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ORIGINAL ARTICLE / ÖZGÜN MAKALE

# Should wide chest wall resections and reconstruction intimidate thoracic surgeons?

*Geniş göğüs duvarı rezeksiyon ve rekonstrüksiyonu göğüs cerrahlarını korkutmalı mıdır?*

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***ABSTRACT***

***Background:*** This study aimed to compare patients in whom wide chest wall resection and reconstruction or primary closure was performed.

***Methods:*** A total of 63 patients who underwent chest wall resection and reconstruction between January 2018 and December 2022 were included in the retrospective study. The patients were divided into two groups: the first group, which included 31 patients (14 males, 17 females; mean age: 44.6±16.4 years; range, 16 to 71 years) who were closed primarily, and the second group, constituting 32 patients (25 males, 7 females; mean age: 54.6±17.2 years; range, 9 to 80 years) who underwent reconstruction with plates and meshes.

***Results:*** There was no significant difference between the two groups in terms of smoking and diabetes. Primary chest wall or metastatic tumor was determined in 33 patients; benign tumor and trauma were determined in 30 patients. The difference between the two groups in mean defect diameter (p=0.009), mean number of plates used (p<0.001), and mean hospital stay (p<0.001) was statistically significant. However, there was no significant difference in terms of complications (p=0.426).

***Conclusion:*** Wide chest wall resection and reconstruction is a safe and feasible surgical procedure when compared with primary closure.

***Keywords:*** Chest wall resection, chest wall tumors, reconstruction, titanium plaque.

***ÖZ***

***Amaç:*** Bu çalışmada, geniş göğüs duvarı rezeksiyonu ve rekontrüksiyonu veya primer kapatma yapılan hastalar karşılaştırıldı.

***Çalışma planı:*** Ocak 2018 - Aralık 2022 tarihleri arasında göğüs duvarı rezeksiyon ve rekontrüksiyonu uygulanan toplam 63 hasta retrospektif çalışmaya dahil edildi. Hastalar iki gruba ayrıldı: primer olarak kapatılan 31 hastayı (14 erkek, 17 kadın; ort. yaş: 44.6±16.4 yıl; dağılım, 16-71 yıl) içeren birinci grup ve plak ve meshler ile rekontsrüksiyon uygulanan 32 hastadan (25 erkek, 7 kadın; ort. yaş: 54.6±17.2 yıl; dağılım, 9-80 yıl) oluşan ikinci grup.

***Bulgular:*** Her iki grup arasında sigara içme ve diyabet varlığı açısından anlamlı bir fark bulunmadı. Otuz üç hastada primer göğüs duvarı veya metastatik tümör saptandı; 30 hastada benign tümör ve travma saptandı. İki grup arasında ortalama defekt çapı (p=0.009), ortalama kullanılan plak sayısı (p<0.001) ve ortalama hastanede kalış süresi (p<0.001) açısından istatistiksel olarak anlamlı fark bulundu. Ancak görülen komplikasyonlar açısından gruplar arasında anlamlı fark bulunmadı (p=0.426).

***Sonuç:*** Geniş göğüs duvarı rezeksiyon ve rekonstrüksiyonu, primer kapatma ile karşılaştırıldığında güvenli ve uygulanabilir bir cerrahi işlemdir.

***Anahtar sözcükler:*** Göğüs duvarı rezeksiyonu, göğüs duvarı tümörleri, rekonstrüksiyon, titanyum plak.

The dynamic structure of the chest wall plays a crucial role in maintaining both respiratory and circulatory processes, in addition to housing essential organs.[1,2] The continuance of these crucial functions depends on the preservation of the anatomical structure. Resection of chest wall tumors, radiation necrosis, infections, and injuries are the numerous reasons for defects in the chest wall.[3] Reconstruction is required to maintain respiratory physiology and close the wound in a way

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that provides a respectable cosmetic appearance. Reconstruction can be carried out utilizing the patient's own tissues or by combining or not combining rigid and nonrigid materials.[1-3] This surgical intervention varies depending on many factors, including indication, personal factors, access to reconstruction materials, current technology, and the surgeon's experience.[3,4]

The optimum material for rigid chest wall reconstruction should be easily shaped and applied, provide enough rigidity while avoiding paradoxical breathing, allow tissue growth, have good tissue compatibility, and not cause a foreign body reaction.[1,4,5] Synthetic materials used in rigid reconstruction include double mesh methyl methacrylate, titanium plates, titanium mesh, and polypropylene-polyester denim prostheses. Chest wall reconstruction has evolved into a field that can be both simple and complex, where patient-specific aspects are prominent and various procedures are applied concurrently with technological advancements.[5] In this study, we aimed to offer our experiences in wide chest wall resection and reconstruction compared with other primary closures of the chest wall defect.

