

Successful method in the treatment of complicated sternal dehiscence and mediastinitis: Sternal reconstruction with osteosynthesis system supported by vacuum-assisted closure

Komplike sternal dehisens ve mediastinit tedavisinde başarılı bir yöntem: Vakum yardımcı kapama ile desteklenen osteosentez sistemli sternal rekonstrüksiyon

Mehmet Furkan Şahin , Alkın Yazıcıoğlu , Muhammet Ali Beyoğlu , Erdal Yekeler 

Department of Thoracic Surgery and Lung Transplantation, Health Sciences University, Ankara City Hospital, Ankara, Turkey

ABSTRACT

Background: This study aims to evaluate the results of the method we used to treat sternal dehiscence and mediastinitis due to median sternotomy following open heart surgery.

Methods: Between July 2014 and March 2019, a total of 13 patients (8 males, 5 females; mean age: 60.3±2.9 years; range, 33 to 74 years) who underwent sternal reconstruction procedure and developed sternal dehiscence and mediastinitis after cardiac surgery were retrospectively analyzed. Data of the patients were retrieved from the hospital records.

Results: Before the procedure, reconstruction was performed by using the Robiscek technique in three cases and a conventional rewiring technique was used in one case. Except for one case, all the other cases had sternal purulent discharge (n=12, 92%). Except for four cases, all cases had at least two fracture lines in the sternum (n=9, 69%). One to 10 sessions of (median=4) vacuum-assisted closure therapy were used in cases before the procedure. At least two bars were placed between the opposite ribs for sternal fixation. Except for three cases, all of the cases were placed transdiaphragmatic harvested omentum in the sternal cavity. Seroma and local infection recurrence occurred in two cases (n=2, 15.3%) and incisional hernia in one case (n=1, 7.6%). Thoracic stabilization was successfully achieved in all cases.

Conclusion: Thoracic stabilization can be successfully achieved in complicated sternal dehiscence cases with sternal reconstruction with STRATOS system supported by vacuum-assisted closure therapy, until the culture turns negative in the preoperative period and by the use of transdiaphragmatic omentum intraoperatively inside the sternal cavity.

Keywords: Mediastinitis, sternal dehiscence, sternal reconstruction.

ÖZ

Amaç: Bu çalışmada açık kalp cerrahisi sonrası median sternotomiye bağlı sternal dehisens ve mediastinit tedavisinde kullandığımız yöntemlerin sonuçları değerlendirildi.

Çalışma planı: Temmuz 2014 - Mart 2019 arasında kalp cerrahisi sonrası sternal dehisens ve mediastinit gelişen toplam 13 hasta (8 erkek, 5 kadın; ort. yaş: 60.3±2.9 yıl; dağılım 33-74 yıl) retrospektif olarak incelendi. Hasta verileri hastane kayıtlarından elde edildi.

Bulgular: İşlem öncesinde üç olguda Robiscek tekniği ile rekonstrüksiyon yapılırken, bir olguda da debridman sonrası konvansiyonel yeniden telleme tekniği uygulandı. Bir olgu dışında tüm olgularda sternal pürülan akıntı mevcuttu (n=12, %92). Dört olgu dışında tüm olguların sternumunda en az iki fraktür hattı mevcuttu (n=9, %69). İşlem öncesinde olgulara 1 ila 10 seans (medyan=4) vakum yardımcı kapama tedavisi uygulandı. Sternal fiksasyon için en az iki adet bar karşılıklı kaburgalar arasına yerleştirildi. Üç olgu dışında tüm olgulara sternal boşluğa transdiyafragmatik çekilen omentum yerleştirildi. İki olguda seroma ve lokal enfeksiyon nüksü (n=2, %15.3) ve bir olguda insizyonel herni (n=1, %7.6) gelişti. Olguların tümünde toraks stabilizasyonu başarı ile sağlandı.

