Stabilization after deep sternal wound infection: assessment of most suitable osteosynthesis system and presentation of a new method for grading bone pathology

Stephan Raab, Evaldas Girdauskas, Sebastian Reindl

Angaben zur Veröffentlichung / Publication details:

Raab, Stephan, Evaldas Girdauskas, and Sebastian Reindl. 2026. "Stabilization after deep sternal wound infection: assessment of most suitable osteosynthesis system and presentation of a new method for grading bone pathology." *Surgical Techniques Development* 15 (2): 25. https://doi.org/10.3390/std15020025.

surgical techniques development

MDPI

Article

Stabilization After Deep Sternal Wound Infection: Assessment of Most Suitable Osteosynthesis System and Presentation of a New Method for Grading Bone Pathology

Stephan Raab [1], Evaldas Girdauskas [2] and Sebastian Reindl [1,*]

[1] Clinic for General, Visceral, Transplantation and Thoracic Surgery, University Hospital Augsburg, Faculty of Medicine, University of Augsburg, Stenglinstr. 2, 86156 Augsburg, Germany; stephan.raab@uk-augsburg.de

[2] Clinic for Cardiac Surgery, University Hospital Augsburg, Faculty of Medicine, University of Augsburg, Stenglinstr. 2, 86156 Augsburg, Germany; evaldas.girdauskas@uk-augsburg.de

* Correspondence: sebastian.reindl@uk-augsburg.de; Tel.: +49-821-400-161929

Abstract

Objective: Osteosynthesis in the case of a sternal wound infection is challenging. It requires osteosynthesis systems that go beyond the usual wire techniques. In principle, there are three different systems, namely plates with locking screws, clips, and distance systems, which are the original methods used in chest wall reconstruction. The aim of this study is to assign these systems to the corresponding sternal pathologies. Patients and methods: This is a retrospective single-center analysis. Bone pathology is divided into three grades: grade I (good substance/no fractures), grade II (good substance/few transverse fractures), grade III (poor substance/substance defects/multiple transverse fractures). The individual osteosynthesis systems are assigned to the different grades accordingly. The suitability of the individual systems is analyzed in the short term and long term. Results: A total of 130 patients were included. Stable osteosynthesis was achieved in all patients. For grade I defects, 75 plates and 24 clips were used. For grade II defects, mainly plates (255) but also clips (16) were used. A distance system was used 24 times for grade III defects. One plate fractured. No other implant-related complications occurred. Discussion: If the different osteosynthesis systems are used according to the bone pathology, a stable chest wall can be restored in all patients. The individual systems have their own specific characteristics, which must be taken into account with regard to the suitability and invasiveness of the procedure. No single system is suitable for treating all sternal pathologies.

Keywords: deep sternal wound infection; sternal osteosynthesis; sternal stabilization

Check for updates

Academic Editor: Andrea Dell'Amore

Received: 12 October 2025
Revised: 8 January 2026
Accepted: 9 June 2026
Published: 11 June 2026

1. Introduction

Since the median sternotomy was introduced as the standard method to provide access for cardiac surgery in 1958, wire cerclage has been standard for closing a sternotomy [1]. This has not changed significantly to this day [2]. The situation is different when restabilizing a sternum after a deep sternal wound infection. Here the conditions are often more difficult, as the bone substance has been altered by infection and previous osteosynthesis. In the treatment of sternal wound infection with osteomyelitis, one approach involves completely resecting the sternum [3]. However, this ignores the fact that the sternum has several functions in the bone structure of the thorax. Firstly, it has a protective function for the intrathoracic organs. It not only deflects mechanical pressure from the front to the side of the ribs but also ensures that the contour of the thorax is maintained. It is also connected to rib pairs C1 to C10 and facilitates breathing [4]. In addition, arm movement forces act directly or indirectly on the sternum. These are muscular forces with attachments close to either the sternum or the sternoclavicular joint, which is the bony connection between the trunk and the upper extremity. If the sternum is resected, all these functions of the sternum are lost. Orthoses and myoplasty are used when attempting to restore the direct protective function. Loss of function with an unstable thorax also requires reconstructive measures. A mesh [5] and myoplasty are often used here. Overall, instability remains in the defect even after the formation of a scar plate. These reconstructive efforts can return the sternum to its natural state, and the question arises as to why the sternum should be resected. Rather, all reconstructive attempts should aim to preserve the sternum [6].

