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ORIGINAL ARTICLE

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Awake sternal fixation; comparison of technical details and early results with sternal fixation methods performed via general anaesthesia

Selcuk Gurz [a,*], Burhan Dost [b], Mehmet Gokhan Pirzirenli [a], Yasemin Buyukkarabacak [a], Aysen Taslak Sengul [a], Cengiz Kaya [b], Necmiye Gul Temel [c], Emine Ozdemir [b] and Ahmet Basoglu [a]

[a] Department of Thoracic Surgery, Ondokuz Mayis University, Medical Faculty, Samsun, Turkey
[b] Department of Anaesthesiology and Reanimation, Ondokuz Mayis University, Medical Faculty, Samsun, Turkey
[c] Department of Thoracic Surgery, Educational and Research Hospital, Samsun, Turkey

* Corresponding author. Department of Thoracic Surgery, Ondokuz Mayis University Medical Faculty, Ondokuz Mayıs Üniversitesi Tıp Fakültesi, Göğüs Cerrahisi Anabilim Dalı, Kurupelit yerleşkesi, Posta kodu: 55270, Körfez, Atakum, Samsun, Türkiye. Tel: +90-533-542-80-41; e-mail: selcuk_gurz@hotmail.com (S. Gurz).

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Awake Sternal Fixation

Summary

In this retrospective study of 129 sternal fractures over a fourteen-year period, 13 patients who underwent fixation for isolated sternal fractures were grouped according to the anesthesia method and sternal fixation technique. Surgical time and length of hospital stay improved significantly over time in all three groups, but more markedly in the awake sternal fixation group.

	Steel Wire Fixation under GA (Group 1) n=4	Plate Fixation under GA (Group 2) n=4	Plate Fixation with S-PIP (Group 3) n=5	p
Surgical time, min, (mean±SD)	98.75±16.52	77.5±35	41±14.74	**0.012**
Hospital Stay, day [median(min-max)]	6 (4-8)	4 (2-14)	1	**0.019**

GA: General Anesthesia, S-PIP: Superficial Parasternal Intercostal Plane Block

Abstract

OBJECTIVES: Isolated sternal fractures are rare pathologies that rarely require surgical fixation. Although different fixation techniques are used, it is routinely performed under general anaesthesia. In our study, we aimed to share the details of the awake sternal fixation technique performed in our clinic and to compare the early results with sternal fixation methods performed under general anaesthesia.

Presented as a poster presentation (EP-037) at the 12th National Congress of the Turkish Society of Thoracic Surgery in Antalya on 19-22 October 2023.

METHODS: Between January 2009 and January 2023, 129 patients who were diagnosed with sternal fracture and who underwent investigations and follow-up in our clinic were evaluated retrospectively. Thirteen patients who underwent surgical fixation for isolated sternal fracture were included in the study. Patients were categorized according to fixation and anaesthetic technique; group 1: fixation with steel wire under general anaesthesia ($n = 4$), group 2: fixation with titanium plate–screw under general anaesthesia ($n = 4$) and group 3: fixation with awake titanium plate–screw with parasternal intercostal plane block ($n = 5$). Demographics, surgical indication, radiological findings, surgical incision, surgical time and hospital stay were statistically compared.

RESULTS: The mean age of the patients included in the study was 55.15 ± 15.01 years and 84.6% ($n = 11$) were male. The most common reason for fixation was displaced fracture (53.8%). Fixation surgery was performed due to pain in 30.8% ($n = 4$) and non-union in 15.4% ($n = 2$) of the fractures. The mean duration of surgery were 98.75 ± 16.52, 77.5 ± 35 and 41 ± 14.74 min, respectively. Duration of surgery was significantly lower in group 3 compared to the other groups ($P = 0.012$). The hospital stay duration for group 1 was 6 days, group 2 was 4 days and group 3 was 1 day. A notable difference was observed among all groups ($P = 0.019$).

CONCLUSIONS: Awake sternal fixation technique with titanium plate–screw system under superficial parasternal intercostal plane block is an easy and effective method for surgical treatment of isolated sternal fractures. This technique showed a direct positive effect on the duration of surgery and hospital stay.