Sonuç: Ameliyat öncesi dönemde kültür negatif oluncaya kadar uygulanan vakum yardımcı kapatma tedavisi ve ameliyat sırasında sternal boşluğa transdiyafragmatik omentum uygulanması ile desteklenen STRATOS sisteminin kullanıldığı sternal rekonstrüksiyon ile komplike sternal dehisens olgularında toraks stabilizasyonu başarı ile sağlanabilir.

Anahtar sözcükler: Mediastinit, sternal dehisens, sternal rekonstrüksiyon.

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Correspondence: Mehmet Furkan Şahin, MD. SBÜ Ankara Şehir Hastanesi, Göğüs Cerrahisi ve Akciğer Nakli Kliniği, 06800 Çankaya, Ankara, Türkiye.

Tel: +90 312 - 552 60 00 e-mail: mfurys@hotmail.com

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Median sternotomy is the most common approach used to reach the heart and mediastinum during cardiovascular surgery.^[1] Sternal instability may develop within the first days or weeks after a median sternotomy due to abnormalities of bone structure or technical problems related to the surgical technique.^[2] This may improve normally, but also reasons such as primary sternum non-union, weak wound healing or excessive strain in the early postoperative period may lead to the development of sternal dehiscence by causing the sternal wires to break in case of etiological risk factors.^[2,3]

Sternal dehiscence and mediastinitis are serious complications developing after cardiac surgery and are associated with significant morbidity and mortality.^[3] The incidence of sternal dehiscence after cardiac surgery is reported between 0.5 and 5.0% in the literature with a mortality rate reaching 50% and morbidity rates ranging from 14 to 47% and is known to cause a significant increase during hospital stay and overall health care costs.^[1,4] Obesity, osteoporosis, chronic obstructive pulmonary disease, diabetes mellitus (DM), corticosteroid intake, and off-midline sternotomy or patients having sternotomy history are the well-known risk factors for sternal dehiscence.^[4,5] When sternal dehiscence develops in the early postoperative period, lung compliance is adversely affected due to impaired chest wall stability, and pulmonary dysfunction may develop. Superficial and mediastinal infections may also lead to the development of mediastinitis with a high mortality rate.^[6] This infective process that cannot usually be controlled negatively affects the psychosocial status and quality of life of the patient during the chronic process. Despite the developments in the postoperative care from past to present and the development of technical measures taken in the intraoperative period, sternal dehiscence and mediastinitis still continue to be an important problem that is difficult to manage. In the management of this undesired complication over the years, primary closure methods by using irrigation catheters after surgical debridement, muscle flap applications for sternal reconstruction, sternal refixation techniques with sternum wires developed after being first proposed by Robicsek et al.,^[7] vacuum-assisted closure (VAC) that may be applied in selected patients recently and methods such as orthopedic, plastic, maxillofacial fixation systems applications and sternal talon systems are used.^[7-15] However, in many of these methods, due to the fact that good bone structure quality and integrity is required, satisfactory results cannot be obtained, particularly in complicated cases, and in some methods due to the disadvantages such as

high costing, prolonged operation times, necessity of experience, no consensus has yet been reached on the sternum closure technique.

In this study, we present a series of patients related to a newly defined technique that can successfully provide sternal refixation even in complicated cases in which sternum bone quality is not good, purulent discharge infection accompanies and/or recurrence could not be averted, despite the conventional methods of refixation.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Health Sciences University, Ankara City Hospital, Department of Thoracic Surgery and Lung Transplantation between July 2014 and March 2019. A total of 13 patients (8 males, 5 females; mean age: 60.3±2.9 years; range, 33 to 74 years) who underwent sternal reconstruction procedure using titanium bars fixed to the ribs with clips (Strasbourg Thorax Osteosynthesis System-STRATOS™, MedXpert GmbH, Heitersheim, Germany) and developed sternal dehiscence and mediastinitis after cardiac surgery were included. Failure of standard techniques were expected due to one or more serious risk factors, or standard approaches were attempted for refixation, but failed. In all our cases, the clinical diagnosis of sternal dehiscence was confirmed by thoracic computed tomography (CT) scan (Figure 1). Data of the cases were analyzed in terms of age, sex, cause of previous median sternotomy, time since the first procedure, number of sternal fractures, microbial agent reproducing in sternal purulent discharge, number of VAC therapies before the procedure, etiological risk factors, use