In principle, the following techniques are available for sternal osteosynthesis:

- Stainless steel wires and thick braided threads (various manufacturers, e.g., Braun, Melsungen, Germany; Ethicon, Johnson & Johnson, New Brunswick, NJ, USA);
- Titanium plates with locking screws (e.g., Synthes, Ethicon, Johnson & Johnson, New Brunswick, NJ, USA; Zimmer Biomet, Warsaw, IN, USA);
- Clips (e.g., MedXpert, Eschbach, Germany; Nitisternum, Europrisme Medical Group, Obernai, France);
- Osteosynthesis at a distance (e.g., MedXpert, Eschbach, Germany).

An exhaustive list of manufacturing companies cannot be provided here. In some cases, products are withdrawn from the market or new ones are added. The systems that were used most frequently in our hospital during the investigation period or that have properties that other systems lack are mentioned.

Although reconstruction techniques and their systems have been described for use in the primary treatment of an osteotomy and in some cases also for stabilization after an infection, not all systems have been taken into account. In 2014, a classification of deep sternal wound infections was introduced with regard to bone substance [7]. Reconstructive techniques are discussed here according to the pathology of the sternum. Since the 2014 classification, new systems for osteosynthesis of the bone have been added and the aim of this study is to evaluate the various systems according to their advantages and disadvantages for different sternal pathologies.

2. Materials and Methods

This study is a single-center retrospective analysis conducted at the University Hospital Augsburg. In total, 7749 patients underwent cardiac surgery using extracorporeal circulation via median sternotomy during January 2014 to December 2023. During this period, all patients with deep sternal wound infection were identified and analyzed. The duration of the follow-up was 12 months. Patients who died during the index hospital stay were included in the analysis of the applied sternal osteosynthesis technique but were excluded from follow-up analyses due to the lack of post-discharge data.

In patients with chronic osteomyelitis or recurrent clinical signs of reinfection during follow-up, bone healing was monitored over a 6-month period. Repeated microbiological swabs were obtained, and targeted antibiotic therapy was administered for at least 3 months in accordance with established osteomyelitis treatment protocols. After completion of therapy, the osteosynthetic material was removed and the wound was re-closed.

In order to be able to classify the advantages and disadvantages of the respective systems, the following classification of bone substance was made, based on intraoperative findings and pre-operative radiologic diagnostics, including chest X-ray and facultative CT-scans of the thorax:

I. Good substance/no fractures (Figure 1);
II. Good substance/few transverse fractures (Figure 2);

III. Poor substance/substance defects/multiple transverse fractures (Figure 3).

The surgical documentation and postoperative X-rays were then used to categorize the patients into the three groups.

Figure 1. Example of grade I pathology. Intraoperative situs immediately before reconstruction. Good bone substance for both sternum halves, no defects, no transverse fractures.

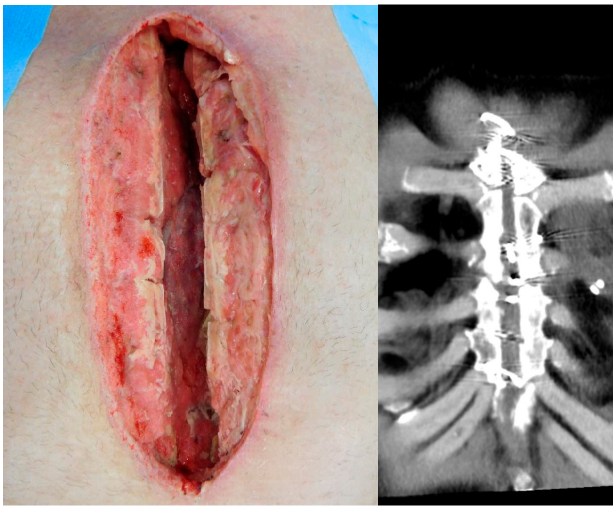

Figure 2. Example of grade II pathology. Good bone substance, but some transverse fractures and small defects due to torn wire cerclages in both sternal halves. (**Left**) Intraoperative situs immediately before reconstruction. (**Right**) Pre-operative CT of the anterior chest wall (soft-tissue window).