## PATIENTS AND METHODS

In this retrospective study, the medical and operation records of 63 patients who underwent chest wall resection and reconstruction with prosthetic materials or not due to primary or secondary malignant neoplasm and trauma at the Gülhane Training and Research Hospital, Department of Thoracic Surgery were examined between January 2018 and December 2022. Patients who underwent chest wall resections due to postthoracotomy empyema (modified Eloesser flap surgeries) and reconstruction performed with custom-designed implants created using three-dimensional printers were excluded. Deciding and performing the restoration of the skeletal integrity, paramount for wide chest wall defects, was the primary aim, and when two or more rib resections were required, skeletal reconstruction was usually performed. Rigid reconstruction materials, such as titanium plates, screws, wire sutures, Prolene mesh, or PTFE (polytetrafluoroethylene) grafts, were used to restore the skeletal integrity (Figure 1).

The patients who underwent chest wall reconstruction at our institution were grouped into two categories: primary closure of the defect without the use of any

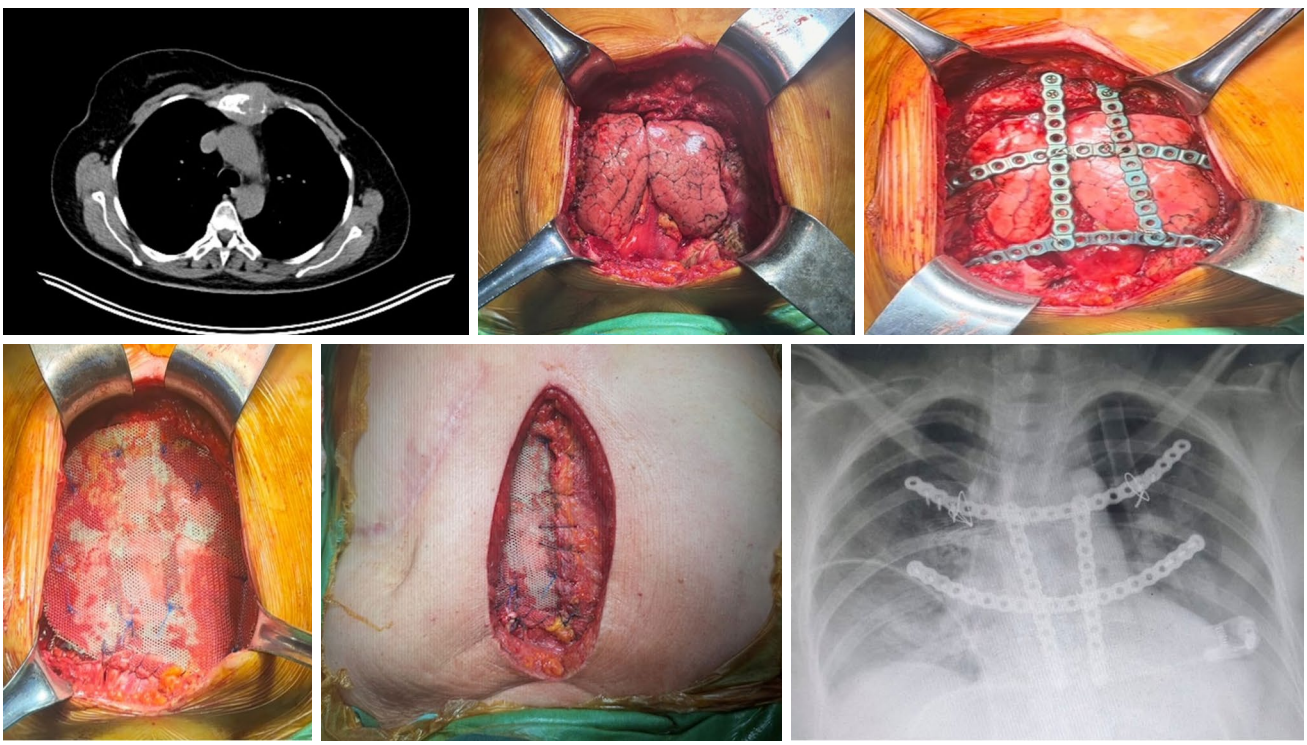

**Figure 1.** Manubrium, bilateral clavicula, and first and second rib resection. Reconstruction with titanium plate and Prolene mesh, covered with the pectoralis major muscle.

