An Overview about Techniques in Chest Wall Reconstruction

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Abstract

Background: Chest wall reconstruction is a complex surgical procedure that aims to restore the integrity of the chest wall after injury or disease. Chest wall reconstruction continues to evolve, with the advent of newer biomaterials and evidence-based surgical approaches aimed at minimizing perioperative morbidity while maintaining functional and physiologic outcomes. Improvements in surgical techniques, critical care, and adjuvant therapies have allowed surgeons to perform more extensive and aggressive surgical resections. However, the resultant defects are often complex and necessitate the use of prosthetic materials and autologous soft tissue rearrangement to restore thoracic skeletal function. The need for a fairly rigid construct to resist paradoxical movement and protect vital organs while allowing physiologic chest excursion has been a longstanding vexing reconstructive challenge. Proline mesh is a synthetic, non-absorbable polypropylene material commonly used in reconstructive surgeries for decades due to its biocompatibility and durability. Proline mesh is a type of surgical mesh that is commonly used in a variety of surgical procedures, including hernia repairs, abdominal wall reconstruction, and chest wall reconstruction. In the context of the chest wall, Proline mesh can be utilized to provide support and stability to damaged or defective areas of the chest wall.

Keywords: Chest Wall Reconstruction

Introduction

Chest wall reconstruction is a complex surgical procedure that aims to restore the integrity of the chest wall after injury or disease. Chest wall reconstruction continues to evolve, with the advent of newer biomaterials and evidence-based surgical approaches aimed at minimizing perioperative morbidity while maintaining functional and physiologic outcomes. Improvements in surgical techniques, critical care, and adjuvant therapies have allowed surgeons to perform more extensive and aggressive surgical resections. However, the resultant defects are often complex and necessitate the use of prosthetic materials and autologous soft tissue rearrangement to restore thoracic skeletal function. The need for a fairly rigid construct to resist paradoxical movement and protect vital organs while allowing physiologic chest excursion has been a longstanding vexing reconstructive challenge **(1)**

Indications

Common indications for chest wall reconstruction include infection, congenital abnormalities, tumor ablation (primary or recurrent), radiation injury, and trauma. Infection may manifest itself as mediastinitis or empyema. Sternal wound infection after cardiac surgery occurs in approximately 0.5 to 9% of cases. Major risk factors for sternal dehiscence and subsequent infection are obesity, diabetes, chronic obstructive pulmonary disease (COPD), and bilateral harvest of internal mammary arteries. Treatment of sternal infection and dehiscence is radical debridement of all infected tissue, culture-directed antibiotic therapy, and obliteration of dead space. In addition, chest reconstruction with vascularized tissue, most commonly pectoralis myocutaneous advancement, rectus abdominus myocutaneous and other flap procedures such as latissimus dorsi or omentum, have proved to be effective treatments and have lowered mortality rates in patients **(2).**

Sternal wounds was classified based on timing of presentation of infection. Type I wounds occur in the first few days postoperatively. These wounds may contain incisional dehiscence with serosanguineous discharge and/or sternal instability. Type II wounds occur in the first several weeks and may present with cellulitis, mediastinal purulence, and positive cultures. Type III wounds occur months to years postoperatively and are distinguished by draining sinus tracts and chronic osteomyelitis. Type II and III wounds are commonly referred for reconstruction by a plastic surgeon. Although rare, congenital defects may present to the reconstructive surgeon as Poland syndrome, pectus excavatum, and pectus carinatum. The incidence of Poland syndrome in the general population is 1 in 30,000. Chest wall dysfunction may occur in Poland syndrome as a result of abnormalities of the costal cartilages including up to total absence of the anterolateral ribs. Patients may demonstrate lung herniation, deformity of the chest wall, and absent musculature. Absence of the sternal head of the pectoralis major is pathognomonic and may be accompanied by hypoplasia or aplasia of the nipple and breast, shortened ipsilateral upper extremity, and brachysyndactyly(**3)**.