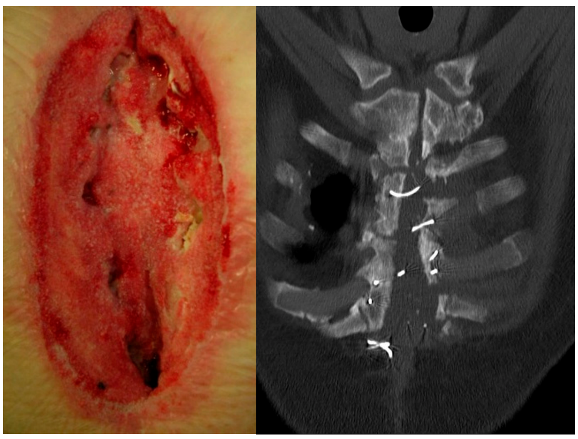

Figure 3. Example of grade III pathology. Poor bone substance, transverse fractures and large substance defects with wide sternal dehiscence of the sternal halves. Good granulation tissue. (**Left**) Intraoperative situs immediately before reconstruction. (**Right**) Pre-operative CT of the anterior chest wall (bone window).

https://doi.org/10.3390/std15020025

The following techniques were available to the team of three experienced surgeons during the study period:

- Stainless steel wires/PDS cords;
- Titanium plates with locking screws;
- Osteosynthesis at a distance;
- Sternum clips (only available from 2016).

The following parameters were evaluated:

- Type of osteosynthesis and systems used;
- Proportion of primary stable osteosyntheses;
- Implant failure (fracture or rupture within the first year).

Sternal closure was primarily achieved with wire cerclages in all patients. After DSWI diagnosis the entire wound was reopened and all foreign material, including the initially used osteosynthesis material, was removed. This was followed by surgical wound debridement with preservation of samples for microbiology and histology. Finally, a local negative pressure system (NPWT) was established and continuous suction was applied. The individual dressing changes took place at 3- to 4-day intervals. Surgical wound debridement and sampling for microbiology were performed at each dressing change. The criteria for secondary closure were bacteriological sterility, good granulation of the wound, low secretion and largely normalized inflammatory parameters.

The following systems were available:

- SternaLock® Blu (Zimmer Biomet, Jacksonville, FL, USA);
- Titanium Sternal Fixation System (DePuy Synthes, Johnson & Johnson, New Brunswick, NJ, USA);
- StraTos sternum clip (MedXpert, Eschbach, Germany);
- StraTos implant bridge (MedXpert, Eschbach, Germany);
- Wires and PDS cords (Ethicon, Johnson&Johnson, New Brunswick, NJ, USA).

The most suitable system was decided on an individual basis depending on the bone pathology. The respective systems were implanted in accordance with the manufacturer's instructions. The decision as to which system was used for which pathology was made as follows:

I. Good bone substance/no fractures: All systems could be used (Figure 4).
II. Good bone substance, single fractures: All systems were used, with the following restrictions: Only plates that could bridge a fracture and had at least 2 screws on each side of the fracture were selected. For clips, only clips with 3 segments were used in order to be able to bridge defects or fractures completely (Figure 5).
III. Poor bone substance, fractures and defects: The primary aim here was to achieve osteosynthesis at a distance. There was no osteosynthesis in the strict sense. The chest wall was stabilized. A system was fixed to the ribs on both sides and a transverse connection and thus stabilization of the two halves of the thorax was achieved. In areas with good bone substance, the systems described under II were used as support (Figure 6).

The materials were covered with sliding myoplasty of the pectoralis major muscle after insertion of bilateral redon drainage.

