










## OPERATIVE TECHNIQUE

# Full-Endoscopic Anterior Odontoid Screw Fixation: A Novel Surgical Technique

Vit Kotheeranurak, MD<sup>1</sup> , Phattareeya Pholprajug, MD<sup>2</sup> , Khanathip Jitpakdee, MD<sup>1</sup> , Pritsanai Pruttikul, MD<sup>3</sup> ,  
Roongrath Chitragran, MD<sup>4</sup> , Weerasak Singhatanadgige, MD<sup>5,6</sup> , Worawat Limthongkul, MD<sup>5,6</sup> ,  
Wicharn Yingsakmongkol, MD<sup>5,6</sup> , Jin-Sung Kim, MD, PhD<sup>7</sup> 

<sup>1</sup>Department of Orthopaedics, Queen Savang Vadhana Memorial Hospital, Sriracha, <sup>2</sup>Department of Orthopaedics, Rayong Hospital, Rayong and <sup>3</sup>The Orthopaedic Center, Bumrungrad International Hospital, <sup>4</sup>Department of Orthopaedics, Phramongkutklao hospital and college of medicine and <sup>5</sup>Department of Orthopaedics, Faculty of Medicine and <sup>6</sup>Center of Excellence in Biomechanics and Innovative Spine Surgery, Chulalongkorn University, Bangkok, Thailand and <sup>7</sup>Department of Neurosurgery, Seoul St. Mary's Hospital, Spine Center, College of medicine, Seoul, South Korea

**Objective:** First, to propose a novel minimally invasive technique of full-endoscopic anterior odontoid fixation (FEAOF) that aims to reduce the risk of retropharyngeal approach (both open and percutaneous techniques) to anterior odontoid screw fixation. Second, to describe steps of the procedure and, lastly, to report the initial outcomes in patients treated with this novel technique.

**Methods:** Four non-consecutive patients who were diagnosed with a displaced odontoid fracture (Anderson-D'Alonzo classification type II and Grauer subclassification type A or B) from 2019 to 2020 underwent surgical fixation by our novel technique for anterior odontoid screw fixation. A detailed technical approach of FEAOF for the surgical treatment of type II odontoid fractures was described, and the patients' outcomes based on postoperative radiographic results including computed tomography (CT), clinical outcome parameters including visual analogue scale (VAS) for neck pain both preoperatively and at postoperative follow-up, and range of neck motion at the final follow-up were reported.

**Results:** The mean age was 33.5 years (24–41), three patients were male. The mean operative time was 93.75 min, and the mean blood loss was 7.5 ml. An immediate post-operative thin-sliced CT showed that all patients achieved satisfactory reduction and proper screw position. No screw malposition or penetration was found. At a 6-month follow-up, a thin-sliced CT demonstrated solid bony union in every case. The mean VAS for neck pain was reduced from 6.5 to 0.6 at the 6-months follow-up. At the final follow-up, all patients showed improvement in ranges of motion without any complications; however, one patient was lost to follow-up.

**Conclusions:** FEAOF is a feasible and effective option for treating type II odontoid fractures. The procedure is less invasive than other techniques and provides clear direct visualization of the involved structures.

**Key words:** Anterior screw fixation; Endoscopy; Full-endoscopic; Minimally invasive; Odontoid fracture

## Introduction

Odontoid fractures can lead to significant morbidities and mortalities, especially in elderly patients.<sup>1–4</sup> Nonunion of odontoid fractures potentially causes chronic neck pain or

significant neurological deficits from spinal cord compression. According to the Anderson–D'Alonzo classification, high nonunion rates of 15%–85% were reported in type II odontoid fractures.<sup>1,5,6</sup> This type of fracture is associated

**Address for correspondence** Vit Kotheeranurak, MD, Department of Orthopaedics, Queen Savang Vadhana Memorial Hospital, 290 Jermjomphol road, Sriracha, Chonburi, Thailand. Email: vit.ko@somdej-mec.or.th, vitinspine@gmail.com

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with poor prognosis and is the most challenging for spinal surgeons. Treatment options for odontoid fractures depend on the fracture configuration, displacement, patient's age, and surgeon's surgical preference. In unstable type II fractures, the surgical treatment options vary and are currently debatable. However, to reduce the nonunion rate in this type of fracture, a surgeon needs to turn an unstable to a stable fracture by producing the most accurate, secure, and stable fixation. For these reasons, surgery plays a major role in the treatment of displaced type II odontoid fractures.