Pectus excavatum is the most common congenital anomaly of the chest and presents a characteristically depressed sternum or "funnel chest" and cardiopulmonary dysfunction that occurs secondarily to rib cartilage overgrowth. Pectus carinatum also occurs due to overgrowth of the rib cartilages, but instead leads to protrusion of the sternum. Injury after radiation therapy results in significant scarring and nonfunctional tissue. Necrotic or significantly devitalized tissue may require debridement and reconstruction. Ablation of chest wall sarcomas or pulmonary and mediastinal tumors with wide margins requires adequate structural and soft tissue reconstruction to maintain functional integrity. Prior to chest wall reconstruction, the status of a patient's pleural cavity, the requirement for skeletal support, and the extent of the soft tissue defect must be fully defined **(4).**

Materials and Techniques

The primary goals of all chest wall reconstructions are to obliterate dead space, restore chest wall rigidity, preserve pulmonary mechanic, protect intrathoracic organs, provide soft tissue coverage, minimize deformity and allow patients to receive adjuvant radiotherapy if indicated. Therefore, a multidisciplinary approach, including input from thoracic surgeons, plastic surgeons, neurosurgeons as well as medical and radiation oncologists is essential. Actually, several synthetic, biologic, and metallic materials are available to reconstruct the chest wall defects, but each prosthetic material has its own advantages and disadvantages and none have proven to be clearly superior. In particular, the benefit of each material and technique of reconstruction need to be weighed against to main indicators, as the risk of infection and other major complications that could be fail the reconstructive result. The recent advance in allograft and homograft production have provided new alternatives for restoring structural stability, preventing the infective complications **(5).**

Synthetic, biologic and titanium meshes

The magnitude of synthetic meshes exist and present the advantages of easy manipulation and handling. They, more or less, all comply with the characteristics of ideal prosthetic material (I) rigidity to abolish paradoxical movement; (II) inertness to allow in-growth of fibrous tissue and decrease the likelihood of infection; (III) malleability to fashion to the appropriate shape at the time of operation; and (IV) radiolucency to create an anatomic reference to do a better follow up and identify a possible local neoplastic relapse. Most patches are non-absorbable synthetic woven meshes: polypropylene, polyester and polytetrafluoroethylene (PTFE) soft tissue patches, usually doubled over and sutured to adjacent ribs and fascia to cover the immediate surface of the chest wall defect. These materials can be stretched uniformly in all directions, allowing uniform tension strength at the bone defect edges. They are simple to use and usually well tolerated when completely covered by viable tissue, provide a barrier that prevents fluid and air moving between pleural and subcutaneous space and propose a scaffold for the in-growth of regenerative connective tissue colonizing their outer and inner surfaces **(6).**

Some authors reported an infection rate between 10% and 25% for synthetic meshes and the needs to remove the infected mesh to resolve the problem. In these cases a Vicryl mesh could be considered due to its inert, nonantigenic, biocompatible and slowly absorbing material or a biologic mesh as like as bovine pericardium prosthesis that have the same tensile strength and elasticity as those synthetic, but some proper physiologic properties of resistance to infection and contamination. Consisting of acellular organic collagen-based matrices it allows for native tissue re-growth and revascularization, stimulating regeneration as opposed to scarring with minimal inflammatory response and less inclination to rejection. Differently to synthetic meshes, it can be placed directly over the lung and viscera without any complications, but not resulting in a rigid reconstruction of the thoracic wall, even if the stability achieved is enough to prevent paradoxical motions or respiratory distress. The only limitation is the elevated costs **(7).**