The result of sternal reconstruction was functionally assessed intraoperatively. Postoperatively, daily clinical assessments were performed to evaluate functional stability, wound condition, and signs of impaired healing or infection. In addition, radiographic control of implant position was routinely obtained by chest X-ray, while computed tomography was performed selectively in cases of unclear findings or suspected implant-related complications. Further complications as a result of re-osteosynthesis were followed up for at least 12 months.

In addition to standard patient characteristics, study-specific variables were extracted from available medical records, including microbiological and histopathological findings, as well as surgical reports from the index operation, all wound revisions and dressing changes, and the surgical stabilization of the sternum.

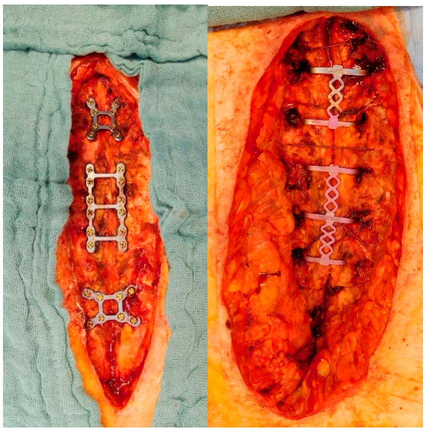

Figure 4. Examples of osteosynthesis for grade I using plates and locking screws (**left**) or sternum clips (**right**).

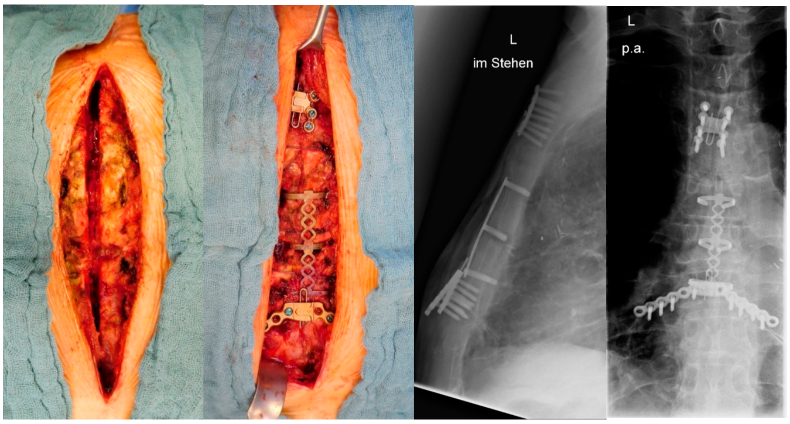

Figure 5. Osteosynthesis for grade II with a transverse fracture bridged using a clip. (**Left**) Intraoperative situs before and after osteosynthesis. (**Right**) Postoperative two-plane chest X-ray.

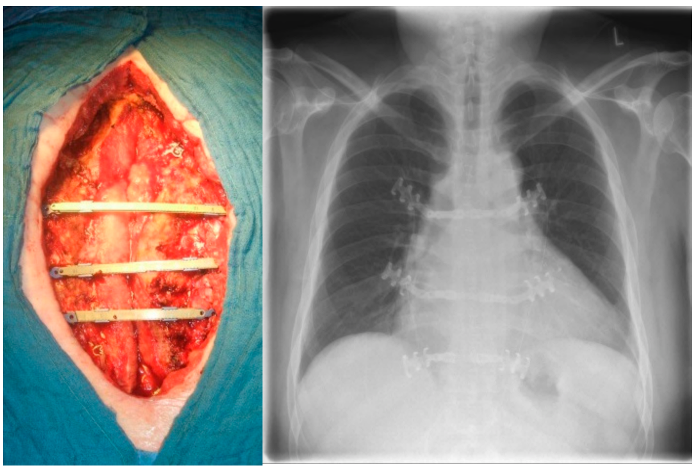

Figure 6. Osteosynthesis for grade III with stabilization at distance. (**Left**) Intraoperative situs showing three titanium implant bridges. (**Right**) Postoperative chest X-ray.