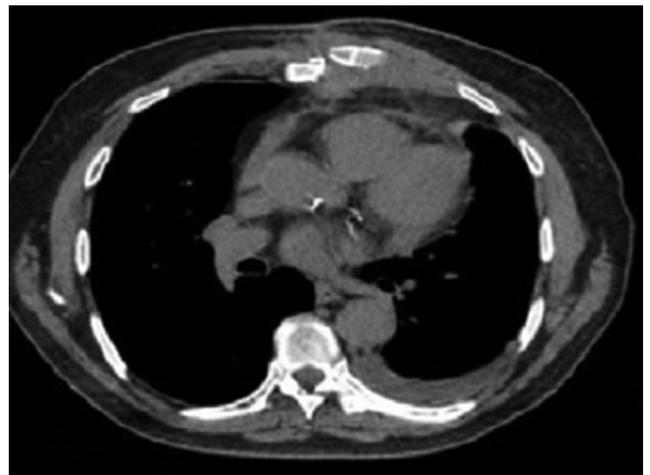


Figure 1. Preoperative thoracic computed tomography showing sternal dehiscence (Patient no. 4).

of intraoperative omentum, number of bars used, complications, and management. A written informed consent was obtained from each patient. The study protocol was approved by the Ankara City Hospital Ethics Committee (date, 16.07.2020, No: E1-20-659). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical technique

In patients who developed sternal dehiscence, the median sternotomy incision from the previous operation was opened first in the operating room conditions, and the broken steel wires were removed, and the degree of sternal dehiscence, bone viability, presence fracture, and infection were evaluated. The entire incision area was cleaned with polyvidone-iodine solution irrigation from the skin to the mediastinum. In

these cases, infection was usually accompanied and debridement was applied until reaching bleeding living tissue to all necrotic-looking wound edges, including the skin, subcutaneous tissue, muscle tissue, the edges of the sternal bone and the cartilage parts of the ribs that were suspected to be affected by the infection. Following the removal of all necrotic tissues in the incision site, a VAC containing silver nitrate sponges was placed (Figure 2a). In the patients who were followed clinically, systemic antibiotic treatment was initiated for the microbial agent that reproduced in the wound. Necessary nutritional and palliative supportive treatments were initiated for patients who became unable to care for themselves due to the infectious process. In all cases accompanied by DM, which is one of the most obvious risk factors of sternal dehiscence and which adversely affects the infective process, targeted blood