Keywords: Awake fixation • Sternal fracture • Sternal fixation

ABBREVIATIONS

IV	Intravenously
S-PIP	Superficial parasternal intercostal plane block
US	Ultrasound

INTRODUCTION

Traumatic sternal fractures are seen in 8% of blunt thoracic trauma and 18% of multi-trauma cases [1, 2]. The extensive use of computed tomography increased the rate of detection of sternal fractures in trauma cases [3, 4]. Sternum fracture associated with multi-trauma indicates a treatment process with high morbidity and mortality risks. In isolated sternal fracture, conservative treatment is usually adequate in the absence of blunt cardiac injury [5]. Chronic non-union, severe pain-causing respiratory distress, displaced fracture or sternal instability are indications for surgical treatment [6].

There are different techniques described for surgical fixation of sternal fractures. The 1st sternal fixation surgery with Kirschner wire was performed by McKim in 1943 [7]. Since then, different fixation materials have been favoured, including stainless steel wire, absorbable and non-absorbable plates. The most commonly accepted technique has been the fixation method using titanium plates and screws [8, 9]. Fixation is usually performed under general anaesthesia. However, in recent years, ultrasound (US)-guided fascial plane block and superficial parasternal intercostal plane block (S-PIP) in the parasternal region have been frequently practiced. This method allows awake sternal fixation especially in isolated sternal fractures with excessive risk of general anaesthesia [10]. In this study, we aimed to share the details of the awake sternal fixation technique performed in our clinic. Furthermore, we compared this method with sternal fixation methods performed under general anaesthesia.

MATERIALS AND METHODS

A retrospective evaluation of 129 patients diagnosed with sternal fracture in our clinic between January 2009 and January 2023 was performed. Thirteen patients who underwent surgical fixation for isolated sternal fracture were included in the study. Patients who were followed-up with conservative treatment, patients who underwent surgical fixation for sternal fracture associated with multi-costal fracture and patients with pathological sternal fracture were excluded from the study. Therefore, our study was planned as a retrospective descriptive observational study. The study was approved by the Ondokuz Mayis University Ethics Committee (approval number: 2023/177; date: 20 May 2023).

The data, demographic and clinical data of the patients included in the study were obtained retrospectively from the hospital digital information system. Demographic data (age, gender, etc.), fracture aetiology, fixation indication, echocardiography findings, anaesthesia method, fixation technique, surgical material, duration of surgery, postoperative complications and length of hospital stay were determined. Patients were grouped according to fixation and anaesthesia technique; group characteristics are shown in Fig. 1. Patients were categorized according to fixation and anaesthetic technique; group 1: fixation with steel wire under general anaesthesia ($n = 4$), group 2: fixation with titanium plate–screw under general anaesthesia ($n = 4$) and group 3: fixation with awake titanium plate–screw with parasternal intercostal plane block ($n = 5$).

Anaesthesia technique

In group 3, oxygen was started with a mask after monitoring. First, 2 mg of midazolam was administered intravenously (IV). Remifentanil infusion (0.05–0.2 mcg/kg/min) was started before the block. Remifentanil infusion was continued throughout the procedure with Ramsay sedation scores of 2 (awake, calm, observing the environment) and 3 (asleep, responding to verbal stimuli). Ondansetron 4 mg was administered for nausea and vomiting prophylaxis and paracetamol 1 g IV was administered for analgesia. The procedure was performed under US guidance as described by Kaya *et al.* [11]. In the parasternal region, a linear US probe (8–13 MHz, GE LOGIQ V1 US System, USA) was placed in the intercostal space adjacent to the fracture line, and a 22-gauge, 50-mm needle was advanced caudally to cranially (Fig. 2). To evaluate the placement of the needle tip, hydrodissection was performed with 1–3 ml of 0.9% normal saline until distribution was observed in the fascial plane (Video 1). After adequate steering was achieved, 15 ml of 0.25% bupivacaine was injected into the interfascial plane. During injection, the distribution of the local anaesthetic in the cranio-caudal direction was