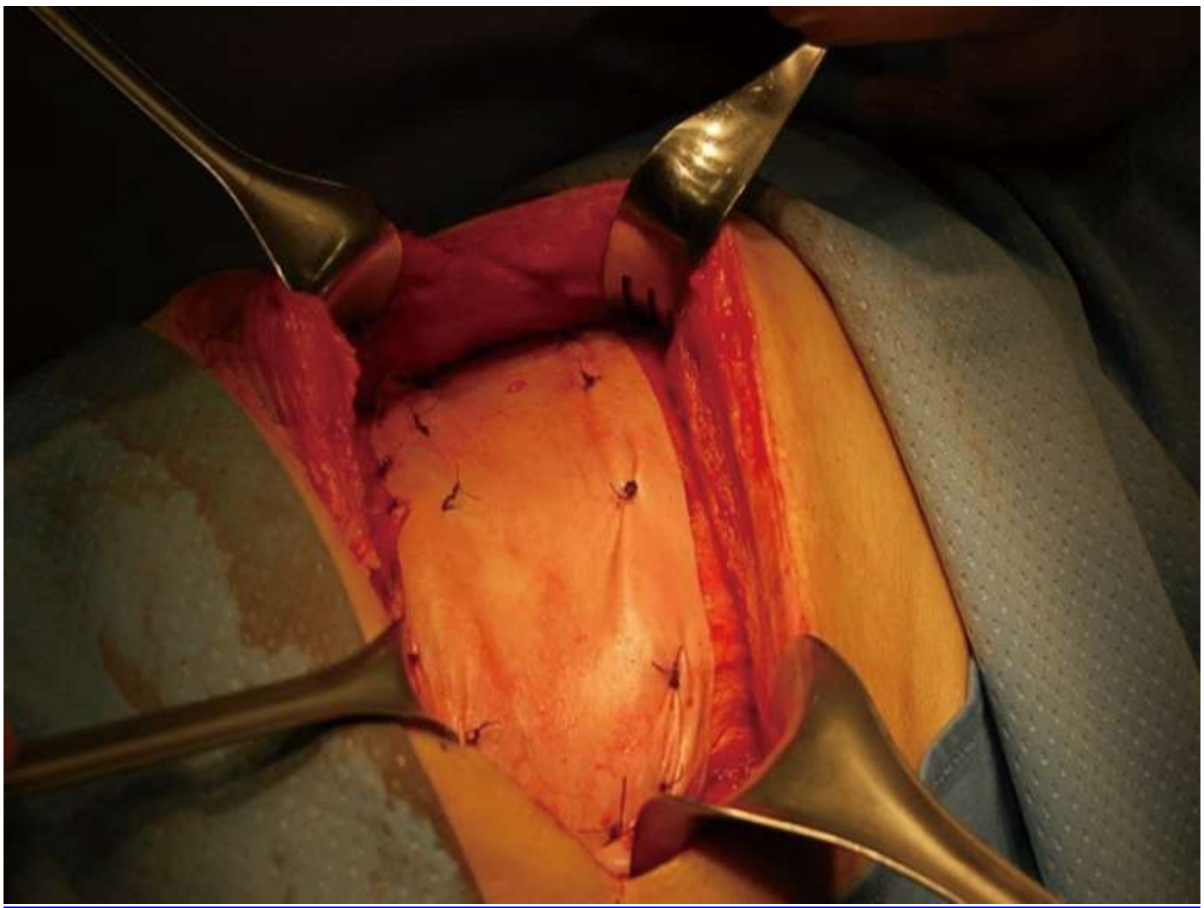

Fig. (1):Intraoperative view of biologic mesh reconstruction of a large defect of the left lateral site after synthetic mesh removal due to infection **(8).**

Recently there were proposed titanium meshes (MDF Medica) that present more strength than synthetic meshes, maintaining the same plasticity and adaptability on the chest wall defect. The 5-mm thickness mesh could obtain the right rigidity on the chest wall, preventing endothoracic organs lesions, preserving the system by infection for the inert condition of titanium and resulting well tolerated by the patient. All these meshes often result safe and useful to resolve the thoracic wall defect, but for anterior, sternal or lower posterior defects could be insufficient, even if well sutured and stretched as a drum, to protect the inner organs. This problem should be resolved with the use of composite implant techniques **(9).**

