



Reduction of comminuted fractures of the anterior wall of the frontal sinus using threaded Kirschner wires and a small eyebrow incision

Da Woon Lee, Si Hyun Kwak, Hwan Jun Choi, Jun Hyuk Kim

Department of Plastic and Reconstructive Surgery, Soonchunhyang University Cheonan Hospital, Soonchunhyang University College of Medicine, Cheonan, Korea

Background: Frontal sinus fractures are relatively rare. Their surgical management significantly differs depending on whether the posterior wall is invaded and the clinical features vary. A bicoronal incision or endoscopic approach can be used. However, the minimally invasive approach has been attracting attention, leading us to introduce a simple and effective surgical method using multiple-threaded Kirschner wires.

Methods: All patients had isolated anterior wall fractures without nasofrontal duct impairment. The depth from the skin to the posterior wall was measured using computed tomography to prevent injury. The edge of the bone segment on the skin was marked, a threaded Kirschner wire was inserted into the center of the bone segment, and multiple Kirschner wires were gently reduced simultaneously.

Results: Surgery was performed on 11 patients. Among them, seven patients required additional support for appropriate fracture reduction. Therefore, a periosteal elevator was used as an adjunct through a small sub-brow incision because the reduction was incomplete with the Kirschner wire alone. The reduction results were confirmed using facial bone computed tomography 1 to 3 days postoperatively. The follow-up period was 3 to 12 months.

Conclusion: The patients had no complications and were satisfied with the surgical results. Here we demonstrated an easy and successful procedure to reduce a pure anterior wall frontal sinus fracture via non-invasive threaded Kirschner wire reduction.

Abbreviations: 3D CT, three-dimensional computed tomography; FSF, frontal sinus fractures; T-K wire, threaded Kirschner wire

Keywords: Bone wires / Facial injuries / Frontal sinus / Minimally invasive surgical procedures

INTRODUCTION

The bicortical structure among the frontal bones is called the

frontal sinus, which is the strongest structure of the skull because it contains two layers of thick bone. Frontal sinus fractures (FSF) are relatively uncommon maxillofacial fractures [1]. FSF account for 5% to 15% of all maxillofacial traumas, while isolated anterior wall fractures account for one-third of all fractures [2,3]. FSF are primarily caused by forces applied directly to the anterior aspect of the skull in the glabellar region. In the anterior wall, the cancellous bone is located between the cortical bones on both sides and thins toward the caudal edge to form the orbital roof. The anterior wall requires a very strong force (800–2,200 pounds) for FSF [4]. However, the posterior wall was relatively thin and directly attached to the dura.

Comminuted fractures of the anterior wall of the frontal sinus are more frequent than simple fractures, as the bone has a sig-

Correspondence: Jun Hyuk Kim

Department of Plastic and Reconstructive Surgery, Soonchunhyang University Cheonan Hospital, Soonchunhyang University College of Medicine, 31 Suncheonhyang 6-gil, Dongnam-gu, Cheonan 31151, Korea
E-mail: psdoctor@schmc.ac.kr

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (2021R1G1A1008337) and was supported by the Soonchunhyang University Research Fund.

How to cite this article:

Lee DW, Kwak SH, Choi HJ, Kim JH. Reduction of comminuted fractures of the anterior wall of the frontal sinus using threaded Kirschner wires and a small eyebrow incision. Arch Craniofac Surg 2022;23(5):220-227. https://doi.org/10.7181/acfs.2022.00934

Received September 29, 2022 / Revised October 4, 2022 / Accepted October 19, 2022

nificant thickness, and it often causes a contour deformation of the central forehead. However, because the surgical site is in the middle of the forehead, attention must be paid to prevent scarring and nerve injury at the incision site during reduction. The sinus structure is often incompletely reduced, which can lead to a persistent forehead contour deformation. Excessive reduction exacerbates spontaneous fractures. Unless adequate reduction is achieved of FSF, the possibility of intracranial and nasopharyngeal communication through the fracture site persists, which may cause severe infectious complications such as meningitis, brain abscess, and mucocele formation [5]. A bicoronal incision is classically used to reduce infectious complications of FSF, but it is invasive and has many complications. Therefore, the surgical goal for anterior FSF should be to achieve a satisfactory aesthetic result without scarring or functional complications. A minimally invasive surgical technique for anterior wall reduction of the FSF using a threaded Kirschner wire (T-K wire) or a small incision in the eyebrow has been introduced recently. However, these surgical techniques have some limitations. Therefore, this study aimed to introduce a novel surgical technique for FSF reduction that involves inserting several T-K wires and a periosteal elevator.