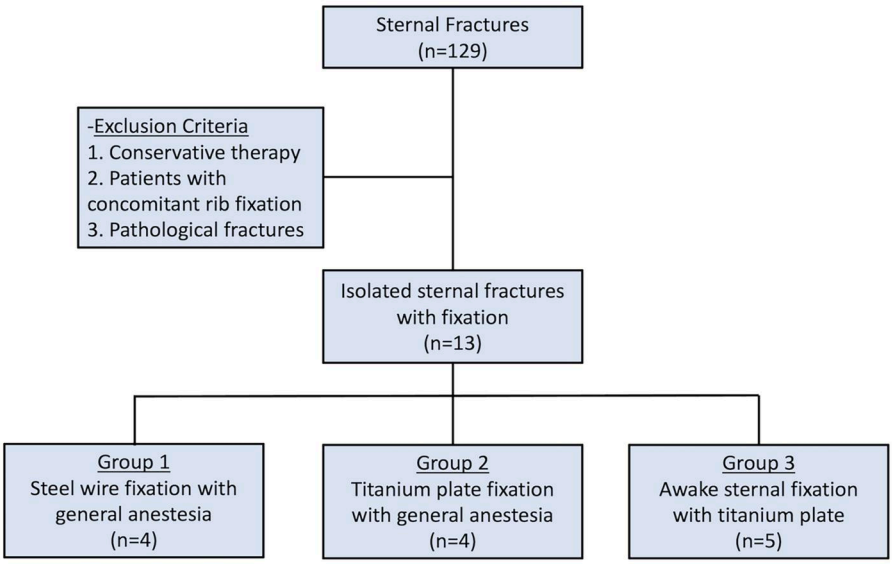


Figure 1: Study flowchart.

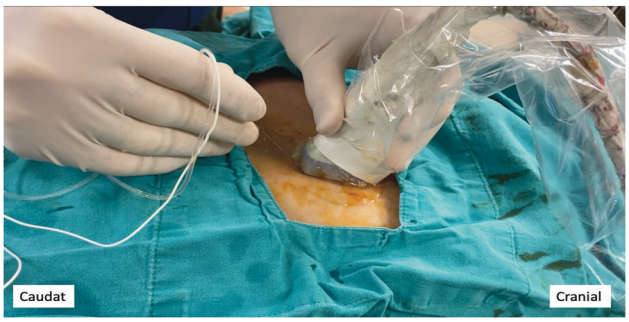
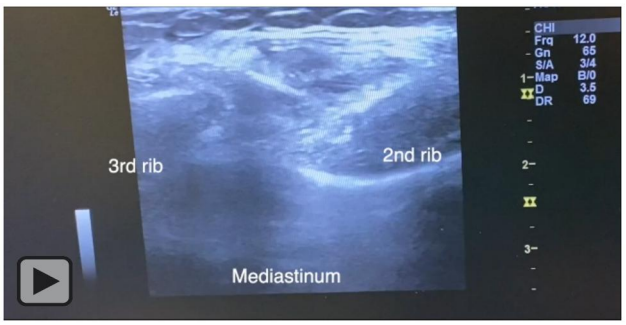


Figure 2: Using an in-plane approach, a 22-gauge, 50-mm needle is inserted from caudal to cranial direction.



Video 1: Hydrodissection with 1–3 ml of 0.9% normal saline until distribution is seen in the fascial plane.

monitored under US guidance. The block was then applied to the opposite parasternal region with the same method. The same procedure was performed at the upper and lower levels to ensure an adequate blockade in the surgical field. Care was taken to ensure that the dose of bupivacaine was < 2.5 mg/kg (ideal body weight). Sensory block was evaluated every 5 min using a needle prick sensation (50 mm long, 22G short bevel; Stimuplex Ultra 360, B. Braun, Germany).

In groups 1 and 2, standard monitoring was performed. Sedation was induced with midazolam (0.03 mg/kg) and remifentanil (0.01–0.2 mcg/kg/min). Anaesthesia was induced with propofol (1–2 mg/kg/ideal body weight). Remifentanil infusion (0.5–1 mcg/kg/puppy body weight, bolus in 30–60 s) was started before induction and continued throughout the operation. Muscle relaxation was achieved using rocuronium (1 mg/kg/lean body weight). Endotracheal intubation was performed after the administration of rocuronium. Desflurane and sevoflurane were used to maintain anaesthesia. At the end of the operation, neuromuscular block was antagonized with neostigmine. Postoperative pain management was provided with 1 mg/kg tramadol IV and 1 g paracetamol IV.