3. Results

A total of n = 130 patients were identified with DSWI after cardiac surgery via median sternotomy (1.7%). Basic patient characteristics were as follows: age (years) 67 ± 15.2, gender (male/female) 6.1:1. The primary cardiac surgery comprised coronary artery bypass grafting in most cases (CABG; 84 patients, 64%) and combined procedures, predominantly CABG with aortic valve replacement (AVR; 14 patients, 11%). Isolated valve procedures included AVR in 13 patients (10%), and ascending aortic replacement (AAR) was performed in 12 patients (9%). Less frequent procedures were closure of Atrial Septum Defect II and mitral valve repair or replacement.

In these 130 patients DSWI was diagnosed 28.6 ± 54.7 days (mean, standard deviation) after primary surgery. All patients were treated with NPWT as described in Section 2. A mean of 6.8 ± 4.5 dressing changes were necessary until sternal reconstruction could be performed 54.8 ± 46.6 days after the initial surgery.

Microbiological sterility could only be achieved in n = 79 patients (60.8%), whereas a colonization with microorganisms remained in n = 51 patients (39.2%). The most common pathogen in these cases was Staphylococcus epidermidis.

Stable osteosynthesis was functionally tested intraoperatively and could always be achieved. There were no complications during implantation. No implants had to be discarded due to material breakage or unsuitable choice. The reconstruction enabled the fracture gap to heal in grades I and II, so that no pseudarthrosis occurred functionally in the follow-up. Table 1 shows how many times each system was used in patients in each grade.

Table 1. Shown is how many times each osteosynthesis system was used for each grade and in how many patients. The data are presented as number of patients (number of times system was used). In grade III pathologies, only 5 patients underwent only stabilization at a distance. The other 20 cases additionally received plate osteosynthesis in areas where the bone still corresponded to a grade II pathology.

	Grade I	Grade II	Grade III
plates/screws	37 (75)	90 (255)	1
clips	14 (24)	16 (16)	0
distance systems	0	0	24

In cases where clips were used for grade I pathologies, additional plates were also used in some cases. For grade II pathologies, this was necessary for all clips. When comparing grade II and grade III pathologies, a significant difference was observed (χ^2, p = 0.0001), with higher-grade pathologies more frequently requiring the use of multiple stabilization systems in a single patient.

In two patients, the osteosynthesis had to be repeated within a week after reclosure. One patient had a pre-existing diagnosis of myelodysplastic syndrome. Plates with screws and sutures had been used. These were completely torn out of the bone or still had adherent bone. Osteosynthesis was then re-performed at a distance using the StraTos system, which then provided stable reconstruction. A second patient fell out of bed during an episode of delirium, which led to a screw/plate system and threads being torn out and a clip being dislocated. Here, too, a re-osteosynthesis was successfully performed at a distance. During follow-up, one patient suffered a material fracture of a screw/plate system. The sternum had stabilized in the meantime and the system could be explanted.

The mean length of hospital stay for patients with DSWI was 60 ± 22.5 days. In-hospital mortality occurred in nine patients (6.9%). Of these, three patients (33.3%) died as a direct consequence of DSWI, two patients (22.2%) due to sepsis, and one patient (11.1%) due to septic erosion of the left ventricle. The remaining deaths were unrelated to DSWI and were caused by trauma, asystole, and hemorrhagic shock. Recurrent wound healing disorders after sternal reconstruction were observed in 30 patients (23.1%). Mortality was higher in patients with sepsis compared to those without sepsis (12.9% vs. 4.9%); however, this difference did not reach statistical significance (Fisher's exact test, OR 2.87, $p = 0.21$). There were no implant-related deaths.

4. Discussion

This study has limitations. First, its retrospective design is inherently associated with potential selection bias and limits causal inference. Second, a possible conflict of interest must be acknowledged, as some of the authors received grants from MedXpert, and stabilization systems manufactured by this company were used in this study. Third, randomization between different systems was not feasible due to the heterogeneous and highly individualized nature of sternal pathologies. Consequently, a direct comparison between individual stabilization systems is not possible and also not the intention of this study.

The aim of this study is to show that stabilization of the chest is possible at any time if the individual systems are used according to their characteristics. A sternal resection without subsequent stabilization should therefore be considered obsolete. On the other hand, individual systems can only be used appropriately for the pathology for which they are suitable.