METHODS

From January 2012 to December 2021, patients with comminuted and segmental anterior wall FSF who underwent surgery performed by a single surgeon using a T-K wire were recruited. Patients with nasofrontal duct injuries, posterior FSF, open fractures, or other facial fractures were excluded. All patients

had apparent forehead depressions but no other hypoesthesia of the supraorbital nerves or external lacerations. After the patient's overall condition was stabilized and soft-tissue swelling of the injured area was reduced, fracture reduction surgery was performed.

The goal of the surgical technique was to quickly achieve both adequate bone healing and aesthetically pleasing results with ease. Under general anesthesia, each patient was placed in the supine position. The operative field was prepared and draped in the usual manner. The bone segments in the depressed area were marked on three-dimensional computed tomography (3D CT) (Fig. 1A). The distance from the skin to the posterior wall of the fracture site was measured using the axial view of the 3D CT to avoid brain injury. A fracture line drawing was made mainly around large bone segments to insert a T-K wire, and the distance of each bone segment from the skin to the posterior wall was measured.

After the distance to the T-K wire was indicated using a surgical skin marker, the wire was carefully inserted into each bone segment. When possible, the T-K wire was positioned close to the most severely sunken area to facilitate fracture reduction and placed around a large, more depressed segment (Fig. 1B). After the skin was penetrated by manual puncturing without drilling, a T-K wire was inserted using a drill once the contour of the anterior wall was touched. The T-K wires were inserted by the selection of well-fixed large bone fragments with the exclusion of unstable bone fragments that were felt by the fingertip or T-K wire tip. To prevent damage to the brain or dura, marked T-K wires were carefully inserted without touching the posterior wall. Subsequently, the fracture fragment was gently



Fig. 1. Intraoperative photographic findings for preoperative design. (A) Marks made on the fractured site with a surgical skin marker. (B) The threaded Kirschner wire is inserted into the most depressed part of the fractured fragment.

pulled with T-K wires that were properly fixed to the bone. Unlike the simple Kirschner wire, the T-K wire had the appropriate pulling force necessary to reduce the FSF.

When the reduction force with T-K wires was insufficient, a mini-periosteal elevator was inserted below the fractured anterior wall through a small sub- or supra-brow incision. The reduction was performed using the lever principle by inserting an elevator into the crevasses of the fracture site through a small incision under the eyebrows. If the reduction was unsuccessful, the incision was extended further, the reduction was performed with the elevator with a direct line of sight, and limited fixation was performed with the plate (Fig. 2). Once it was confirmed that sufficient reduction had been achieved by palpation with a fingertip, the T-K wires were gently removed. The immediate postoperative results were determined using ultrasonography (Fig. 3). The algorithm is illustrated in Fig. 4. Once the reduction results were confirmed, the fracture site was protected for 2

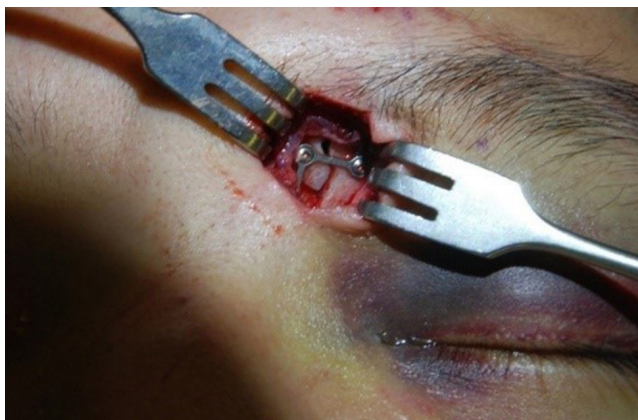


Fig. 2. If proper reduction is not achieved with a periosteal elevator, a plate and limited fixation are used.