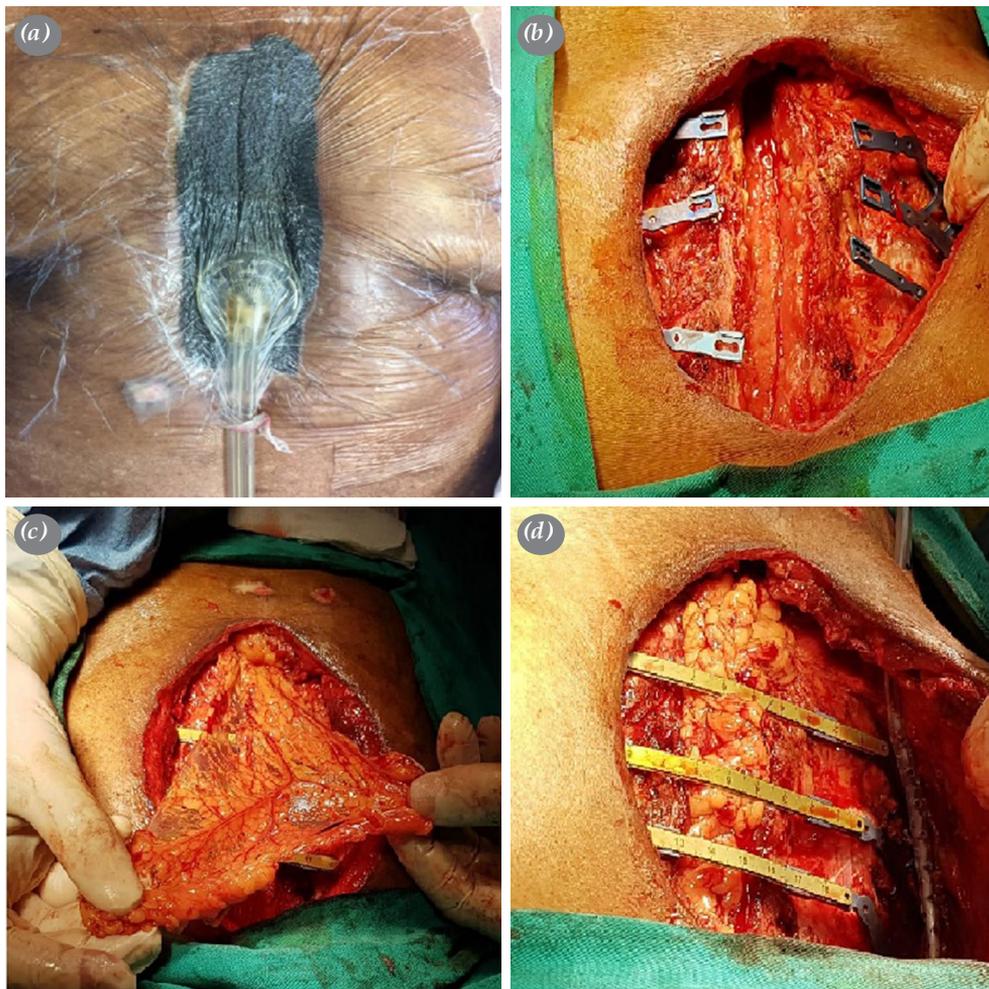


Figure 2. Phases of STRATOS reconstruction procedure. Omental flap marked with white arrow. (a) Vacuum-assisted closure application, (b) costal bar placement, (c) prepared omental flap, (d) view of fixated ribs.

sugar regulation was achieved by subcutaneous insulin administration (fasting blood glucose <180 mg/dL). The VAC sponge replacement, which can usually be performed under local anesthesia, and wound debridement for cleaning necrotic tissues were applied in approximately three- to four-days periods. At each VAC sponge change, the wound was re-cultured before the irrigation of the wound with a polyvidone-iodine solution. These applications were continued patiently, until the pathogen was culture-negative. When the cleaning of the wound was confirmed, the patient was prepared for the sternal refixation procedure. The last VAC sponges were removed under general anesthesia and the procedure was started by re-culturing from the wound site.

In the osteosynthesis system called STRATOS that we use in our reconstruction procedure, each implant that provides stabilization consists of two costal clips that are connected with a straight connecting bar. With three different angled costal clips and an adjustable length connecting bar, this system allows for optimal anatomic stabilization. First, the bilateral pectoral muscles are released from the sternal parts of the ribs. The periosteum on the anterior faces of the ribs, between which the

stabilization bars are planned to place, are stripped and the bone parts of these ribs are made suitable for the application of the clips. The costal clips are attached to the bone parts of the ribs by means of their small handles that are designed not to tighten the subcostal vascular nerve package. It should be ensured that the costal clips are not applied to the cartilage segments of the ribs (Figure 2b). The plates at the ends of the clips are adjusted to be at the same angle and across from each other and are fixed by placing connecting bars between the clips and thus, achieving sternal fixation from one rib to the other (Figure 2d, Figure 3). At least two bars should be applied for a sufficiently stiff sternal fixation. To avoid seroma or local infection in the sternal cavity formed from the sternal lysis, the omentum is released transdiaphragmatically under the sternotomy incision and pulled into the sternal cavity and identified both in the area and through the diaphragm (Figure 2c). The Hemovac drain is placed under the pectoral muscles that were initially freed, and the procedure is completed by identifying the muscles in front of the sternum (Figure 4).