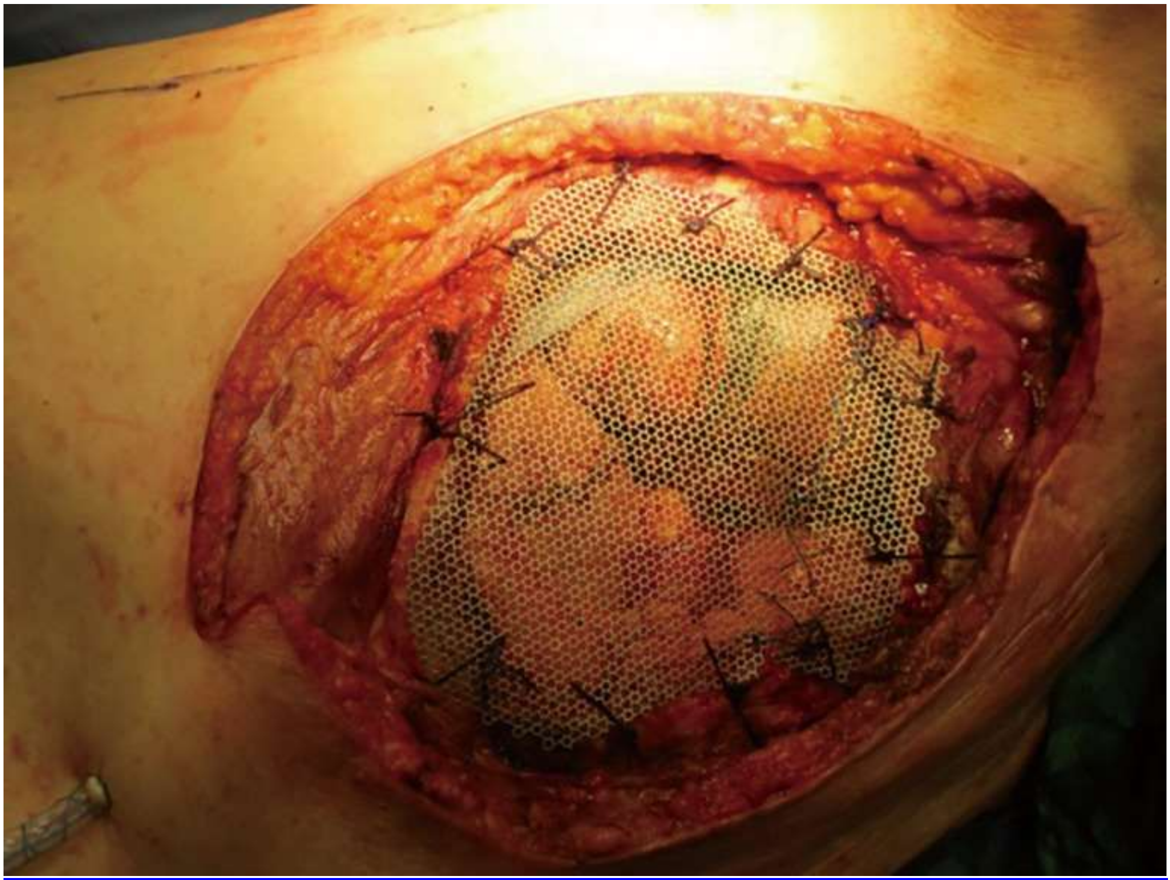

Fig. (2):Intraoperative view of a large lateral rib resection reconstructed with a titanium prosthesis fixed to the costal segments with interrupted non-absorbable stitches **(8).**

Methyl Methacrylate

Methyl Methacrylate is usually sandwiched between two layers of the mesh to strengthen the rigidity of the reconstruction. This product has been the best choice to reconstruct the sternum, ribs and chest wall, entirely or partially. It could be prepared on the surgical field, where a first layer of polypropylene mesh is fixed straight on the base of the rib defect and the methyl methacrylate substitute is then added to the defect shape and covered with a second layer of the prosthesis, hardening an exothermic reaction and becoming rigid and forming a cast that conforms to the defect; or, most commonly, the prosthetic system is designed in the same manner on the back table. With this technique, most of all for extensive anterior and lateral chest wall defects, paradoxical movements and chest deformities are prevented. However methylmethacrylate material seems not to be permeable to fluids and therefore are considered to increase pain and excessive chest wall rigidity **(10).**