In order to discuss which system should be used for which pathology, basics regarding sternal reconstruction have to be considered. When does a deep sternal wound infection occur even under sterile osteosynthesis conditions? In such situations, there is always much discussion about risk factors such as diabetes mellitus, obesity and other factors [8]. While these risk factors can no longer be influenced at the point of closure, they should be considered in choosing a system with greater stability and better anchoring. The risk factors that can be influenced by the surgeon are as follows:

- Unstable osteosynthesis with too few bridges and disregard of the shear forces;
- Bleeding and hematoma formation in the area of osteosynthesis;
- Impaired blood flow to the sternum.

The ideal osteosynthesis must sufficiently counteract the forces acting laterally. The number of bridges across the fracture gap is recommended by most plate manufacturers and should be taken into account, as this is usually preceded by stress tests. Many of the plates used also have a cross-connection between the individual bars. During osteosynthesis, care should always be taken to ensure that at least 2 bars are connected to each other in order to absorb shear forces. MedXpert clips also have this option. Nitinol clips can only bridge one intercostal segment [9]. Ultrasound has shown that these clips allow movement in the fracture gap. Distraction forces act primarily on the costal arch and less strongly on the manubrium. Accordingly, safe osteosyntheses should be performed at these two anchor points. Several (at least three) bridging procedures should be performed between these two points, which can also compensate for shear forces.

After aortocoronary bypass surgery, the blood supply to the sternum is already impaired by the removal of the internal thoracic artery. It should not be further harmed by a closure technique with more impairment of the vessels, for example, by cerclage, according to Robicsek. The superiority of plates over this special wiring method has already been demonstrated [10]. Like plates, clips hardly impair the blood supply to the sternum. Both systems can therefore be used in the same way.

Bone sequestra that are not supplied with blood should also be removed. Here, too, the resulting defect must be bridged.

https://doi.org/10.3390/std15020025

All the systems used have shown that they can be used safely for specific indications. On the other hand, it is also the case that not all systems can be used appropriately for every sternal pathology.

4.1. Grade I: Good Bone Substance and Lack of Defects or Transverse Fractures

Various stabilization systems can be applied in this setting. In most cases, stabilization at a distance is not required. Both clip and plate systems can be used directly on the sternum with comparable results, without the need for parasternal rib preparation, thereby reducing the risk of pleural or intercostal injury. PDS cords are commonly used as an adjunct to provide compression across the fracture gap, as plates primarily maintain stability rather than generate compression, whereas clips allow compression during implantation.

4.2. Grade II: Good Bone Substance but Defects and Transverse Fractures

Single-segment clips are not suitable in this setting; therefore, multi-segment clip systems should be used. Wire cerclage has only limited applicability for transverse fractures and is not appropriate for defect bridging. Plate selection must be adapted to the individual fracture pattern and defect size, as no single plate type can be generally recommended. Regardless of the system used, plates should be fixed with at least three screws on each side of the fracture.

4.3. Grade III: Poor Bone Substance with Defects and Transverse Fractures

In these cases, stabilization should be performed at a distance. While long plates spanning the defect and anchored to the ribs may be used, systems specifically designed for chest wall reconstruction, such as the StraTos system, appear more suitable for this indication. A 20-hole plate was also used in this analysis. At least three bridges should be applied, ensuring adequate anchoring at the predefined fixation points.

More recent studies emphasize that successful management of DSWI relies on both adequate infection control and restoration of sufficient sternal stability. Several contemporary reviews and clinical series support the use of rigid titanium plate fixation following radical debridement and, where appropriate, vacuum-assisted therapy, reporting improved mechanical stability and favorable healing conditions compared with conventional wire cerclage [11,12]. These concepts are reflected in current treatment algorithms, which prioritize rigidity and load distribution rather than a single implant type [13].

