New Device for Securing Nasotracheal Intubation Tube During Oral and Maxillofacial Surgery

Kyotaro Koshika¹, Tatsuki Hoshino¹, Yasunori Shibata², Takashi Ouchi¹ and Toshiya Koitabashi¹

¹ Department of Anesthesiology, Tokyo Dental College Ichikawa General Hospital, 5-11-13 Sugano, Ichikawa, Chiba 272-8513, Japan
² Shibata Orthodontic Clinic, 1-23-2 Oi, Shinagawa-ku, Tokyo 140-0014, Japan

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Abstract

Since 2018, we have been using a 3D printer to fabricate a proprietary device for fixing nasotracheal tubes. The aim of this retrospective study was to investigate the impact of this nasotracheal intubation (NTI) fixation device. It has been used in 335 patients undergoing general anesthesia for oral and maxillofacial surgeries. No necrosis or permanent tissue damage was observed, and none of the patients developed complications requiring treatment. No unintentional tube-related incidents such as extubation, dislocation of the tube, or disconnection between the tube and the artificial respiration circuit occurred either. This fixation device offers three advantages: safety, no impediment to surgery, and minimal invasiveness. Of these, safety is the most important. The high degree of immobilization it offers makes it possible to prevent injury to the nasal ala when the tracheal tube is tugged to the cranial side. There is also a high degree of immobilization at the connection site between the tracheal tube and anesthesia circuit, making it possible to prevent disconnection due to intraoperative pressure. In addition, safety during fixation is less likely to differ depending on the degree of proficiency of the individual anesthesiologist. The presence of a groove through which the sampling tube of the capnometer can be passed makes it possible to prevent the problem of flexion of the sampling tube, rendering detection impossible during surgery. Thus, use of this fixation device offers the potential to improve immobilization of the tracheal tube and increase intraoperative safety. However, there remain several problems that need to be addressed with this novel device. Further improvements aimed at enhancing safety are planned, therefore.

Key words: Nasotracheal intubation — General anesthesia — Oral surgery — Fixation device — 3D printer
Introduction

Nasotracheal intubation (NTI) is one of the most common methods of maintaining general anesthesia during oral and maxillofacial surgeries. It involves a tracheal tube being passed through the nose to allow better isolation and good surgical access during intraoral procedures\(^6\). Nasotracheal intubation has several drawbacks, however. Compression from the tube may cause superficial necrosis of the nasal ala and deformation of the external nose\(^8\). Therefore, fixation of the tracheal tube during NTI is important. Until recently at our institution, a sponge was placed on the patient’s forehead. A heat and moisture exchanger (HME) was then placed on top of the sponge, and a tape used for fixation. It proved impossible to avoid complications with this method, however, such as injury to the nasal ala or forehead, unintentional tube-related incidents such as extubation, dislocation of the tube, or disconnection between the tracheal tube and the artificial respiration circuit. Therefore, since 2018, we have begun using a 3D printer to fabricate a proprietary device for fixing the nasotracheal tube (Fig. 1). The aim of this retrospective study was to investigate the impact of this NTI fixation device.

Method

Complications occurring in patients in whom the NTI fixation device was used were retrospectively investigated based on medical and anesthesia records. This study was approved by the Ethics Committee of Tokyo Dental College Ichikawa General Hospital (Approval Number: I 19-81)

1. Method for creating device

1) The software used was 123D\(^\circ\) Design (AUTODESK\(^\circ\), Tokyo, Japan). An image of the HME (Hygrobac S [Covidien Japan, Tokyo, Japan]) used at our institution was created (Fig. 2-A).

2) The body of the fixation device was created. a) A right-angled parallelepiped was created 80 mm in width, 120 mm in height, and 120 mm in depth. Next, b) a ball with a 100-mm radius was created, and subtraction of b) from a) performed (Boolean operation) (Fig. 2-B).

3) The body of the fixation device was processed to be filled with HME and the tube. Subtraction was performed at the following sites: HME, flex, and the sampling tube of the capnometer (Fig. 2-C).

4) Edges and corners were trimmed to eliminate any sharpness (Fig. 2-D).

5) Error checking was performed with a Meshmixer\(^\circ\) (AUTODESK\(^\circ\), Tokyo, Japan), and the slicer was an Ultimaker Cura (Ultimaker, Utrecht, Netherlands).

6) A 3D printer (Creality 3D CR-10S [BONSAI LAB, Tokyo, Japan]) was used to fabricate the NTI fixation device based on the data created. The material used was thermoplastic polyurethane because of its lightness and flexibility. The settings were as follows: layer height, 0.1 mm; outer contour (wall thickness), 0.8 mm; infill density, 15%; print temperature, 230\(^\circ\)C; build plate temperature, 0\(^\circ\)C; print speed, 40–60 mm/sec; fan activated/support activated; and support overhang angle, 50\(^\circ\).

7) Fabrication took approximately 20 hours. The weight of the complete fixation device was 142 g, and the materials cost.

Fig. 1 New device for securing nasotracheal intubation tube
A: View from top. B: View from side. Size of device: a) 80 mm wide \(\times\) b) 120 mm deep \(\times\) c) 120 mm high
approximately ¥300.