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.00 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean \pm standard deviation (SD), median (min-max) or number and frequency, where applicable. The Spearman correlation analysis was used to evaluate the bilateral relationship between continuous variables without normal distribution. A *p* value of <0.05 was considered statistically significant.

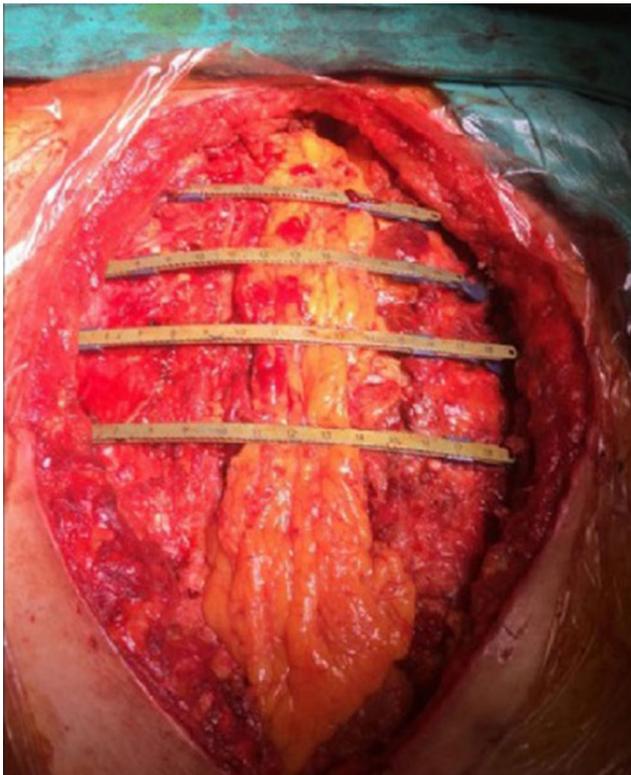


Figure 3. Intraoperative view of omental flap and rib fixator application.



Figure 4. Postoperative posteroanterior chest X-ray showing sternal fixation bars placed between opposing ribs.

RESULTS

Baseline characteristics of the patients are shown in Table 1. The first median sternotomy incisions of all cases were closed with sternal steel wires. Previous causes of median sternotomy were coronary artery bypass grafting (CABG, n=10), mitral valve replacement (MVR, n=2), and myxoma excision (n=1). The median time to the first heart operation was 72 (range, 40 to 574) days before the procedure. Refixation techniques were attempted for sternal dehiscence developing after the primary procedure in four cases. These cases were referred to our clinic, as the sternal dehiscence recurred (n=4, 30.7%). Reconstruction with the Robiscek technique was applied in three cases and a conventional rewiring technique was applied in one case after debridement. At least one of the etiological risk factors was present in all our cases. The most frequently accompanying risk factor in our cases was DM (n=7, 53.8%).

All of our cases, except for one, had sternal purulent discharge (n=12, 92%) and 10 of these cases had deep sternal wound infection confirmed by bacterial growth isolated from purulent discharge cultures. The most common microbial agents were methicillin-resistant *Staphylococcus aureus* (MRSA) (n=3) and acinetobacteria baumannii (n=3) (Table 2). Except for four cases, all cases had at least two fracture lines in the sternum (n=9, 69%; fracture count range: 2 to 4). Before our reconstruction procedure,

all patients received VAC therapy (1-10 sessions, median: 4). VAC therapy was applied until the pathogen-negative culture result was obtained in cases with reproduction in the sternal purulent discharge, and until the wound site was sufficiently cleaned in cases with no reproduction in the discharge.