In contrast, polymer-based systems such as polyetheretherketone (PEEK) devices have primarily been evaluated in the context of primary sternal closure or prophylactic stabilization in high-risk patients. While clinical studies have demonstrated their safety and effectiveness in reducing sternal complications compared with wire cerclage [14,15], evidence supporting their routine use for secondary reconstruction after established DSWI remains limited.

In addition, other systems that were not used in this retrospective analysis should be named here: double wires or Panduits can be used in the same way as single wires but have a wider contact surface [16]. They can therefore be used in principle for grade I pathologies but, like single clips, cannot absorb shear forces.

Several new systems for complete sternal replacement have come onto the market in recent years. They have been discussed in various articles as individual case analyses [17]. Alloplastic tissue or 3D-printed sterna are also available. What all these systems have in common is that their application has so far only been anecdotal. Therefore, a conclusive assessment cannot be made, especially since, as discussed above, complete sternal replacement is no longer necessary after DSWI.

Overall, no single system is suitable for treating all sternal pathologies following a deep sternal wound infection. Combinations of different systems are often helpful. However, not every surgical unit is able to provide several systems. A plate system and PDS cords should always be available as a basis. The StraTos system has proven its worth for grade III pathologies. Sternal clips are a possible alternative to plates, as they have the advantage that the bone (often with osteomyelitis or osteoporosis) does not have to be drilled or screwed, but the systems always enclose the compact bone.

5. Conclusions

Stabilization of the chest wall after a deep sternal wound infection is always possible. The appropriate osteosynthesis system must be selected for this. The categorization of the bone substance into three grades is helpful in selecting the appropriate system.

Author Contributions: Conceptualization, S.R. (Stephan Raab); methodology, S.R. (Stephan Raab); validation, S.R. (Stephan Raab) and S.R. (Sebastian Reindl); formal analysis, S.R. (Stephan Raab) and S.R. (Sebastian Reindl); resources, S.R. (Stephan Raab) and S.R. (Sebastian Reindl); data curation, S.R. (Sebastian Reindl); writing—original draft preparation, S.R. (Stephan Raab); writing—review and editing, S.R. (Sebastian Reindl); visualization, S.R. (Stephan Raab) and S.R. (Sebastian Reindl); supervision, E.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki, and was initially approved by the Ethics Committee of ETHIKKOMMISSION BEI DER LMU MÜNCHEN (protocol code 21-0861, 23 September 2021). Due to supplementary research during the peer-review process, additional patients were included and further analyses were conducted. Therefore, ethical approval was sought again and granted by the Ethics Committee of LMU Munich (project no. 26-0256; date of approval: 4 May 2026).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: Stephan Raab received lecture fees and travel grants from MedXpert. Sebastain Reindl received lecture fees and travel grants from MedXpert. Evaldas Girdauskas has no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

DSWI	Deep Sternal Wound Infection
NPWT	Negative Pressure Wound Therapy

References

1. Gerbode, F.; Braimbridge, M.V.; Melrose, D.G. Median sternotomy for open cardiac surgery during total heart-lung by-pass. *AMA Arch. Surg.* **1958**, *76*, 821–824. [CrossRef] [PubMed]
2. Çiçek, S. Sternal closure: Wires are still the king! *J. Thorac. Cardiovasc. Surg.* **2018**, *156*, 1596–1597. [CrossRef] [PubMed]
3. Banic, A.; Ris, H.B.; Erni, D.; Striffeler, H. Free latissimus dorsi flap for chest wall repair after complete resection of infected sternum. *Ann. Thorac. Surg.* **1995**, *60*, 1028–1032. [CrossRef] [PubMed]
4. Meadows, J.A., 3rd; Staats, B.A.; Pairolero, P.C.; Rodarte, J.R.; Arnold, P.G. Effect of resection of the sternum and manubrium in conjunction with muscle transposition on pulmonary function. *Mayo Clin. Proc.* **1985**, *60*, 604–609. [CrossRef] [PubMed]
5. Lardinois, D.; Müller, M.; Furrer, M.; Banic, A.; Gugger, M.; Krueger, T.; Ris, H.B. Functional assessment of chest wall integrity after methylmethacrylate reconstruction. *Ann. Thorac. Surg.* **2000**, *69*, 919–923. [CrossRef] [PubMed]
6. Tocco, M.P.; Ballardini, M.; Masala, M.; Perozzi, A. Post-sternotomy chronic osteomyelitis: Is sternal resection always nec-essary? *Eur. J. Cardiothorac. Surg.* **2013**, *43*, 715–721. [CrossRef] [PubMed]