plate, mesh, or muscle flap (n=31; 14 males, 17 females; mean age: 44.6±16.4 years; range, 16 to 71 years) and (chest wall reconstruction with a plate or mesh, with or without a muscle flap (n=32; 25 males, 7 females; mean age: 54.6±17.2 years; range, 9 to 80 years). In the second group, chest wall stabilization with a titanium plate for traumatic patients was included. Occasionally, titanium plate reconstruction was used following the resection of two ribs if there was significant rib length and if a part of the sternum had also been resected (Figure 2).

The patient's comorbid conditions and demographics, the location of the lesion, the number of ribs removed, the state of the lung resection, the soft tissue or skin reconstruction, the materials utilized during the operation, 30-day mortality, postoperative complications, reasons and frequency of reoperations, late problems related to reconstruction, and length of stay were all recorded. Complications that developed within 30 days postoperatively or complications such as pneumonia, atelectasis, respiratory failure, and prolonged air leakage (>7 days) that developed due to the reconstruction technique were evaluated. Epidural analgesics, intravenous analgesic infusions, and patient-controlled analgesics were all used to manage postoperative pain.

## RESULTS

Of the 32 patients who needed chest wall reconstruction, 15 underwent only plaque implantation without an additional prosthetic patch or autologous flap reconstruction, while one patient required only a prosthetic patch. The remaining 16 patients underwent plaque implantation with a prosthetic patch but with or without additional autologous flap reconstruction. Twenty-seven (38.1%) patients were smokers, and 12 (19.1%) patients had diabetes mellitus. The demographic features of the two groups are summarized in Table 1. Of the 63 patients, 33 had primary malignant or metastatic tumors, while the