Surgical technique

Steel wire fixation. The patient was placed in supine position. A cranio-caudal 8–10 cm midsternal incision was made over the mobile area due to sternum fracture. Skin and subcutaneous fat tissue were passed. The fracture line was clearly defined and the pectoral muscles around the fracture were released from the sternum. The sternum was suspended cranial and caudal to the fracture line with posterior release. Two steel wire sutures (Number 5, Ethicon®, Johnson & Johnson Medical NV. EMEA UK) were fixed by crossing the full thickness of sternum (Fig. 3). Subcutaneous tissues were closed by placing a Hemovac drain.

Titanium plate–screw fixation. Preoperatively, in sagittal views of thoracic tomography, screw length was planned by measuring the thickness of the sternum in the areas where screw implementation area was planned (Fig. 4). The patient was placed in supine position. A cranio-caudal 4–6 cm midsternal incision was performed over the sternum fracture line. Skin and subcutaneous adipose tissue were incised. The fracture line was clearly localized and isolated from the adjacent tissues. Titanium sternal plate (Sternal titanium H plate, MEDPLATES®, RAMED Medikal, Izmir, TURKEY) was placed on the surface of the sternum. The sternal plate was stabilized to the sternum with screws of appropriate size for the bone tissue (Fig. 5). Subcutaneous tissues were closed properly.

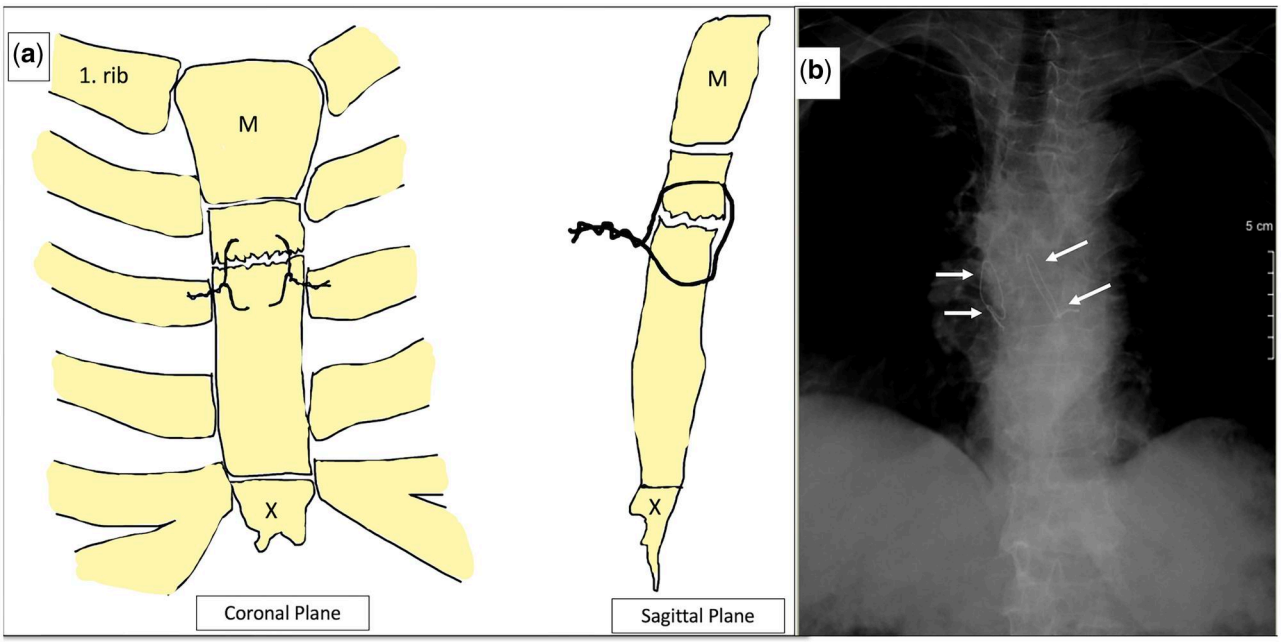


Figure 3: Illustration of sternal fixation with steel wire (**a**) and postero-anterior X-ray view (**b**) (steel wire sutures are marked with white arrow). M: manubrium sterni; X: xyphoid.