There was a weak positive correlation between the number of sternum fractures and the number of VAC sessions, although this relationship was not statistically significant ($r=0.227$; $p=0.36$). Adequate sternal fixation was achieved in eight of our cases by applying three bilaterally placed bars between the third, fourth, and fifth ribs (n=8, 61.5%), in three of them by applying bilaterally placed two bars between the third, fourth or the fourth, fifth or the third, fifth ribs (n=3, 23.1%) and in two of the cases by applying four bilaterally placed bars between the second, third, fourth, and fifth ribs. In all other cases, except for three cases, the transdiaphragmatically harvested omentum was inserted into the substernal area or the sternal cavity that was not completely closed, despite the sternal fixation. In our first experiences with our procedure, omentum was not applied to the remaining sternal cavity in cases that we thought we provided adequate sternal closure. However, two (15.3%) of these three cases without omentum were observed to develop a recurrence of seroma and local infection as postoperative complications. Although there seemed to be a negative relationship between

Table 1. Baseline characteristics of patients

Patient no	Age/Sex	BMI	Previous procedure	Elapsed time (days)	Comorbidities
1	70/M	29.4	CABG	62	DM
2	65/M	24.5	CABG	53	OP
3	65/M	26.3	CABG	54	COPD, chronic cough
4	61/M	28.4	CABG + RP	59	DM
5	65/F	26.7	CABG + revision	40	DM
6	33/M	29.1	CABG+ RP	72	DM
7	56/F	20.3	MVR	132	OP
8	67/M	29.4	MVR	414	DM
9	61/F	21.5	CABG	94	DM + OP
10	56/M	29.9	CABG	377	DM
11	62/F	27.9	CME	73	OP
12	49/M	33.7	CABG + RP	574	Obesity, chronic cough
13	74/F	20.3	CABG	49	COPD, chronic cough

BMI: Body mass index; CABG: Coronary artery bypass grafting; DM: Diabetes mellitus; OP: Osteoporosis; COPD: Chronic obstructive pulmonary disease; RP: Robiscek procedure; MVR: Mitral valve replacement; CME: Cardiac myxoma excision.

Table 2. Pre- and postoperative features of the sternal fracture, wound culture, used bar numbers

Patient	Sternal fracture number	Pathogen bacteria	VAC* procedure number	Omental flap	Postoperative complication	Fixation bar number (Rib number)
1	-	-	3	-	-	2 (4, 5)
2	2	<i>P. aureginosa</i>	4	+	-	3 (3, 4, 5)
3	3	<i>Acinetobacteria</i>	2	-	Seroma	2 (3, 5)
4	3	MRSA	2	+	-	4 (2, 3, 4, 5)
5	4	<i>S. aureus</i>	1	+	-	4 (2, 3, 4, 5)
6	2	<i>P. aureginosa</i>	10	-	Wound infection	3 (3, 4, 5)
7	3	MRSA	7	+	-	3 (3, 4, 5)
8	2	<i>Acinetobacteria</i>	5	+	-	2 (3, 4)
9	2	<i>Acinetobacteria</i>	8	+	-	3 (3, 4, 5)
10	-	MRSA	6	+	Incisional hernia	3 (3, 4, 5)
11	-	-	2	+	Bar fracture	2 (3, 5)
12	2	-	3	+	Bar fracture	3 (3, 4, 5)
13	-	<i>K. pneumonia</i>	5	+	-	3 (3, 4, 5)

VAC: Vacuum-assisted closure; *P. aeruginosa*: *Pseudomonas aeruginosa*; MRSA: Methicillin-resistant *staphylococcus aureus*; *K pneumonia*: *Klebsiella pneumonia*.