To stabilize these fractures, many techniques have been proposed, including posterior cervical instrumented fusion and anterior odontoid screw fixation (non-fusion technique). Patients with reducible type II odontoid fractures with Grauer subclassification type B are considered good candidates for anterior odontoid screw fixation.<sup>7,8</sup> This technique has many advantages over posterior fusion procedures, including a high union rate, immediate stability, preservation of cervical spine motion, less soft tissue injury, and the possibility to be performed in patients with anomalies such as ponticulus ponticus or high riding vertebral artery.<sup>9</sup> However, there are many serious complications related to the anterior retropharyngeal approach to odontoid fixation. These include possible injury to the pharynx, esophagus, airway, vascular, and neural structures.<sup>9,10</sup> Surgical approach and screw-related complications have been reported in both open and percutaneous techniques.<sup>9-11</sup>

To minimize these risks, the use of full-endoscopic surgery in anterior odontoid screw fixation procedures was initiated. The endoscopic system can help the surgeon visualize the appropriate screw entry point and surrounding structures resulting in increased screw placement accuracy and reduced soft tissue injury. The aim of the study is to, first, propose a novel minimally invasive technique of full-endoscopic anterior odontoid fixation (FEAOF) that aims to reduce the risk of retropharyngeal approach (both open and percutaneous techniques) to anterior odontoid screw fixation, second, to describe steps of the procedure and lastly, report the initial outcomes in patients treated with this novel technique.

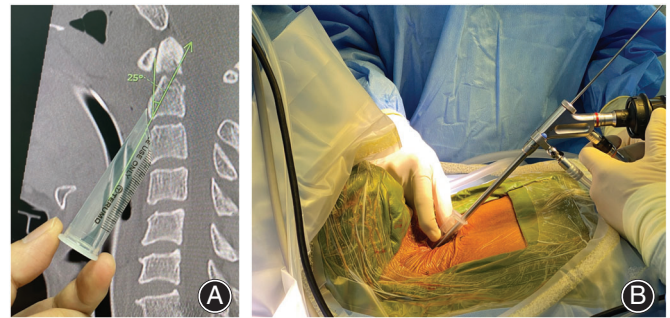
## Methods and Materials

### Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (i) diagnosis of displaced odontoid fracture, Anderson-D'Alonzo classification type II and Grauer subclassification type A or B; (ii) reducible odontoid fracture; and (iii) age between 20–80 years. The exclusion criteria were as follows: (i) morbid obesity; (ii) barrel-shaped chest; (iii) neurologically compromised; (iv) severe comminutions; and (v) associated neck or airway injuries.

### Ethical Considerations

Informed consent was obtained from all participants in the study, and all procedures were approved by the ethics



**Fig. 1** A preoperative preparation of the syringe working sleeve for a full-endoscopic system (A), the application of syringe working sleeve and the endoscopic system during the procedure (B).

committee of the institution (EC number 30/2020). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

## Surgical Technique

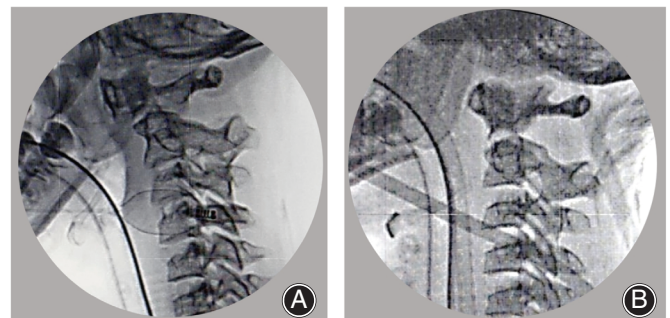
### Preoperative Planning

Certain prerequisites are necessary to utilize this technique. A recent fracture has a higher likelihood of fracture reduction. An oblique fracture pattern perpendicular to the screw trajectory results in the greatest biomechanical benefit. The patient's body habitus must allow proper screw trajectory. The presence of anomalies such as a barrel-shaped chest, short neck, and cervical or thoracic kyphosis may have an impact on results.<sup>7,9</sup>