https://doi.org/10.3390/std15020025

7. van Wingerden, J.J.; Ubbink, D.T.; van der Horst, C.; de Mol, B. Poststernotomy mediastinitis: A classification to initiate and evaluate reconstructive management based on evidence from a structured review. *J. Cardiothorac. Surg.* **2014**, *19*, 179. [CrossRef] [PubMed]
8. Kamensek, T.; Kalisnik, J.M.; Ledwon, M.; Santarpino, G.; Fittkau, M.; Vogt, F.A.; Zibert, J. Improved early risk stratification of deep sternal wound infection risk after coronary artery bypass grafting. *J. Cardiothorac. Surg.* **2024**, *19*, 93. [CrossRef] [PubMed] [PubMed Central]
9. Reiss, N.; Schuett, U.; Kemper, M.; Bairaktaris, A.; Koerfer, R. New method for sternal closure after vacuum-assisted therapy in deep sternal infections after cardiac surgery. *Ann. Thorac. Surg.* **2007**, *83*, 2246–2247. [CrossRef] [PubMed]
10. Ozden, Y.; Ozcelik, S.; Bastopcu, O.M.; Ozden, S.; Kisa, U.; Kuplay, H. Tradition or Innovation in Sternal Dehiscence Repair: Robicsek Versus Titanium Plate. *Sisli Etfal Hastan. Tip. Bul.* **2023**, *57*, 124–129. [CrossRef] [PubMed] [PubMed Central]
11. Blake, A.; Condrey, M.; Hansen, L.; Mehan, V. Management of Sternal Wounds, Infections, and Sternal Non-Union with Plate Fixation: Result from a Single Site Experience. *Surg. Infect.* **2023**, *24*, 131–140. [CrossRef] [PubMed]
12. Grapow, M.; Haug, M.; Tschung, C.; Winkler, B.; Banerjee, P.; Heinisch, P.P.; Fassl, J.; Reuthebuch, O.; Eckstein, F. Therapy options in deep sternal wound infection: Sternal plating versus muscle flap. *PLoS ONE* **2017**, *12*, e0180024. [CrossRef] [PubMed]
13. Khashkhusha, A.; Butt, S.; Abdelghaffar, M.; Wang, W.; Rajananthanan, A.; Roy, S.; Khurshid, B.N.; Zeinah, M.; Harky, A. Sternal Wound Reconstruction Following Deep Sternal Wound Infection: Past, Present and Future: A Literature Review. *J. Cardiovasc. Dev. Dis.* **2024**, *11*, 361. [CrossRef] [PubMed]
14. Stelly, M.M.; Rodning, C.B.; Stelly, T.C. Reduction in deep sternal wound infection with use of a peristernal cable-tie clo-sure system: A retrospective case series. *J. Cardiothorac. Surg.* **2015**, *10*, 166. [CrossRef] [PubMed]
15. Shu, D.; Li, J.; Zhao, Y.; Yang, Y. Comparison of polyetheretherketone cables and stainless steel wires for sternal fixation after median sternotomy. *J. Int. Med. Res.* **2021**, *49*, 3000605211041265. [CrossRef] [PubMed]
16. Omer, S. Polymer cable tie closure of the sternum: Is it an acceptable fix? *J. Thorac. Cardiovasc. Surg.* **2018**, *156*, 1611–1612. [CrossRef] [PubMed]
17. Sanna, S.; Brandolini, J.; Pardolesi, A.; Argnani, D.; Mengozzi, M.; Dell'Amore, A.; Solli, P. Materials and techniques in chest wall reconstruction: A review. *J. Vis. Surg.* **2017**, *3*, 95. [CrossRef] [PubMed] [PubMed Central]

https://doi.org/10.3390/std15020025