A fracture of the methacrylate is possible and most of all increases the risk of infection. Wound complications are reported on 10–20% of patients at 90 days, requiring the removal of the prostheses in approximately 5% of patients. Nevertheless, several case series reported on important functional results, without an high infection rate. Most of the authors agree that complete coverage with viable soft tissue in this chest wall reconstruction is an essential step to minimize the risk of local complications. Other composite implant techniques, applying silicone tubes, rubber and Carbone fiber systems have been described in case reports **(11).**

Polytetrafluoroethylene (PTFE)

PTFE (GORE-TEX) is another material well-suited and commonly used for chest wall reconstruction. Similar to methyl methacrylate, PTFE is watertight and causes minimal foreign body reaction; however, it is flexible, allowing it to conform to the chest wall. Most commonly 2 mm thick PTFE mesh is stretched over the chest wall defect using heavy permanent suture. To provide chest wall stability, it is important to pull the mesh as tight as possible, with sutures laced around or through adjacent ribs. A bone drill or sharp towel clip works well, creating holes in ribs for fixation. PTFE can be used to stabilize large chest wall defects and should be completely covered with viable tissue after implantation. Its use is absolutely contraindicated in infected fields. However, if the mesh became infected and the patient is not septic, immediate removal is not always indicated **(12).**

Titanium plates

About 5 years ago, considering the favourable experiences obtained with titanium implants in other fields of prosthetic surgery (orthopedic, maxillo-facial surgery) a new dedicated titanium plates system was introduced for the treatment of the chest wall diseases. This system was introduced to support the chest wall reconstruction after demolition for neoplastic disease, as like as to fix the fractures of the thoracic cage after trauma and sternal dehiscence **(13).**

Titanium is an ideal prosthetic material, as it has an high resistance to corrosion, a low specific weight, a remarkable resistance to traction, it is diamagnetic and compatible with MRI, but, above all, is biologically inert and highly biocompatible. Actually, there are several types of rib prosthesis systems, the oldest one is the Borrelly steel staple-splint system. The STRATOS system could be an evolution of the previous system, securing to the rib ends clips that resemble claws at the two ends of the bar. The MatrixRIB and MDF Medica devices use a comfortable well-remodellable bar with holes for screws to threated the bar to the ribs or the sternum. To obtain an optimal fixation, it is fundamental to lock screws to the bone bicortically and to use at least three screws for blocking each side of the bar. It’s adaptable to a wide variety of chest wall defects, allowing to recreate the anatomical and physiological appearance of the thoracic cage **(14).**

Some reports in the literature confirmed the easy use and the rapid learning curve of this device, that is very useful for clavicle substitution too However, we must consider that in trauma patients titanium plates are always the only material used for chest wall stabilization, while in neoplastic cases the reconstruction of the chest wall requires integration with traditional techniques, such as synthetic biologic or titanium meshes and various muscle flaps. Many authors agree that titanium system represents a better solution in the reconstruction of large full-thickness defects, restoring the rigidity of the thoracic cage and preventing respiratory and infective complications. Few complications, as plate fracture, bar dislocation and thoracic pain, are described for this system. Bar fracture rate varied from 0 to 11% in some series; plate dislocation frequently is due to the mismatch between the screws length and rib thickness, or the destruction of the bone threads that lock the screws into the rib, due to repeating re-drilling in the same hole **(15).**