2. Method of fixation

1) Tape was used for fixation so that the patient’s surgical cap would not fall off (Fig. 3-A).

2) The nasotracheal tube was fixed to the nasal ala with a tape that had been cut to have a bifurcation (Fig. 3-B).

3) A gauze of approximately 1 cm in thickness was placed on the forehead, with the NTI fixation device placed on top; the HME was then set (Fig. 3-C).

4) A tape was used to fix the NTI fixation device in the patient (Figs. 3-D).

Results

The NTI fixation device was used in 335 patients who underwent general anesthesia for oral and maxillofacial surgeries. Although redness of the nasal ala developed in several of the patients after extubation, it disappeared quickly soon after. No necrosis or permanent tissue damage was observed, and none of the patients developed complications requiring treatment. No unintentional tube-related incidents such as extubation, dislocation of the tube, or disconnection between the tube and the artificial respiration circuit occurred either.

Discussion

This report described a proprietary device for fixation of a nasotracheal tube that was developed and fabricated at our institution. When used for tracheal tube fixation, this fixation device offers three advantages: safety, no impediment to surgery, and minimal invasiveness.

Of these, safety is the most important. As this fixation device is fabricated by scanning and cutting-out the HME in advance, creating
a perfect fit for the HME, the high degree of immobilization thus achieved makes it possible to prevent injury to the nasal ala when the tracheal tube is tugged to the cranial side. There is also a high degree of immobilization at the connection site between the tracheal tube and the anesthesia circuit, making it possible to prevent disconnection due to intraoperative pressure. In addition, safety during fixation is less likely to differ depending on the degree of proficiency of the individual anesthesiologist. The presence of a groove through which the sampling tube of the capnometer can be passed makes it possible to prevent the problem of flexion of the sampling tube, rendering detection impossible during surgery. Placing the fixation device on approximately 1 cm of gauze can prevent injury to the forehead from compression. Thus, the use of this fixation device offers improved safety during general anesthesia.

The second advantage is that it does not impede surgery. As this device is fixed to the forehead, oral surgeries in the maxillofacial area, mouth, and neck are not impeded.

The third advantage is that it is minimally invasive. This fixation device is non-invasive, as it is fixed to the patient with tape. However, careful attention must be paid to the possibility that inadequate immobilization with tape could cause the NTI fixation device to slip off the patient’s forehead, causing the tracheal tube to be pulled backward, compressing the nasal ala. Figure 3-D shows an example of how firm fixation with tape may be achieved.

This fixation device is believed to meet the criteria required for fixation of tracheal tubes. Previously reported methods of fixation include tube ligation, suturing the tube to the pericranium, using a disposable catheter stopping, using a Mayo table to support the tube, using custom-made splints, and creating a fixation device by bending a wire. If the tube is ligated, there is the risk of perforation of the cuff inflation line, resulting in a cuff leak and subsequent failure of ventilation. Suturing the tube to the patient is also invasive. Using a Mayo table limits the surgeon’s positioning and impedes surgery. Fixation of devices by means of a bent wire can cause occipital pain and hair loss. A common disadvantage of the reviewed methods is the risk of endotracheal tube kinking and compression over the nasal alar cartilage while rotating or tilting the patient’s head. Our fixation device allows all these shortcomings to be avoided,

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Fig. 3 Method of fixing nasotracheal intubation tube fixation device to patient
A: Tape was used for fixation so that patient's surgical cap would not fall off. B: Nasotracheal tube was fixed to nasal ala with tape cut to have bifurcation. C: Gauze approximately 1 cm in thickness was placed on forehead, with NTI fixation device placed on top; HME then set. D: Tape was used to fix nasotracheal intubation fixation device in patient.
However, the novel NTI fixation device reported here was fabricated using a 3D printer. When manufacturing with a 3D printer, weight, material, and shape can be freely modified. This is important as the shape of the HME differs from one manufacturer to another. This novel method of fabrication using a 3D printer allows the NTI device to be tailored to the shape of the HME used on each installation. In the near future, we hope to be able to create a customized fixation device that matches the shape of the patient’s forehead using a 3D printer.

There are several problems that need to be addressed with this fixation device, however. To prevent complications during long surgeries, a further reduction in weight and improvements in flexibility would be desirable. Changes to the materials or settings might make it possible to fabricate a softer, more flexible fixation device. Durability is also essential, however. Therefore, the search for optimal materials and settings remains challenging. The curve of the surface of the current fixation device in contact with the patient constitutes a sphere with a radius of 100 mm. We are currently considering how to achieve fabrication that matches the mean values of the curve of the forehead surface in Japanese people, as this would allow for a better fit and improve immobilization.

**Conclusion**

At our facility, a 3D printer was used to fabricate a proprietary nasotracheal tube fixation device. Use of this fixation device offers the potential to improve immobilization of the tracheal tube and increase intraoperative safety. We intend to make further improvements aimed at further enhancing safety.

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**Correspondence:**

Dr. Kyotaro Koshika
Department of Anesthesiology,
Tokyo Dental College Ichikawa General Hospital,
5-11-13 Sugano, Ichikawa, Chiba
272-8513, Japan
E-mail: koshikakyotarou@tdc.ac.jp