Preoperative X-ray or computed tomography (CT) scans are used to measure the length of the screw and the proper angle of the syringe, which is used as a soft tissue protector. The syringe tip cutting angle ranges between 25° and 40° depending on the fracture line (Fig. 1A).

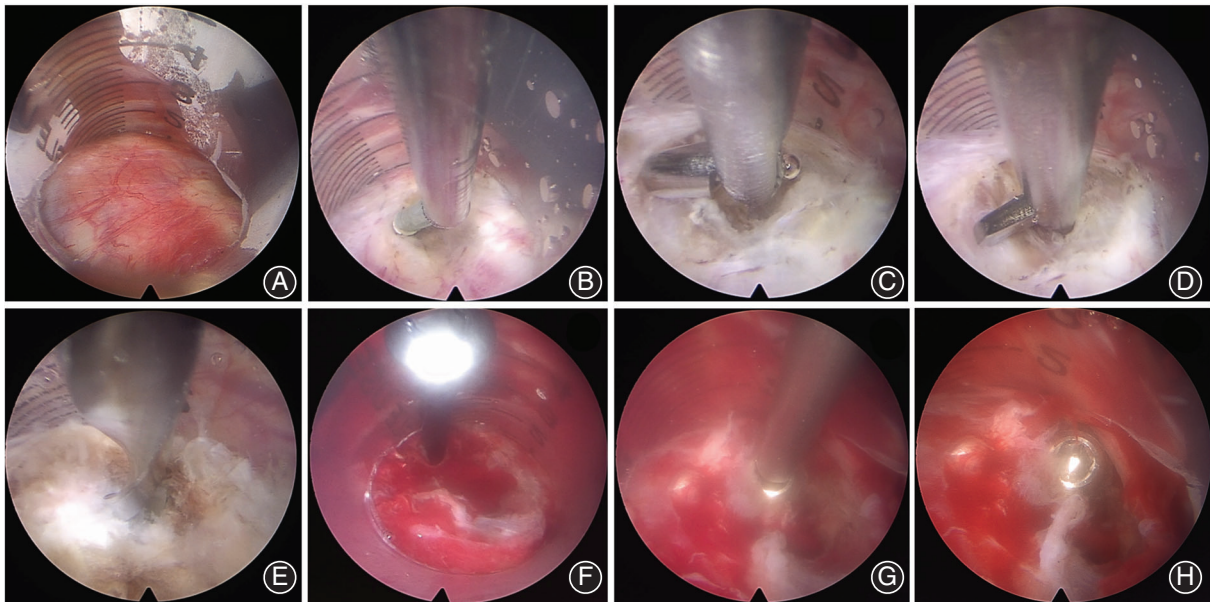
### Position, Anesthesia, and Approach

The FEAOF surgery is performed using the Vertebis System (RiwoSpine, GmbH, Knittlingen, Germany). Under general anesthesia, the patient is placed in a supine position. The