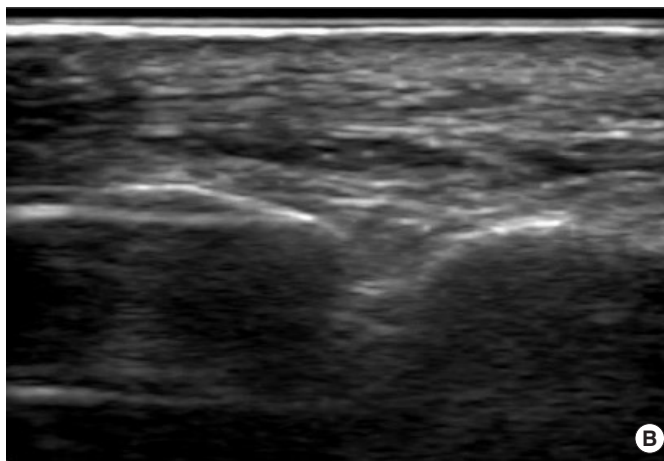


Fig. 3. (A) An ultrasonography transducer is placed on the patient's skin. Bony fragments were repositioned using a periosteal elevator. (B) Post-reduction evaluation of repositioning of the bony fragment.

weeks using an Aquaplast (WFR Corp, Ramsey, NJ, USA) splint.

RESULTS

Eleven patients (five men and six women; mean age, 33.5 years) who were treated for comminuted anterior wall FSF were selected (Table 1). The most common fracture mechanism was traffic accidents caused by other direct impacts. All 11 patients underwent reduction using multiple T-K wires. Among them, four patients were able to achieve successful reduction with only T-K wires. But among the remaining seven, five of them underwent reduction using multiple T-K wires and a periosteal elevator. Two patients required a second reduction attempt using multiple T-K wires and limited bone fixation using a plate by extension of the incision.

The mean operation time was 30.5 minutes. On postoperative days 1 to 3, the reduction results and complications were confirmed using 3D CT. All patients were hospitalized for 5 to 7 days and treated with systemic antibiotics. The follow-up period was 3 to 12 months. During the follow-up period, transient hypoesthesia occurred in two patients, both of whom recovered within 1 month. No patients had any complications, such as persistent numbness, pneumocephalus related to the posterior table, or brain injuries, and all were satisfied with the surgical results (Table 2).

Patient 1

A 33-year-old woman visited our hospital with forehead depression after a direct impact during a traffic accident. A preoperative 3D CT scan revealed a depressed and comminuted fracture of the anterior wall of the frontal sinus. The reduction was