omentum application and complication development, it was not statistically significant ($p=0.25$). In the management of these complications, in both cases skin incision reopened in the early postoperative period and two more VAC sessions were applied to the patient who developed seroma, and three more VAC sessions to the other patient who developed a local infection, and then control was achieved by placing the transdiaphragmatically harvested omentum in the sternal cavities. Bar separation was encountered as a postoperative complication in our two other cases ($n=2$, 15%). In both cases, three bars were used for sternal fixation, and it was found that the lowermost bars placed between the bilateral fifth ribs were separated from the ribs with the costal clips in the postoperative seventh month and postoperative ninth month, respectively. It was thought that the connection bar placed between the costal clips was not placed at the right angle and the presence of obesity from risk factors caused this situation. Since the remaining bars could provide sternal fixation well enough, it was sufficient to remove the broken bar with a minimal incision for the management of this complication. In one of our cases in which the omentum was applied intraoperatively into the sternal cavity, incisional hernia developed in the postoperative 14th month. Hernia repair was made using a prolene mesh.

At least one-year follow-up of all cases was completed and thoracic stabilization was successfully achieved in all cases during an average of 240 days postoperative follow-up (Figure 2d, Figure 3). Pre- and postoperative features of sternal fracture, wound culture, and used bar numbers are listed in Table 2.

DISCUSSION

Sternal dehiscence and mediastinitis, which can develop after cardiac and thoracic surgery, is a serious complication with significant morbidity and mortality rates that adversely affect the quality of life of patients. Although many techniques and methods have been attempted in the management of sternal dehiscence and mediastinitis, no consensus has been reached on the sternal closure technique that provides a definitive solution.

If sternal instability develops in the early postoperative period, successful results can be obtained by reconstruction with steel wires following wound debridement.^[1] However, in cases with poor bone quality, multiple sternum fractures or risk factors that predispose to instability, steel wires may fail to prevent excessive movement and develop sternal dehiscence due to reasons such as loosening, breaking, or cutting bone.^[16] To avoid problems encountered in standard closures with steel wires and to increase the sternal

stability, the sternal refixation technique which is done by basic rewiring was proposed by Robicsek et al.^[7] and this method was developed and used widely in sternal dehiscence management.^[10] However, in cases which bone quality is not sufficient, multiple fractures are present in the sternum, and infection causes complications, it is common that the sternum closure wires used in refixation techniques with these classic steel wires damage the cortical layer in the bone and cause loss of strength in the osteosynthesis line.^[1] In situations that force chest wall stability, such as normal respiratory movements or coughing, the tension in the osteosynthesis line increases further and predisposes to deep wound infections and thus to recurrence of sternal dehiscence.^[1,17] In the literature, the principles of rigid plate and screw osteosynthesis obtained from muscle flaps or craniomaxillofacial and orthopedic surgery to close the sternal defect have been attempted for sternal refixation in the treatment of such cases, which recombination is not possible with simple rewiring.^[1,17,18]

Muscle flap applications are used to provide chest wall reconstruction in the management of sternal dehiscence and infection.^[18] It has been reported that pectoralis major flaps, rectus abdominis transposition flaps, latissimus dorsi flaps, other pedicle flaps and free tissue flaps can be used for reconstruction.^[15,18,19] It has also been described in the literature that the use of omentum in the treatment of mediastinitis and in the management of deep sternal wound infection prevents prolongation of local infection with its immunological and angiogenetic features and facilitates healing of the sternal wound in a way that facilitates primary closure of superficial tissues.^[14,17,20] The main disadvantage of reconstruction applications with muscle flaps is that a sufficient rigid thoracic refixation cannot be achieved only with muscle flap applications.^[21]