**Fig. 2** Pre- and post-reduction intraoperative X-ray.

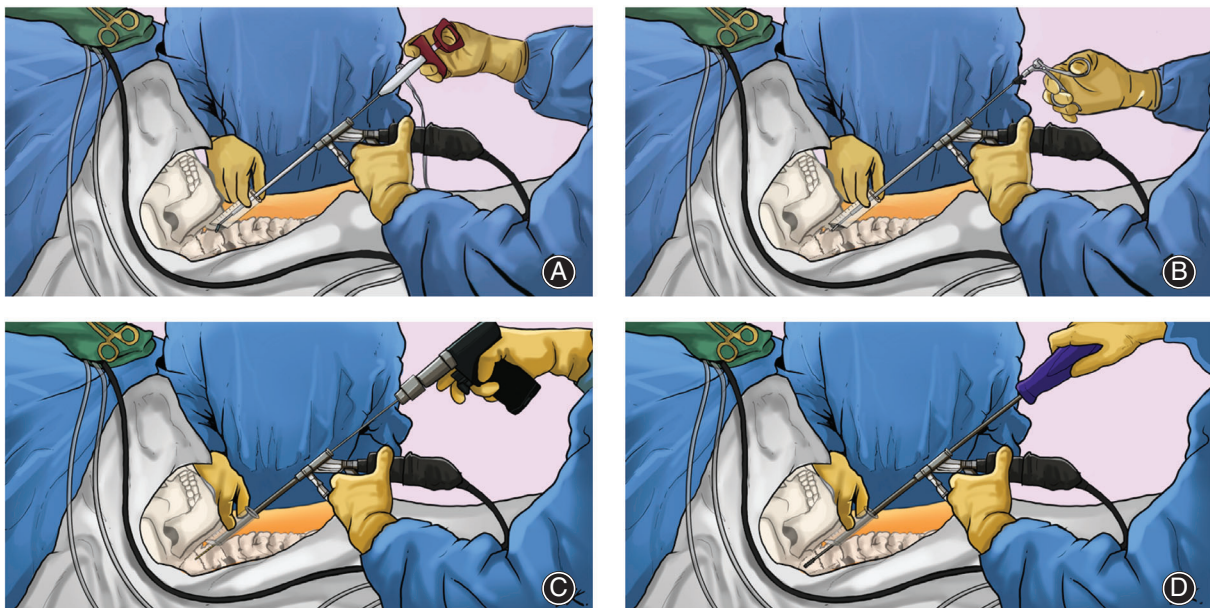




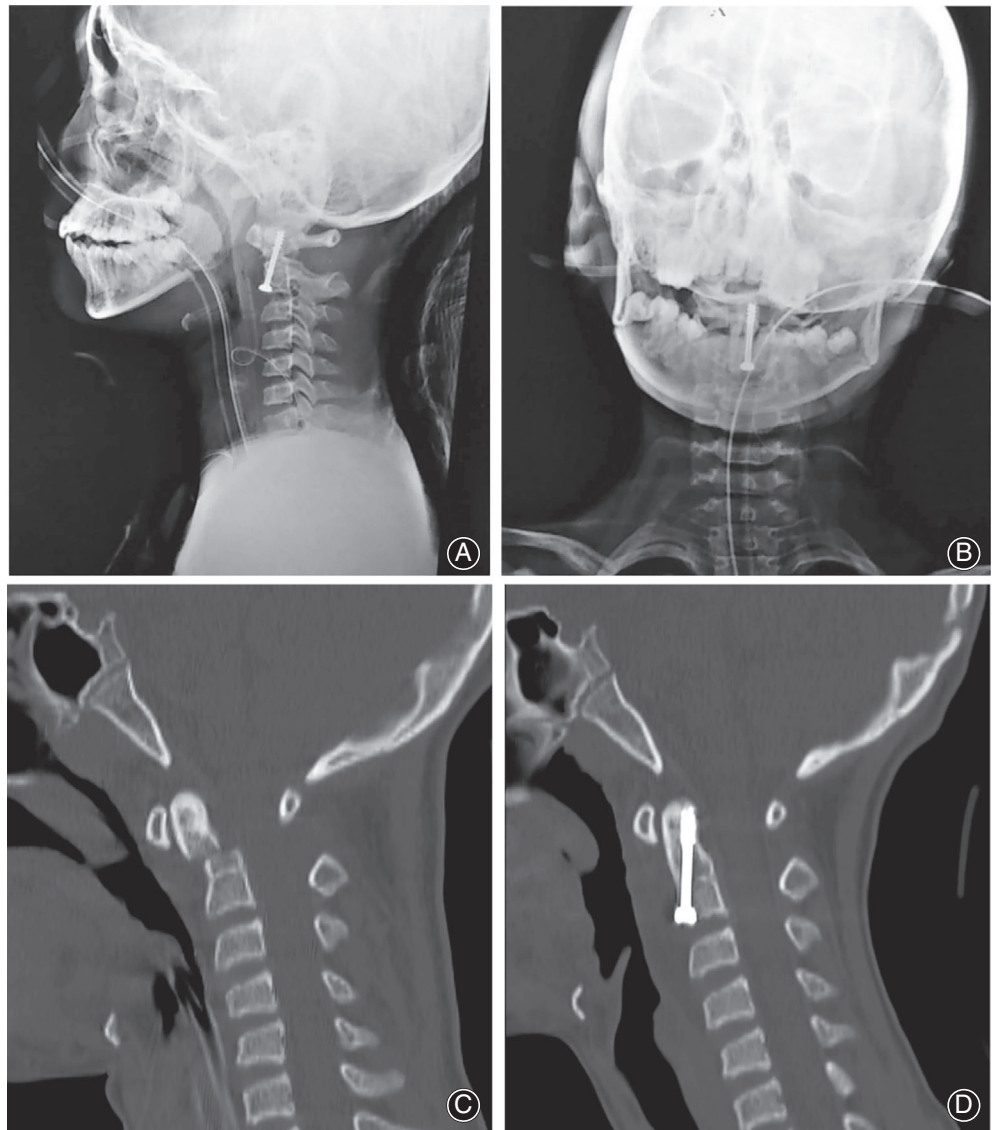
**Fig. 3** Intraoperative endoscopic views. The anterior aspect of C2/3 intervertebral disc (A), various kinds of endoscopic instruments for identification of a proper screw entry point: a 4-Mz radiofrequency bipolar cautery (B), a pituitary rongeur for tissue grasping (C), and a punch forceps for tissue cutting (D), endoscopic views of entry point drilling (E), and screw insertion (F–H).