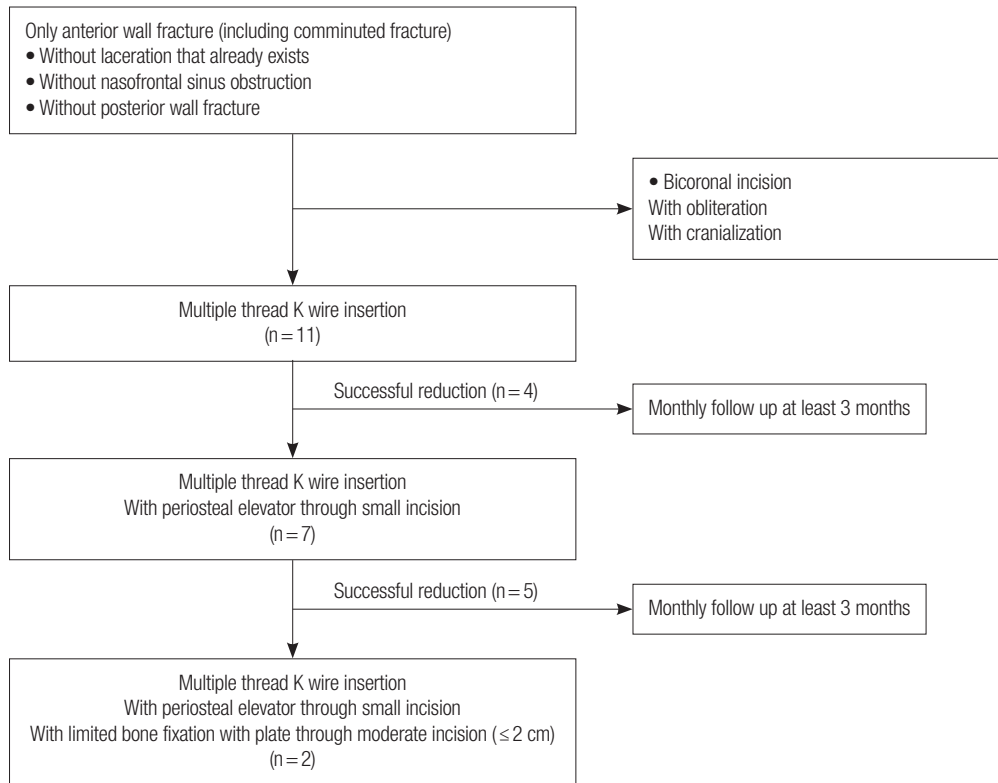


Fig. 4. Flow diagram of our surgical technique.

Table 1. Patient demographic and injury features

Variable	Value (n = 11)
Age (yr), mean ± SD	33.5 ± 11.5
Sex, No. (%)	
Men	5 (45.5)
Women	6 (54.5)
Mechanism of injury, No. (%)	
Traffic accident	6 (54.5)
Physical assault	2 (18.2)
Falling	1 (9.0)
Sports injury	1 (9.0)
Other	1 (9.0)
Location, No. (%)	
Right	7 (63.6)
Left	2 (18.2)
Both	2 (18.2)

SD, standard deviation.

performed using only two T-K wires inserted into stable large bone segments, followed by miniplate fixation. A postoperative CT scan showed a nearly perfect bony contour of the frontal bone with no definite scarring (Fig. 5).

Patient 2

A 23-year-old woman experienced blunt trauma directly in the

Table 2. Surgical results

Variable	Value (n = 11)
Interval from trauma to surgery (day), mean ± SD	7.9 ± 4.8
Operation time (min), mean ± SD	33.5 ± 9.9
Operation method, No. (%)	
T-K wire	4 (36.4)
T-K wire with periosteal elevator	5 (45.5)
T-K wire with limited plate fixation	2 (18.2)
Follow-up period (mo), mean ± SD	6.9 ± 3.4
Complication, No. (%)	
Transient forehead hypoesthesia	2 (18.2)
No complication	9 (88.8)

SD, standard deviation; T-K wire, threaded Kirschner wire.

frontal area of the skull. A preoperative CT scan showed comminuted anterior wall FSF with multiple bone segments and severe frontal depression. Three T-K wires were first inserted into the large bone segments to reduce the fracture; however, the reduction force appeared weak. Therefore, we supplemented the reduction force by supporting the lower surface of the anterior wall using a periosteal elevator through a supra-brow incision. The postoperative CT showed excellent contour of the frontal bone (Fig. 6). No specific complications were observed 6 months later in either case.