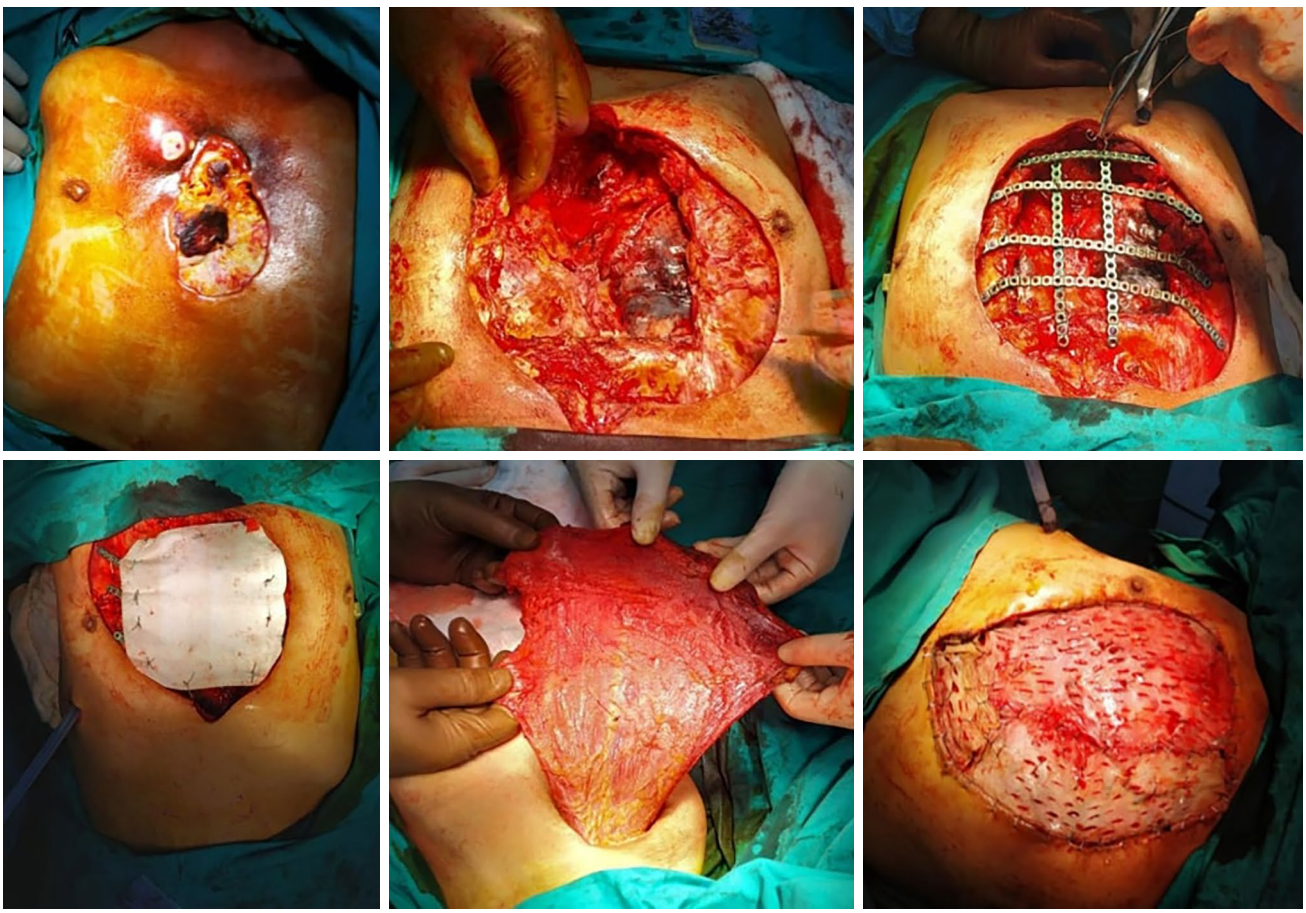

**Figure 2.** An intraoperative image of wide chest wall resection and reconstruction with titanium plate, polytetrafluoroethylene, and latissimus dorsi muscle flap.

remaining 30 had benign tumors and trauma. In terms of severe comorbidities and smoking status, the primary closure and chest wall reconstruction groups were equivalent. The primary closure group was younger, and the sex ratios were significantly different between the two groups.

The significant differences between the primary closure and chest wall reconstruction groups are summarized in Table 2. Remarkably, patients in the chest wall reconstruction group had considerably greater deficiencies than in the primary closure group (37.5 $cm^2$ *vs*. 20 $cm^2$, p=0.009). In comparison to the primary closure group, more ribs were removed in the chest wall reconstruction group (p=0.001). There were no significant differences between the groups in malignant pathologies or the number of concomitant lung resections (p=0.532 and p=0.245). Concomitant lung resections were performed in 13 of the 33 malignant patients.

The complication rates were not different between the two groups (p=0.426). There was no postoperative respiratory failure in any patient. In the first 30 days, one patient suffered chylothorax, three patients developed postoperative pneumonia, and two patients acquired a wound infection. There was no 30-day mortality in any group.

**Table 1. The demographic features of patients**

| | Primary closure group (n=31) | | | | Chest wall reconstruction group (n=32) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | Mean±SD | Range | n | % | Mean±SD | Range | *p* |
| Age (year) | | | 44.6±16.4 | 16-71 | | | 54.6±17.2 | 9-80 | 0.022 |
| Sex | | | | | | | | | 0.007 |
| Male | 14 | 45.2 | | | 25 | 78.1 | | | |
| Female | 17 | 54.8 | | | 7 | 21.9 | | | |
| Diabetes | 4 | 12.9 | | | 8 | 25 | | | 0.222 |
| Smoking | 11 | 35.5 | | | 13 | 40.6 | | | 0.674 |

**Table 2. The operative variables of the two groups**

| | Primary closure group (n=31) | | | | Chest wall reconstruction group (n=32) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | Median | IQR | n | % | Median | IQR | *p* |
| Malignant pathology | 15 | 48.4 | | | 18 | 56.3 | | | 0.532 |
| Concomitant lung resection | 5 | 16.1 | | | 8 | 25 | | | 0.245 |
| Median defect size ($cm^2$) | | | 20 | 37.5 | | | 37.5 | 88.5 | 0.009 |
| Median number of ribs resected | | | 1 | 1 | | | 3 | 1.5 | <0.001 |
| Median days of hospital stay | | | 3 | 2 | | | 7 | 9.5 | <0.001 |

IQR: Interquartile range.