head is positioned over the end of the table and fixed with a Mayfield clamp in an extended position to allow the appropriate trajectory for fixation. A dual fluoroscopic technique is used for anteroposterior (AP) and lateral X-ray images. Anatomic reduction is performed and confirmed *via* fluoroscopy

(Fig. 2A,B). A radiolucent bite block is placed in the mouth to allow an unobstructed AP open-mouth view. After prepping and draping, the tip of a 10mL polyethylene syringe is cut at the exact degrees measured preoperatively. It is essential to make sure that the cut end of the syringe is blunt and



**Fig. 4** The FEAOF technical steps. Radiofrequency use (A), pituitary rongeur use (B), drilling via the custom-made syringe (C), tightening of the screw (D).



**Fig. 5** Example of the case done by the FEAOF technique: immediate postoperative X-ray showed the realigned fracture with minimal gap seen in the lateral (A) and anteroposterior (B) views. Pre- and 12 months postoperative CT scans (C and D) showed a fracture reduction and a proper screw placement and union.

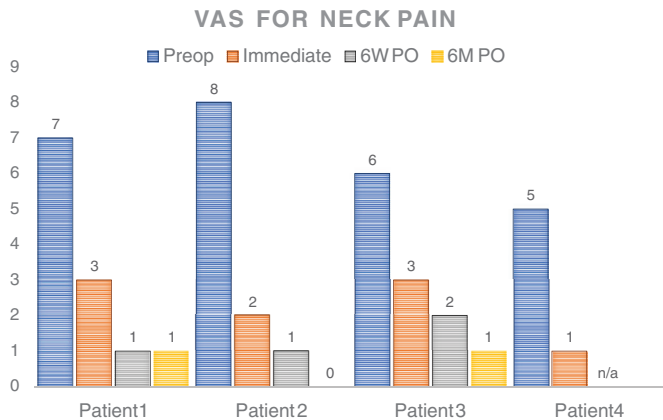
smooth before insertion. A 3–4 cm oblique skin incision is made at the sternocleidomastoid groove at the level of the C4/5 intervertebral disc. Gentle dissection is performed between the carotid sheath (laterally) and medial structures,

which include the strap muscles, esophagus, and trachea. Narrow size Langenbeck retractors are used to guard the surrounding structures. The longus coli muscles are identified and the anterior aspect of the C2/3 intervertebral disc is

**TABLE 1** The clinical characteristics of the patients in the case series

No.	Age (yrs)	Sex	Type	Operative time (min)	EBL (ml)	Complications	Follow-up (mos)	Union
1	33	M	IIA	115	10	None	12	Yes
2	24	M	IIB	75	5	None	10	Yes
3	41	F	IIB	100	5	None	7	Yes
4	36	M	IIA	85	10	None	n/a	n/a

Abbreviation: EBL, estimated blood loss.