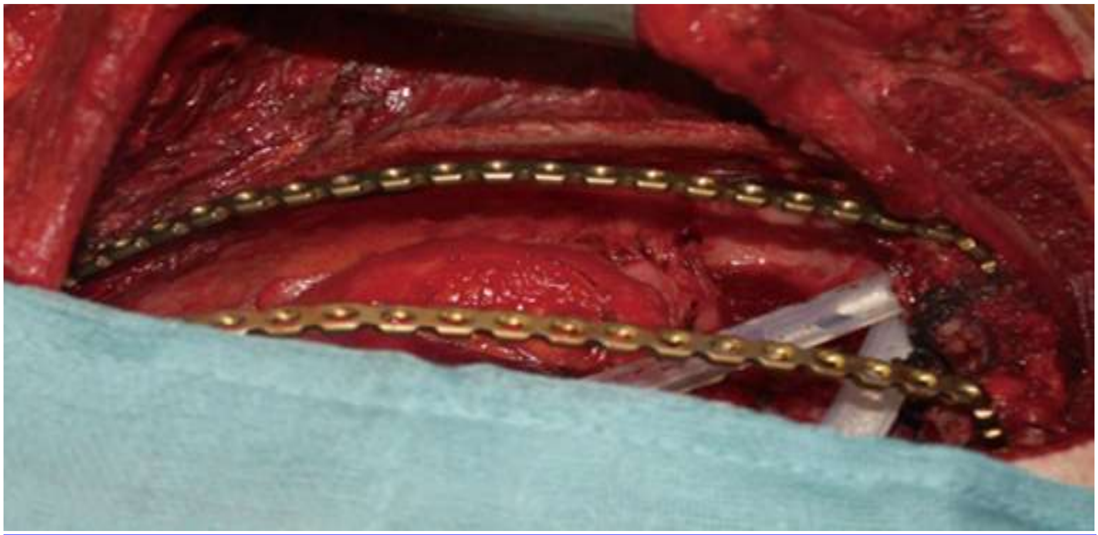

Fig. (3):Intraoperative view of two titanium bars fixed on rib segments to restore chest wall conformation and rigidity **(8).**

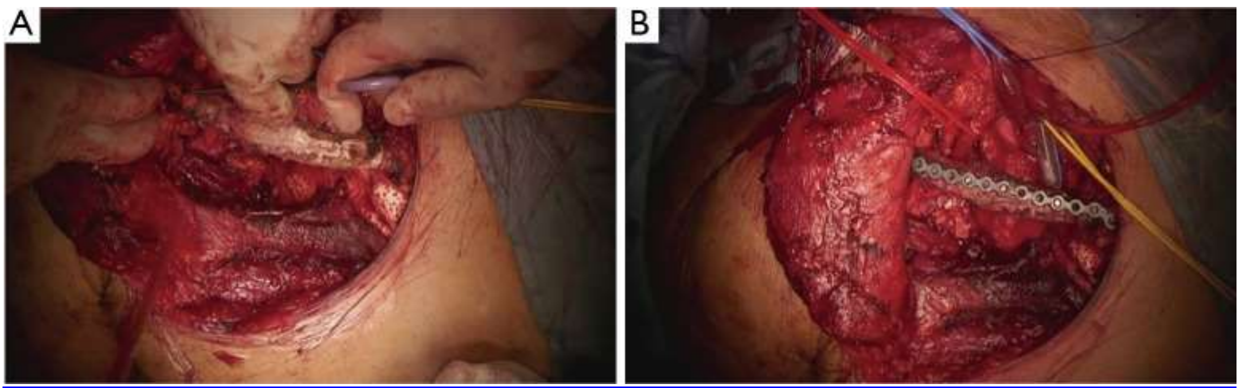

Fig. (4):Intraoperative view of a right subtotal clavicle resection and reconstruction with rib segment (A) and titanium plate fixed to the rib (B), to the sternum and the distal part of the clavicle **(8).**