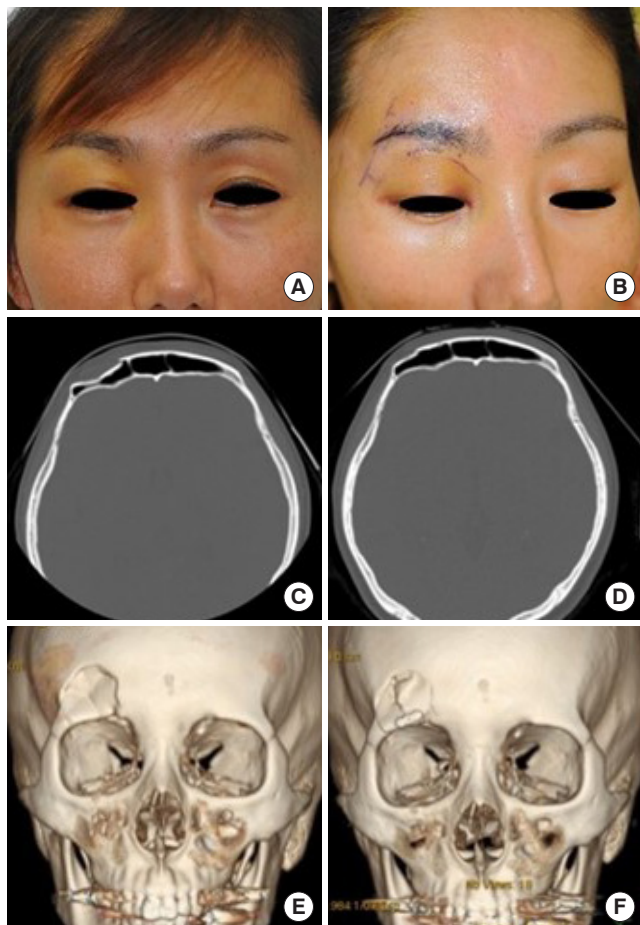


Fig. 5. A 33-year-old woman with comminuted fracture of the anterior wall of the frontal sinus incurred in a traffic accident (patient 1). Photographic images taken (A) before and (B) after surgery. Comparison of axial computed tomography images (C) before and (D) after surgery. Visual improvement in the contour is evident. Comparison of changes in three-dimensional computed tomography images (E) before and (F) after surgery.

DISCUSSION

After Riedel introduced frontal sinus exenteration in 1898, FSF treatment focused on managing the frontal sinus mucocele. As the surgical technique evolved over time, the reconstruction aimed to achieve an accurate contour of the anterior wall of the FSF, and managing infection has become more important. In 1979, McGrath and Smith [6] reported anterior FSF surgical success using wires and minimal incisions over a bicoronal incision.

For several decades, the bicoronal incision has been a popular surgical method for FSF. This method is the most common because it involves a large incisional wound. A large dissection range secures a wide field of view, making it ideal for the treatment of extensive fractures. It is also a general approach for FSF