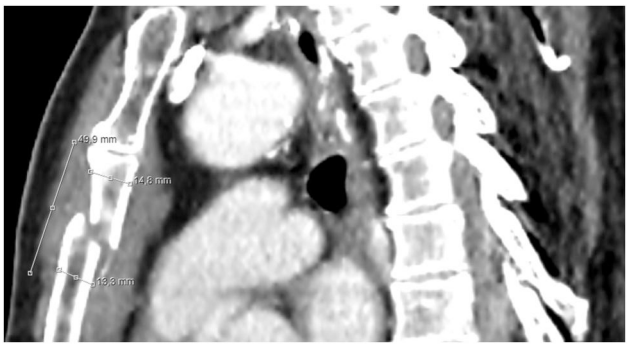


Figure 4: Sternum thickness measurement in sagittal views of thoracic tomography for determination of screw length.

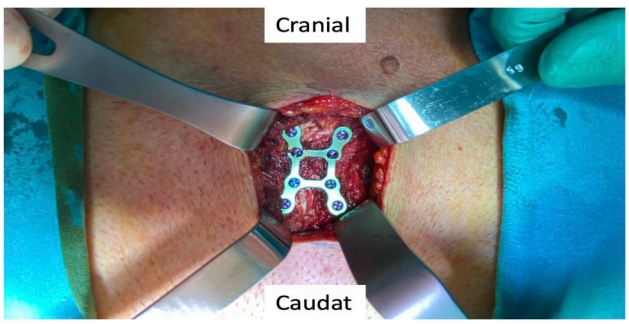


Figure 5: Intraoperative image of the titanium 8-hole H plate and 8 screws used after awake sternal fixation.

Statistical analysis

The analysis of the data was conducted using IBM SPSS V23. The compliance with normal distribution was assessed using the Kolmogorov–Smirnov test. The chi-square test was employed to compare categorical variables across groups. For quantitative data that did not adhere to a normal distribution, the Kruskal–Wallis test was utilized to compare the data among groups of 3 or more. The results of the analyses were presented as the mean ± standard deviation and median (minimum–maximum) for quantitative data, while categorical data were presented as frequency (percentage). A *P*-value of <0.05 was considered to be statistically significant.

RESULTS

Age distribution was homogenous between the groups, and no significant difference was found between the 3 groups. The mean age was 59 ± 8.98, 41 ± 17.6 and 63.4 ± 9.07 years in groups 1, 2 and 3, respectively. Of the patients included in the study, 84.6% ($n = 11$) were male and 15.4% ($n = 2$) were female. The aetiology of sternum fractures included motor vehicle accidents with a rate of 46.2% and fall-related injuries with a rate of 38.5%. The reasons for isolated sternum fixation treatment were, in order of frequency, 53.8% ($n = 7$) displaced fractures, 30.8% ($n = 4$) pain and 15.4% ($n = 2$) non-union fractures. Because of trauma, poststernal localized haematoma was detected in 2 patients on computed tomography images and minimal pericardial effusion was detected in 1 patient on echocardiography. The size of incision was 6.5 ± 1.9, 6.5 ± 1 and 5 ± 1.4 cm in groups 1, 2 and 3, respectively, and there was no difference between the groups. There was a significant difference in duration of surgery between the groups ($P = 0.012$). The mean duration of surgery was 98.75 ± 16.5, 77.5 ± 35.0 and 41 ± 14.7 min in groups 1, 2 and 3, respectively. In our study, which the length of hospital stay was not homogeneously distributed, a significant difference was found between the groups ($P = 0.019$). The median length of hospital stay was 6 (4–8), 4 (2–14) and 1 day in groups 1, 2 and 3, respectively. The distribution of data according to the groups is shown in Table 1.