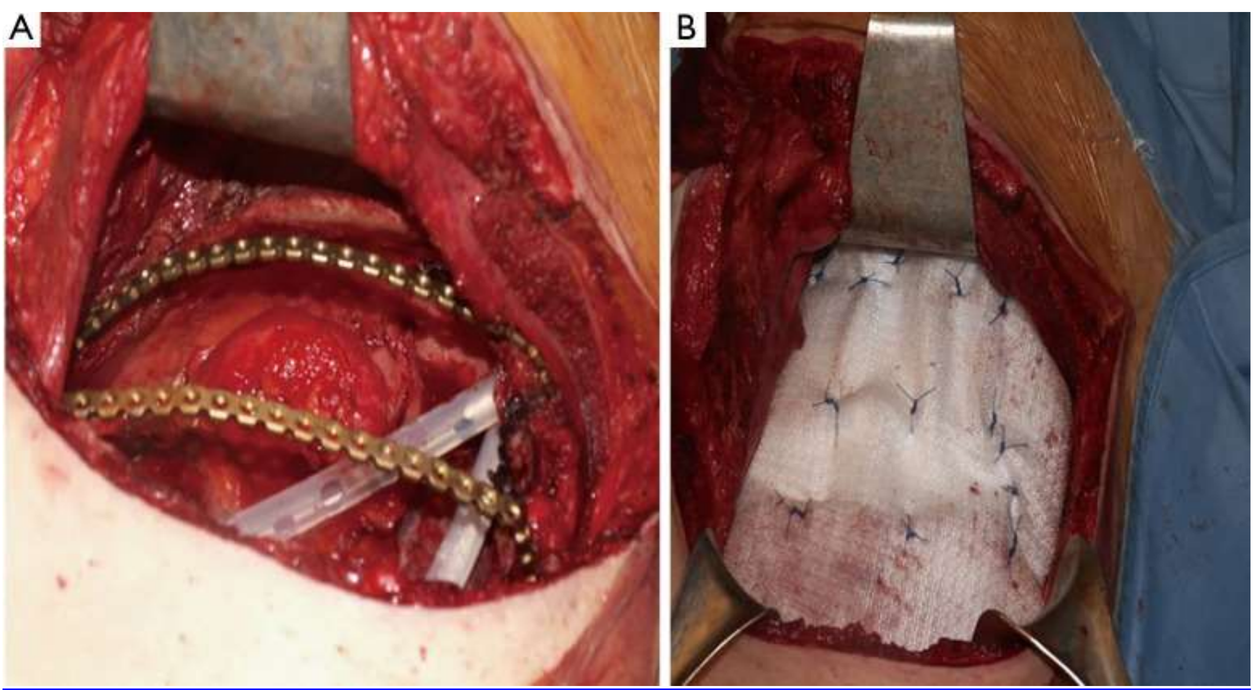

Fig. (5):Titanium plate reconstruction of large chest wall resection for chondrosarcoma and covered with polypropylene synthetic mesh fixed to the rib segments and to the plates with interrupted stitches **(8).**