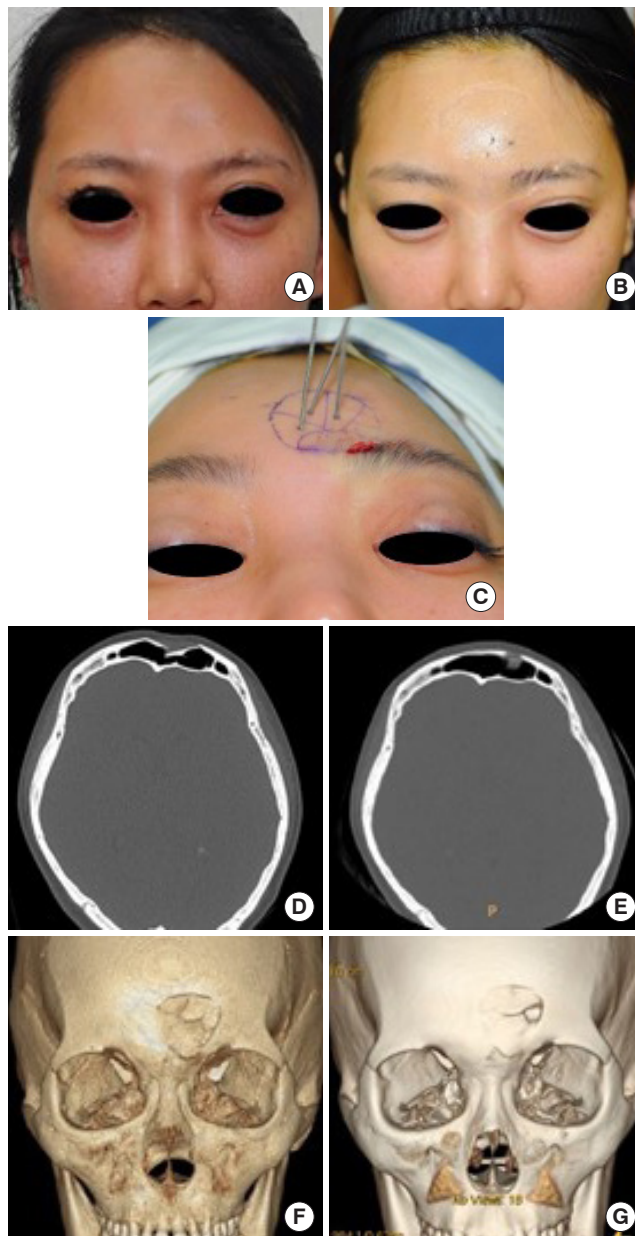


Fig. 6. A 23-year-old woman with comminuted fracture of the anterior wall of the frontal sinus incurred by blunt trauma (patient 2). Photographic images taken (A) before and (B) after reduction. (C) Intraoperative image. Reduction with only three threaded Kirsch wires was not possible, hence, a small incision was made in the supra-brow area to obtain a supporting force with the periosteal elevator. Axial computed tomography images taken (D) before and (E) after surgery. Visual improvement in the contour is evident. Comparison of changes in three-dimensional computed tomography images (F) before and (G) after surgery.

obliteration or cranialization [7,8]. The coronal approach is associated with complications, such as sensory and motor deficits, scarring on the forehead, and alopecia localized to the scalp [4].

To avoid these complications, the authors have described various minimally invasive surgical techniques for FSF [9,10]. To

reduce patient discomfort, increase aesthetic results, and achieve appropriate fracture reduction, less invasive surgery is gradually being performed. These techniques can be divided into two types: external and endoscopic. The external approach is useful if the patient has a laceration at the time of the injury. There is a relatively simple way to access the fracture site by using a periosteal elevator [11], and it is also possible to access the fracture site by making a small incision in the eyebrow near the fracture site [12,13]. An inexperienced surgeon can perform the reduction relatively successfully owing to the ease of access. Although the complications of bicoronal incision can almost be eliminated, facial paresthesia can result. An additional limitation in younger patients is the risk of a noticeable forehead scar.

The endoscope has been widely used since its introduction in 1996 and continues to evolve [14]. The endoscope allows the approach through the nose and hairline. The hairline approach reduces the fracture site through caudal dissection after an incision is made in the hairline. However, its disadvantages include a long operation time, difficult surgical technique, and incomplete fixation [15]. In the case of reduction using the transnasal approach, a second sinusotomy is possible [16]. However, this is true only in cases of non-displaced outer-table fractures, and fixation is difficult. Overall, the endoscopic surgical method has a steep learning curve, and it is difficult to access the upper and lateral sides of the frontal sinus. Moreover, it is difficult to reduce and understand the depth to the posterior wall. In addition, surgery for comminuted fractures is practically impossible. Another disadvantage is that an assistant surgeon must hold the endoscope. Therefore, surgeons face a dilemma in choosing a minimally invasive approach for treating comminuted FSF.

A surgical technique for non-comminuted anterior wall fracture of the frontal sinus using a T-K wire or a small incision in the eyebrow was introduced [17]. Kim et al. [18] also introduced a method of percutaneously approaching the frontal anterior wall, inserting a screw, and then treating the fracture through wiring. Bourry et al. [19] reported reduction and rigid fixation of the anterior wall of the FSF via an upper blepharoplasty incision but that access to the upper and lateral FSF sites was impossible.

However, these methods have disadvantages. When an anterior wall fracture is multiple or segmental, such as in a comminuted fracture, it is difficult to return it to its original shape. Additionally, the fracture fragments could not be elevated despite their strong reduction power, the fracture segments did not return to the normal position, or the fragments were misaligned or dropped into the sinus space. FSF has a thick bone and fractures into multiple segments when subjected to a cer-

tain amount of force, limiting surgery to a sub-brow incision or an endoscopic approach. Consequently, successful results were difficult to achieve. Therefore, we attempted to correct the fracture by placing multiple T-K wires on each large fractured bone segment. If the fracture was not elevated by T-K wires, a small periosteal elevator was inserted into the frontal bone cavity through a small incision near the eyebrow and the depressed bone segments were simultaneously elevated. Here we described a simple and effective closed reduction method using multiple T-K wires and small sub-brow incisions.