**Table 3. Subgroup analysis of chest wall reconstruction with plate or mesh, with or without muscle flap**

| | Plate implantation alone (n=15) | | | | Plate implantation and mesh usage with or without muscle flap repair (n=17) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | Mean±SD | IQR | n | % | Mean±SD | IQR | *p* |
| Age (year) | | | 56.9±16.9 | | | | 51.6±17.8 | | 0.404 |
| Sex | | | | | | | | | 0.326 |
| Male | 11 | 73.3 | | | 14 | 87.5 | | | |
| Female | 4 | 26.7 | | | 3 | 12.5 | | | |
| Median number of plate | | | 2 | 2 | | | 3 | 1.5 | 0.059 |
| Median number of screw | | | 6 | 6 | | | 10.5 | 4 | 0.037 |

IQR: Interquartile range.

The mean duration of postoperative follow-up was not different between the two groups (primary closure group, 659.7±431.5 days *vs*. chest wall reconstruction group, 606.4±344.3 days; p=0.589). In terms of long-term complications, seven patients required reoperation. As a result of a fistulized infection in the skin, two patients in the primary closure group underwent reoperation. In the chest wall reconstruction group, three patients had reoperation for recurrences, one patient for bronchopulmonary fistula, and one patient for osteomyelitis. No lung herniation was observed in any patient during follow-up.

Further analysis of the patients in the chest wall reconstruction group focused on their method of reconstruction, namely plaque implantation alone and plaque implantation combined with mesh with or without muscle flap repair. In terms of patient demographics, there was no statistically significant difference between the two groups (Table 3). No significant differences were found for the operative variables.

## DISCUSSION

In many ways, it is crucial to manage defect repair following significant chest wall resections. It is anticipated to minimize mechanical disruption of the chest wall and maximize the maintenance of respiratory function. Although there are no hard and fast rules, it is widely accepted that lesions smaller than 5 cm in any region and even up to 10 cm in the posterior thoracic wall do not necessitate reconstruction.[6] Reconstruction is often required for posterior defects around the inferior scapula and anterior defects.[7] This retrospective series was used to record, examine, and compare the clinical outcomes of different methods of chest defect repair in our center with those of titanium plate reconstruction of the chest wall.

A prosthetic material should be sufficiently rigid, compatible with the rib cage's concavity, chemically and physically inert, allow for tissue growth, be radiolucent, infection-resistant, and cost-effective. The lack of quality prospective research limits an assessment of the literature on clinical outcomes after chest wall excision and prosthetic reconstruction. Consequently, a few small case studies and anecdotal surgeon experience guide current practice.[4,6,8,9] Weyant et al.[7] found no difference in overall complication rates in their study of 262 patients with a rigid prosthesis (Marlex methyl methacrylate sandwich), a nonrigid prosthesis (polypropylene or PTFE), or no prosthesis. Notably, wound complications such as seroma, hematoma, and infection were slightly higher in the methyl methacrylate group compared to the patch group. We may probably conclude that prosthetic chest wall reconstruction can preserve preoperative pulmonary function based on the literature that is currently available.[9,10] This is supported by our study's finding that patients using prosthetic material experienced similar complication rates to those of primary closure patients.

Thoracic surgeons are familiar with the importance of maintaining chest wall dynamics with skeletal stabilization and clinical improvement in multiple rib fractures and flail chest after trauma. The wide range of fractures observed in flail chest injuries can be accommodated by titanium plate implant systems, which also offer dependable fixation.[11] The titanium plate's shape is user-friendly and ergonomic, which can lessen the likelihood of a prosthesis fracture.[12,13] Better chest wall reconstruction is made possible by the titanium plate, which imitates natural anatomy and physiology to address greater deficiencies and lower the risk of respiratory failure.[13]

The improvements comprise more accurate preoperative localization of rib fractures utilizing ultrasonography or three-dimensional computed tomography reconstruction technologies, as well as more reliable rib fixation using specifically created plating systems.[14] Selective metal laser sintering three-dimensional prototyping technology has yielded encouraging results for surgeons who want to increase the adaption of the reconstruction material to respiratory mechanics and generate the material that is closest to the original. A three-dimensional model of the bones can be extracted from computed tomography images using this technology to help the surgeon understand the defect that would appear after resection and construct a patient-specific prosthesis.[15] Thus, a prosthesis that is an exact duplicate of the original can be used to rectify the malformation. However, there is now a restricted supply of this technology, which calls for certain pieces of equipment and skills. Furthermore, the production of 3D implants takes longer and costs more than with conventional techniques. Moreover, stabilizing this kind of material during the repair of a significant defect is challenging.