**Fig. 6** The VAS score for neck pain of the participants.

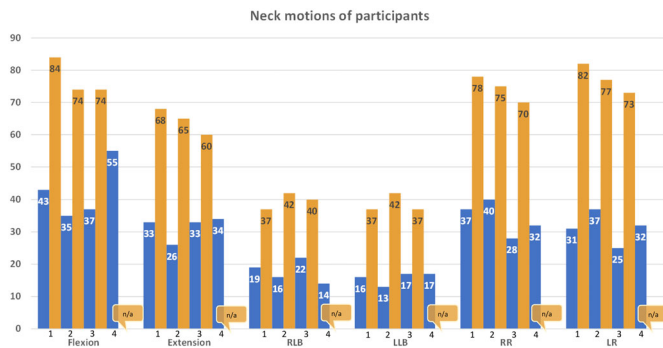
approached. The beveled syringe is then carefully introduced into the disc space and the endoscope is applied through the syringe (Fig. 1B).

#### Entry Point Identification

An isotonic saline solution is used as the irrigation fluid. The water pressure and flow are set at approximately 80 mmHg and 0.8 L/min. An appropriate entry point is visualized endoscopically and checked by biplanar fluoroscopy. The superior part of the C2/3 intervertebral disc is cauterized using a 4-MHz bipolar radiofrequency electrocautery and partly removed using various types of endoscopic instruments (Fig. 3A–D).

#### Drilling and Screw Fixation

Drilling is performed through an endoscope (Fig. 3E, Fig. 4A) that is closely monitored by biplanar fluoroscopy. At this point in the procedure, the irrigation fluid flow and pressure are increased for better visualization, which is



**Fig. 7** The neck motions of participants between 6 weeks and 6 months postoperatively. RLB, right lateral bending; LLB, left lateral bending; RR, right rotation; LR, left rotation.

compromised by bone bleeding. A partially threaded screw is tightened under both fluoroscopic and endoscopic views (Fig. 3F–H, Fig. 4B,C). Procedures using the cannulated screw system can also be performed in the same manner. This system decreases bone bleeding from the drilling step. The skin is closed in a subcutaneous fashion without retention of a surgical drain after a final bleeding check. Postoperative images are obtained (Fig. 5A,B). A hard collar is applied for 4–6 weeks after surgery.

#### Outcome Measurement

Operative time and blood loss were recorded as intraoperative outcomes. Postoperative outcomes were divided into two main points including imaging analysis and patient clinical outcomes.

#### Radiographic Assessment

All patients received a thin-sliced CT preoperatively (Fig. 5C) and immediately postoperatively to verify screw position and fracture reduction. At a 6-months follow-up, another CT for evaluating fracture union was performed (Fig. 5D).

#### Clinical Assessment

##### Visual Analogue Scale (VAS) Scores for Neck Pain

Neck pain was evaluated using the VAS scoring system preoperatively, immediately after the surgery, and at 2-weeks, 3-months, and 6-months follow-up postoperatively. The scale ranges from 0 to 10 which indicates the severity of pain. A score of 0 indicates no pain and a score of 10 indicates the most severe pain.

##### Neck Ranges of Motion

All patients were evaluated. Neck motion in all planes including flexion, extension, rotation, and lateral bending was measured by standard goniometer at 2-months and 6-months follow-up, and after the CT showed a united fracture (Fig. 5D).