In many cases of FSF, the bone fragment is dropped owing to tearing of the periosteum or mucosa, resulting in less or more reduction, a common phenomenon in closed reduction. Therefore, it is necessary to simultaneously increase the fracture fragments. However, a significant amount of force is required to simultaneously raise the fracture fragments, and it is difficult to apply the pulling force of the T-K wire, which requires the help of a lever force directly below the fractured fragment. Therefore, in this study, the reduction force was doubled using a periosteal elevator instead of multiple T-K wires. This led to shortened surgical time and effective reduction results. Our surgical technique took approximately 30 minutes, similar to or shorter than that of the other surgical techniques. Also, in terms of confirming the results of surgery, the follow-up 3D CT demonstrated accurate and satisfactory surgical results. Additionally, our procedure is minimally invasive and does not require an assistant surgeon, a disadvantage of endoscopic and bicoronal approach. Therefore, if this surgical method is used efficiently, the bicoronal approach can be avoided in the comminuted FSF, and the operation can be performed more easily and quickly than the endoscopic approach.

Our surgical technique also had certain limitations and risks. First, because the incision is insufficiently applied for rigid fixation, plating to achieve complete fixation is impossible [20] and the fracture fragment may be more misaligned or fall into the sinus space during surgery. This limitation is common to all FSF surgical methods except bicoronal incision. This can be overcome using a probe method via a real-time navigation guide, which has recently attracted attention [21,22]. If the degree of fracture reduction is immediately judged intraoperatively using real-time navigation, an acceptable reduction result can be obtained by increasing the surgical accuracy without rigid fixation. According to a recent literature review, real-time navigation is only sometimes used for surgery using the bicoronal approach for FSF; when the bicoronal approach is combined with this minimally invasive surgical technique, an improved effect is obtained. The second limitation is that the use of a T-K wire can injure the posterior wall, prompting surgeons

to carefully avoid serious complications of cerebrospinal fluid leakage. Third, the number of patients in our study (n = 11) was insufficient to highlight the surgical method's merits. A larger multi-institutional study with more patients is needed. Finally, it is necessary to further develop the existing surgical method by combining it with the endoscopic approach developed in this study that is being increasingly used for FSF reduction.

Here we described a simple and effective reduction method using multiple T-K wires and a small sub-brow incision. This surgical method eliminates the disadvantages of bicoronal incision and can compensate for the disadvantages of the endoscopic approach. This surgical technique is efficient for treating comminuted FSF. It is also relatively simple and easy, its results are reliably predicted, and it has the advantage of achieving patient cosmetic satisfaction. A more objective comparison with other surgical methods in more patients is needed in the future.

NOTES

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical approval

The study was approved by the Institutional Review Board of Soonchunhyang University Hospital (IRB No. 2022-03-036-004) and was performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained.

Patient consent

The patients provided written informed consent for the publication and use of their images.

ORCID

Da Woon Lee <https://orcid.org/0000-0002-0266-8480>
 Si Hyun Kwak <https://orcid.org/0000-0001-9594-700X>
 Hwan Jun Choi <https://orcid.org/0000-0002-0752-0389>
 Jun Hyuk Kim <https://orcid.org/0000-0002-0266-8480>

Author contribution

Conceptualization: Jun Hyuk Kim. Data curation: Da Woon Lee, Jun Hyuk Kim. Formal analysis: Hwan Jun Choi. Funding acquisition: Da Woon Lee. Methodology: Si Hyun Kwak, Jun Hyuk Kim. Project administration: Da Woon Lee. Visualization: Da Woon Lee, Si Hyun Kwak. Writing - original draft: Da Woon Lee. Writing - review & editing: Si Hyun Kwak. Supervision: Hwan Jun Choi, Jun Hyuk Kim.