Achieving skeletal stabilization is the primary objective of rebuilding the defect following chest wall excision.[4,13,14] A primary closure can be used to successfully restore the chest wall if the skeletal stability is intact. Autologous muscles are used for

primary closure, such as the pectoralis major, rectus abdominus, latissimus dorsi, and external oblique or trapezius muscles.[4]

Larger resections are likely to necessitate sophisticated reconstruction. However, while the number of resected ribs differed between patients who underwent primary closure and those who underwent complex reconstruction in this study, the defect size did not differ significantly. In several prior articles, the number of resected ribs was utilized as a marker to emphasize the defect width. We compared the size of the defect in terms of mathematical area, which we believe will provide more reliable information. In this respect, we suggest that the size of the defect or the number of ribs removed should not be used as a stand-alone indication for the need for complex reconstruction requiring additional material. In our opinion, the location of the defect is the most significant factor. We believe that the most important determining factor in reconstruction is the localization of the defect.

Both the primary closure group and the chest wall reconstruction group included patients who underwent malignancy-related resections and concomitant lung resections. However, the complication rate and length of hospitalization were not different. In malignant patients in whom a clean surgical margin is targeted, the defect may be closed with less sophisticated methods depending on its localization and size. However, we did not find evidence that complex reconstruction increases the complication rate.

The median hospital stay and complications were not different between the patients who underwent plate implantation alone and those in whom plate and mesh were used together. Moreover, the median defect diameter closed in these patients was similar. Therefore, it can be argued that reconstructions characterized by the use of multiple materials do not make patients more vulnerable to complications.

Wong et al.[13] reported no in-hospital or early postoperative mortality in their 10-year experience with long-term outcomes after chest wall reconstructions with titanium plates. They emphasized that titanium plates provide a safe and effective reconstruction, and long-term complications are rare and manageable.

In-hospital mortality was reported to be more than 7% in earlier studies.[4] However, we did not observe any in-hospital mortality in our study. We did not observe any prosthetic breakage, screw loosening, or plate malrotation. This can be explained both by improved perioperative management due to surgical techniques, including the use of steel wire to stabilize the plate in critical areas, improvements in material quality, and the fact that all patients were adults. The pediatric patient group, in which growth continues, is more sensitive to complications related to the growth-limiting effect of titanium plates. The data on chest wall reconstruction in pediatric patients is insufficient, and precisely how best to treat these patients is still under debate.

Our length of hospitalization is consistent with the median length of hospitalization of 7 days in previous series.[4,6,13] This is contrary to the approach that suggests that with each foreign material to be used in complex reconstruction, recovery is prolonged and complications increase. Although we suggest that clinicians should keep in mind that less is better and no approach is the best, we believe that one should not avoid using prosthetic material when necessary.

There are a number of limitations to this study. First, owing to the study's retrospective design, patients' needs for reconstruction varied widely. In addition, the study is exploratory in nature and has a limited sample size. Second, the surgeon's experience has a role in determining the sort of surgery and reconstruction that is chosen. Furthermore, as primary repair generally fails to provide adequate support for tissue defects, attaining negative margins in malignant lesions is likely to result in bigger chest wall deficiencies and necessitate more intricate reconstructions. A comprehensive follow-up of the potential benefits of reconstruction was not possible due to the lack of documentation of patients' individual clinical details.

In conclusion, this study created a baseline for comparing clinical outcomes, particularly long-term postoperative issues with the use of a plate or mesh, with or without a muscle flap, in complex reconstructions. It might be quite challanging to reconstruct extensive chest wall defects after chest wall excision. Increasing the quality of life of patients and decreasing mortality after chest wall resection is closely related to preventing early and late complications in patients. As a result, future prospective studies that incorporate assessments of quality of life and lung function employing various reconstruction techniques are necessary.

**Ethics Committee Approval:** The study protocol was approved by the Gülhane Training and Research Hospital Ethics Committee (date: 14.02.2023, no: 2023-60). The study was conducted in accordance with the principles of the Declaration of Helsinki.

**Patient Consent for Publication:** A written informed consent was obtained from the patients and/or parents of the patients.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Author Contributions:** Idea/concept: M.S.I., K.K., H.I.; Design: H.I., K.K.; Control/supervision: K.K., H.C..; Data collection and/or processing: M.Y, U.U., D.K.; Analysis and/or interpretation: M.S.I., E.S., H.I.; Literature review: M.S.I., H.I., E.S.; Writing the article: M.S.I., K.K., H.I.; Critical review: H.C.

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