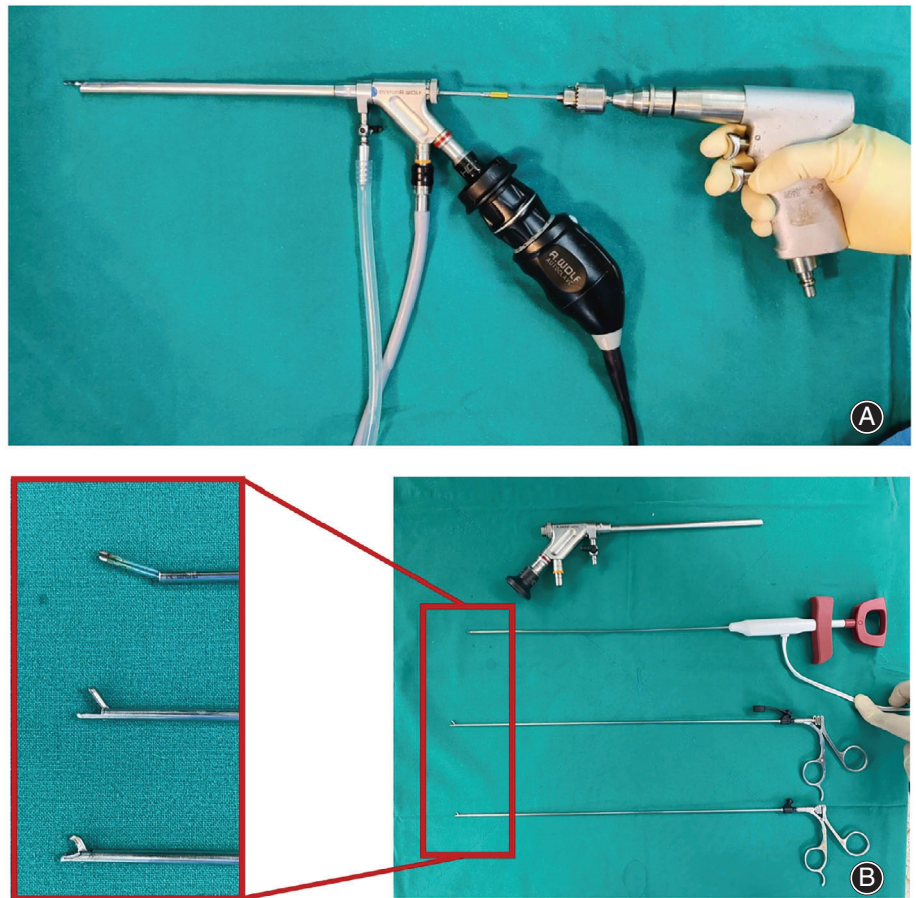
#### Results

Four patients, who sustained a motor vehicle accident that resulted in neck pain without neurological deficits, were diagnosed with displaced odontoid fractures, Anderson–D’Alonzo classification type II and Grauer subclassification type A or B underwent FEAOF. Two patients were type IIA and two patients were type IIB. The mean age was 33.5 years (24–41), three patients were male. Details of patient characteristics are shown in Table 1.

#### Intraoperative Observed Results

All fractures were reduced, and the secure fixations were achieved by the FEAOF technique. The mean operative time was 93.75 min (75–115 min), and the mean blood loss was 7.5 ml (5–10 ml).





**Fig. 8** Drilling via an endoscopic unit (A), various endoscopic tools (B).

### Radiographic Results

Four non-consecutive patients underwent this novel technique. An immediate post-operative thin-sliced CT show that all patients achieved satisfactory reduction and proper screw position. No screw malposition or penetration was found. At a 6-months follow-up, a thin-sliced CT demonstrated solid bony union in all patients.

### Clinical Results

#### VAS Scores for Neck Pain

The mean VAS for neck pain was reduced from 6.5 to 0.6 at the 6-months follow-up (Fig. 6).

#### Neck Ranges of Motion

The mean range of neck motion at 6-weeks and 6-months follow-up were increased from 42.5° to 77.3° in flexion, from 31.5° to 64.3° in extension, from 17.75° to 39.7° in right lateral bending, from 15.75° to 38.7° in left lateral bending, from 34.25° to 74.3° in right rotation, and from 31.25° to 77.3° in left rotation (Fig. 7). At the final follow-up, all patients showed a better range of motion without any complications, however, there was one lost to follow-up (Table 1).

