flexibility of the endoscope and the robotic arms, appropriate visualization of the thyroid gland and facilitation of the operation are achieved.

Declaration of Competing Interest

None declared.

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