In complicated cases in which bone viability is reduced, infection accompanies, and sternal reconstruction is difficult to manage with classical approaches, sternal closure methods using titanium reconstruction plates, cables and screws have been proposed to close the sternal defect.^[1,17] Compared to other techniques, these methods have certain advantages such as supporting osteogenesis by keeping bone fragments together and limiting their movement throughout the healing process and not affecting blood flow in the fracture site.^[13] Depending on the width and shape of the sternum, making the choice of the type and number of plates to be used in these methods and determining the places at which the plates would be placed on the sternum requires experience and also

a good surgical talent is needed to keep the length of the screws in the sternum in proper dimensions to not reach the chest cavity and damage the organs.^[22] The need for experience and care may be interpreted as the disadvantages of these methods. A new procedure using the osteosynthesis system called STRATOS, which eliminates these disadvantages of the sternal refixation methods using titanium reconstruction plates, is also applied with the help of titanium plates and was first defined in 2010.^[17] Using this procedure, which provides stabilization from one rib to the other in the transverse plane without the need to free the substernal area, the fixation area is formed between the bone ribs where the bone quality is better and away from the broken sternum.^[17] If the sternal parts cannot be drawn sufficiently close, the dead space between can be filled with the transdiaphragmatic omentum and, therefore, local infection control and wound healing are supported.^[17] The most critical point in this technique is the placement of the connection bar between the two costal clips at the right angle. If the connecting bar to be placed between the clips is placed inattentively between the two clips with an angle difference in the transverse plane, the tension force caused by the compulsive actions that would require the expansion of the thoracic wall in the postoperative period cannot be distributed evenly on every point of the bar; thus, the connection bar cannot meet the tension pressure, thereby, breaking from the parts where the force is felt more or dislocation of the costal clips with the bar may occur. In the management of this complication that we encountered in our two cases in our study, excision of the broken bars with the help of minimal skin incisions is sufficient and adequate stabilization can be achieved with the remaining bars in these cases.

Another advantage of this procedure is that local infection control and a rigid sternal refixation can be achieved by bringing the sternal margins closer to each other as close as possible by filling the base of the sternal gap with the transdiaphragmatically harvested omentum. In our study, in most of our cases, the dead space which can occur in the mutual joining of the sternal bone parts was filled with the omentum released by the transdiaphragmatic approach. The application of the omentum, the immunological and angiogenetic properties of which are known, prevents the development of seroma and local infections that may develop in the cavity and supports wound healing.

We believe that the control of infection in the preoperative period is the most important factor

affecting postoperative success in this procedure using the osteosynthesis system, which is usually used in the management of complicated cases with purulent discharge infection and in which sternum quality is not good. The VAC method, which has shown successful result even in difficult-to-manage complications such as mediastinitis and post-pneumonecemic empyema, can be used as an aid to facilitate wound closure before sternal reconstruction.^[23,24] Negative pressure therapy used prior to reconstruction has been shown to reduce infection by decreasing the total number of dressing changes and to reduce the exact closure time.^[18,23] The use of VAC as a “bridge” until the definitive closure procedure also increases the chances of postoperative success by enabling the improvement of patients' conditions, who cannot care for themselves due to the infective process and accompanying comorbidities, with nutritional and palliative supports.^[18,24] To ensure infection control before sternal reconstruction with the STRATOS system, we apply the necessary VAC method that we patiently apply until the culture negative status is achieved at the wound site and the necessary nutritional and palliative support treatments for our patients with poor performance, until the sternal closure procedure in addition to the systemic antibiotic treatments applied for the microbial agent. We believe that all these approaches are effective in the postoperative success of this procedure.

There are several limitations to our study. The most important limitations are the retrospective nature of the study, the small sample size, and its inability to compare with a control group.

In conclusion, with the use of preoperative vacuum-assisted closure treatment and the application of transdiaphragmatic omentum into the intraoperative sternal space, reconstruction procedure using the STRATOS system can successfully achieve sternal refixation in complicated cases, which the sternum bone quality is not good, the sternal fractures accompany, the sternum edges and cartilage parts of the ribs have lysis, purulent discharge infection accompanies and recurrence cannot be averted despite the conventional methods of refixation. We also believe that the treatment of mediastinitis and sternal dehiscence should be managed by thoracic surgeons, since surgery of the anatomical structures of the thoracic wall primarily involves thoracic surgery.

Declaration of conflicting interests

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