Table 1: Comparison of categorical data according to groups

	Group 1 ($n=4$)	Group 2 ($n=4$)	Group 3 ($n=5$)	*P*
Age (year), mean ± SD	59 ± 8.98	41 ± 17.6	63.4 ± 9.07	0.53
Sex, *n* (%)				0.478
Male	3 (75%)	3 (75%)	5 (100%)	
Female	1 (25%)	1 (25%)	0 (0%)	
Aetiology, *n* (%)				0.689
Fall-related injury	2 (50%)	2 (50%)	1 (20%)	
Motor vehicle	1 (25%)	2 (50%)	3 (60%)	
Other	1 (25%)	0 (0%)	1 (20%)	
Indication, *n* (%)				0.256
Pain	1 (25%)	0 (0%)	3 (60%)	
Displaced fracture	3 (75%)	3 (75%)	1 (20%)	
Non-union	0 (0%)	1 (25%)	1 (20%)	
Post-sternal haematoma, *n* (%)				0.568
Yes	2 (50%)	1 (25%)	3 (60%)	
No	2 (50%)	3 (75%)	2 (40%)	
Echocardiographic pathology, *n* (%)				0.979
Yes	1 (25%)	1 (25%)	1 (20%)	
No	3 (75%)	3 (75%)	4 (80%)	
Surgical incision (cm), mean ± SD	6.5 ± 1.9	6.5 ± 1	5 ± 1.4	0.255
Surgery time (min), mean ± SD	98.75 ± 16.52[a]	77.5 ± 35[a]	41 ± 14.74[b]	0.012
Hospital stay (days), median (min–max)	6 (4–8)[a]	4 (2–14)[a]	1[c]	0.019[K]

Chi-square test. One-way ANOVA test. A *P*-value of <0.05 was considered statistically significant.

[a,b,c] No difference between groups with the same letter.

K: Kruskal–Wallis test.

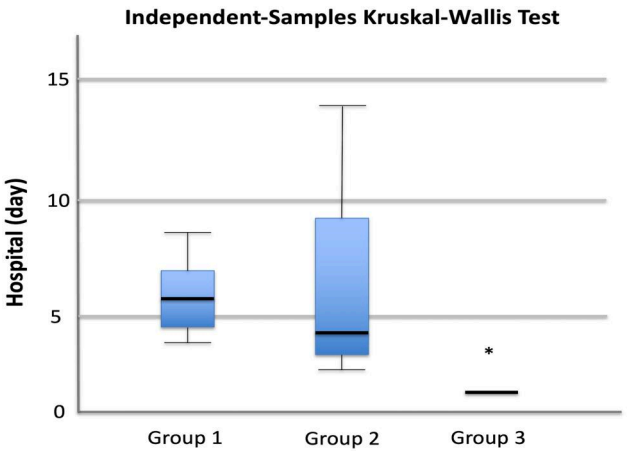


Figure 6: Box plot of Kruskal–Wallis test for median length of hospital stay. A downwards trend can be discerned, indicating a shorter length of hospital stay for group 3 compared to groups 1 and 2 ($P=0.019$).

In pairwise comparison of the median length of hospital stay in 3 different groups, group 3 was found to be significantly shorter than the other groups (Fig. 6). There was no difference in the length of hospital stay between groups 1 and 2, which underwent fixation with general anaesthesia (Table 2).

The minimum follow-up period was 9 months. None of the patients in groups 1 and 2 had any long-term complications related to surgery. In group 3, one patient's plate was removed at the end of the 2nd month due to screw dislocation. Notably, the patient had a displaced sternal fracture. Re-stabilization was not required when the plate was removed.

DISCUSSION

Isolated sternum fracture is a rare pathology. Generally, sternal fracture is treated with conservative methods. Knobloch *et al.* reported the indication for sternal fixation as pain that prevents breathing and non-union of the sternum [2]. Azenha *et al.* showed that sternal fixation for sternal non-union after sternal fracture was good outcome, and Bauman *et al.* showed that sternal fixation for severe pain significantly decreased pain and the use of analgesia in patients [12, 13]. In our study, the indications of isolated sternal fractures treated with fixation are consistent with the current literature. Different fixation methods have been described since the 1st implementation of sternal fixation. This study demonstrated that surgical treatment of non-displaced isolated sternal fractures can be performed quickly and effectively with awake sternal fixation. When compared with the fixation methods performed under general anaesthesia in our clinic, the early results of awake sternal fixation were found to be better in duration of surgery and hospital stay.