REFERENCES

1. Sakat MS, Kilic K, Altas E, Gozeler MS, Ucuncu H. Comminuted frontal sinus fracture reconstructed with titanium mesh. *J Craniofac Surg* 2016;27:e207-8.
2. Kim J, Choi H. A review of subbrow approach in the management of non-complicated anterior table frontal sinus fracture. *Arch Craniofac Surg* 2016;17:186-9.
3. Gerbino G, Rocca F, Benech A, Caldarelli C. Analysis of 158 frontal sinus fractures: current surgical management and complications. *J Craniomaxillofac Surg* 2000;28:133-9.
4. Nahum AM. The biomechanics of facial bone fracture. *Laryngoscope* 1975;85:140-56.
5. Bellamy JL, Molendijk J, Reddy SK, Flores JM, Mundinger GS, Manson PN, et al. Severe infectious complications following frontal sinus fracture: the impact of operative delay and perioperative antibiotic use. *Plast Reconstr Surg* 2013;132:154-62.
6. McGrath MH, Smith CJ. A simple method to maintain reduction of unstable fractures of the frontal sinus. *Plast Reconstr Surg* 1981;68:948-9.
7. Strong EB. Frontal sinus fractures: current concepts. *Cranio-maxillofac Trauma Reconstr* 2009;2:161-75.
8. Manolidis S, Hollier LH Jr. Management of frontal sinus fractures. *Plast Reconstr Surg* 2007;120(7 Suppl 2):32S-48S.
9. Jin HR, Shim WS, Jung HJ. Minimally invasive technique to reduce the isolated anterior wall fracture of the frontal sinus. *J Craniofac Surg* 2019;30:2375-7.
10. Hewitt DK, Scheidt TD, Calhoun KH. Depressed anterior table fracture: a minimally invasive method of reduction. *Ear Nose Throat J* 2009;88:734-5.
11. Hwang K, Song YB. Closed reduction of fractured anterior wall of the frontal bone. *J Craniofac Surg* 2005;16:120-2.
12. Meiklejohn BD, Lynham A, Borgna SC. A simplified approach for the reduction of specific closed anterior table frontal sinus fractures. *Br J Oral Maxillofac Surg* 2014;52:81-4.
13. Kim KS, Kim ES, Hwang JH, Lee SY. Transcutaneous transfrontal approach through a small peri-eyebrow incision for the reduction of closed anterior table frontal sinus fractures. *J Plast Reconstr Aesthet Surg* 2010;63:763-8.
14. Graham HD 3rd, Spring P. Endoscopic repair of frontal sinus fracture: case report. *J Craniomaxillofac Trauma* 1996;2:52-5.
15. Shumrick KA. Endoscopic management of frontal sinus fractures. *Facial Plast Surg Clin North Am* 2006;14:31-5.
16. Yoo MH, Kim JS, Song HM, Lee BJ, Jang YJ. Endoscopic transnasal reduction of an anterior table frontal sinus fracture: technical note. *Int J Oral Maxillofac Surg* 2008;37:573-5.
17. Shin SJ, Lim H, Park DH, Park MC. Closed reduction of fractured anterior wall of the frontal sinus using threaded K-wires.

- J Craniofac Surg 2012;23:e251-3.
18. Kim NH, Kang SJ. A simple aesthetic approach for correction of frontal sinus fracture. J Craniofac Surg 2014;25:544-6.
 19. Bourry M, Oliver C, Maalouf J, Corre P, Bertin H. Surgical approach of isolated fracture of the anterior wall of the frontal sinus: the upper eyelid incision. J Stomatol Oral Maxillofac Surg 2019;120:240-3.
 20. Hahn HM, Lee YJ, Park MC, Lee IJ, Kim SM, Park DH. Reduction of closed frontal sinus fractures through suprabrow approach. Arch Craniofac Surg 2017;18:230-7.
 21. Shin HS, Kim SY, Cha HG, Han BL, Nam SM. Real time navigation-assisted orbital wall reconstruction in blowout fractures. J Craniofac Surg 2016;27:370-3.
 22. Franz L, Isola M, Bagatto D, Tuniz F, Robiony M. A novel approach to skull-base and orbital osteotomies through virtual planning and navigation. Laryngoscope 2019;129:823-31.