### Discussion

A type II fracture is the most common type of odontoid fracture.<sup>4</sup> However, these fractures have the poorest prognosis; the fracture line occurs through the waist of the odontoid process, often resulting in nonunion.<sup>2</sup> The upper cervical spine is different from the rest of the subaxial cervical spine,<sup>14</sup> because atlantooccipital joints bear more than 50% of the flexion and extension motion in the cervical spine, and the normal atlantoaxial joint is responsible for 50% of cervical spine rotation.<sup>15</sup> The discovery of X-Ray in 1895 brought about a shift of paradigm in the practice of spinal surgery.<sup>12</sup> Fractures of the odontoid process are relatively common injuries.<sup>4</sup> Today, high technology has been used in the medical practice,<sup>13</sup> and this technical progress in the discipline of spinal surgery has led to many new operative procedures, such as endoscopic anterior odontoid fixation.

The use of an anterior odontoid screw, an osteosynthetic technique, is a surgical option for type II odontoid fractures with favorable fracture lines. The technique provides immediate stability, improves fracture union over nonoperative treatment, and preserves major cervical mobility.<sup>8</sup> Even with operative treatment using anterior odontoid screw fixation, a nonunion rate of 10%, screw-related complications, suboptimal screw position, and approach-related complications such as dysphagia and hematoma have been reported.<sup>9-11</sup> To minimize approach-

related complications and surrounding soft tissue injury, minimally invasive cervical spine surgery was introduced. Endoscopic-assisted surgery was reported in 2003 by Hashizume *et al.*<sup>16</sup> however, the authors used a micro-endoscopic camera system. They found improved visualization allowing a smaller incision, decreased blood loss, and reduced surrounding soft tissue injury compared to the traditional open technique.

### ***A Proposal of the Novel Technique: Advantages, Surgical Difficulty, Feasibility, and Pitfalls***

To the best of our knowledge, the current technique was the first to describe the use of a full-endoscopic system in performing anterior odontoid screw fixation. Apart from its minimally invasive nature, full-endoscopic surgery has many advantages. A continuous fluid irrigation system provides surgeons with a better field of visualization and helps reduce bleeding by local vasoconstriction effect from the lower temperature of the irrigation fluid. A channel of the camera unit is available for drilling or inserting a K-wire and tightening the screw through the instrument (Fig. 8). Bleeding from bone after drilling can hinder the working field, this can be solved by elevating the flow and pressure of the endoscopic system and moving the scope closer to the bleeding spot. The FEAOF technique should be performed by endoscopically trained surgeons. Converting to a traditional open technique must be prompted in any case of unexpected events. Using an orthosis for 4 to 6 weeks post-operatively helps reduce the load to the cervical spine and remains an important step in the anterior screw fixation method. The dens has only half of its original strength

immediately after screw fixation and will gain its normal strength when the fracture is fully healed.<sup>14,16-18</sup>

### ***The Initial Results of the FEAOF***

In our study, all patients achieved the goal of surgery including acceptable fracture reduction, good screw position with secure fixation resulted in solid bony union and gain a good range of neck motion without any surgical complications as mentioned.

This study had some limitations regarding the validity, how accurately an investigation answers the study question, and the strength of the study conclusions.<sup>14</sup> In this study, validity refers to how endoscopic technique is useful for odontoid type 2 fractures which the authors reported only four cases, so that one should keep in mind that this study reported only a small number of patients, which is our limitation, thus the validation of this technique could be achieved from a prospective study in the future.

This novel FEAOF technique is a possible and effective option for treating type II odontoid fractures. Owing to the minimally invasive nature of the full-endoscopic system, direct visualization and less soft tissue compromise are the main advantages of this technique.

### **Conflict of Interest**

Authors WS and WL have received speaker honorarium from Medtronic company. Author JSK is consultant to RiwoSpine, GmbH, Germany and Elliquence, LLC, USA. All authors declare that there are no conflicts of interest.

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