Steel wire cerclage, which is routinely used for closure of sternotomy, has also been used for fixation in sternum fractures [9]. Therefore, in the following years, plates with different alloys and different locking mechanisms have been preferred in sternum fixation as an easy and effective procedure [1, 6, 9, 14–17]. Zhao *et al.* recommended the use of titanium plates for internal fixation of the sternum in their study of 64 cases [18]. In our clinic, different fixation techniques were performed in accordance with the developing technology and techniques. Until 2012, steel wire cerclage was preferred for sternal fixation, but later titanium plates were preferred due to ease of implementation. The decrease in operation times was an evidence of the ease of implementation. The difference in the times for groups 2 and 3 is due to 3 factors in our opinion: (i) considering the duration of anaesthesia effect in the patient who underwent block, incision, dissection and stabilization with a plate were performed very quickly without wasting time. (ii) In group 2, 75% of the patients underwent stabilization due to displaced sternal fractures. This is likely a factor that prolongs the mean time. (iii) Parasternal block has been performed in the last 2 years. Increased stabilization experience and improved techniques may also shorten the mean time. In addition, Hemovac drains were used without closing the surgical incision after steel wire fixation, but this practice has been abandoned in current surgeries.

Thomas *et al.* in 2016 showed that US-guided S-PIP is an effective method for the control of severe pain due to sternum fracture [19]. In recent years, S-PIP has been used as an alternative to general anaesthesia in cardiac surgeries with high risk of general anaesthesia [20–22]. Szamborski *et al.* reported that US-guided S-PIP can be safely preferred in thoracic surgery due to the risks of general anaesthesia procedures during the pandemic period [23]. Therefore, for the 1st time in our clinic, awake sternal fixation surgery using US-guided S-PIP with titanium plate was performed in a patient with high risk of general anaesthesia due to 2nd cervical vertebral fracture [10]. In the next period, this procedure was continued in appropriate cases. In our study, we found a significant decrease in the operation time and hospital stay of the patients who underwent awake sternal fixation.

Table 2: Pairwise comparisons of the groups in terms of length of hospital stay

	Test statistic	Standard error	Standard test statistic	Significances	Adjusted significance[a]
Group 3–group 2	5.200	2.569	2.024	0.043	0.129
Group 3–group 1	6.825	2.569	2.657	0.008	0.024
Group 1–group 2	1.625	2.708	0.600	0.548	1.000

Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05.
[a]Significance values have been adjusted by the Bonferroni correction for multiple tests.

Limitations

Our study had certain limitations. Retrospective design was the most obvious limitation because the radiological images of some patients could not be accessed in the patient's digital information system. In addition, since isolated sternal fractures are rarely encountered pathologies and rarely treated with fixation surgery, the limited number of patients included in the study was another limitation.

CONCLUSION

In conclusion, awake sternal fixation technique using titanium plate–screw system is an easy and safe method for posttraumatic non-displaced isolated sternal fractures. This technique can be preferred in selected patients because of short operative times, effective results in the early postoperative period and short hospital stay. However, we think that larger case series will contribute to the feasibility of the technique.

FUNDING

None declared.

Conflict of interest: none declared.

DATA AVAILABILITY

The data underlying this article will be shared on reasonable request to the corresponding author.

Author contributions

Selcuk Gurz: Conceptualization; Data curation; Methodology; Visualization; Writing—original draft. **Burhan Dost:** Data curation; Investigation; Project administration; Visualization; Writing—review and editing. **Mehmet Gokhan Pirzirenli:** Formal analysis; Supervision; Validation; Writing—original draft. **Yasemin Buyukkarabacak:** Formal analysis; Investigation; Methodology; Supervision; Writing—review and editing. **Aysen Taslak Sengul:** Conceptualization; Data curation; Methodology; Resources; Supervision; Visualization; Writing—review and editing. **Cengiz Kaya:** Methodology; Supervision; Writing—review and editing. **Necmiye Gul Temel:** Data curation; Methodology; Validation; Visualization; Writing—original draft. **Emine Ozdemir:** Data curation; Investigation; Validation; Visualization; Writing—review and editing. **Ahmet Basoglu:** Conceptualization; Formal analysis; Methodology; Supervision; Writing—review and editing.

Reviewer information

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