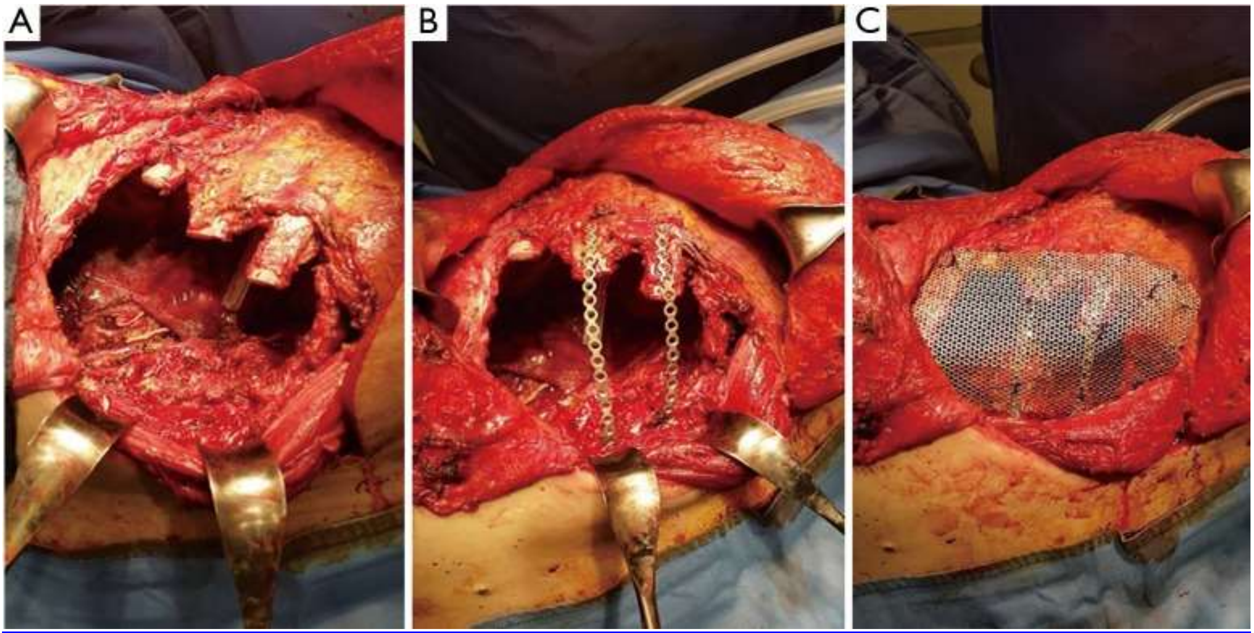

Fig. (6):Reconstruction of a 5-ribs resection defect with 2 titanium bars fixed on rib segments by 3 screws for each side and completed with a titanium prosthesis fixed to the rib segments and bars with interrupted non absorbable stitches to give more rigidity to the thoracic wall **(8).**

Particularly, this system is very safe in sternal traumas and tumours. The sternum is very important for chest wall stability and its integrity is mandatory for respiratory mechanism. Titanium plates and meshes permit to restore the sternal defect reconstructing its integrity in traumas and recreating an anterior stability of the thoracic cage in partial or total sternectomies. Regarding the sternal reconstruction, other systems are described in some series. An easy technique was reported to reconstruct the sternal floor applying Kirschner's wires in the spongiest aspect of the cut ribs, associated with silicone molds that are threated on ribs and wires and tied with ligatures at both the extremities. Methylmethacrylate is injected in the mold to fill it totally. This technique provide excellent stability and offer a suitable support to receive a regional or omental flap **(14).**

Other dedicated sternal prostheses are the Ley prostheses, a very thick titanium alloy plate shaped as a stepladder. This device, initially designed for stabilization of the sternum after post-operative mediastinitis, results flexible and adapting to sternal silhouette. Pedersen reported the application of Ley prostheses in the reconstruction of 3 cases of sternal chondrosarcoma with good results. Regarding the use of a sternal ceramic prosthesis constituted of hydroxyapatite and tricalcium phosphate (Ceratite) creating a customized prosthetic bone tailored to the anterior thoracic wall defects with slots and holes in the Ceratite prosthesis as fasteners. It's an original idea with many advantages, as the possibility to provide the useful template for bone growth, strength and biocompatibility but the great disadvantage of excessive cost **(1)**

Allograft and homograft

Both human and porcine bioprosthetic materials have been developed over the past decade in response to the need for complex chest wall reconstruction in infected irradiated and re-operative fields. Cryopreserved allografts and homografts, recovered from cadaveric donors and stored at –80°, are being more commonly used for restore structural integrity in large chest wall defects. These materials represent a potentially limitless source for chest wall reconstruction and have been shown to exhibit differences in cytotoxicity, bacterial adhesion and biomechanical properties, compared to traditional prosthetics. The major advantage is that they are able to incorporate into native tissue with revascularization and cellular repopulation, making them more resistant to infection and useful in contaminated fields. Sternal allograft transplantation represents an ideal example of allograft for anterior chest wall reconstruction following sternectomy for tumors or infective processes. Bone grafts act as a structure for osteoprogenitor cells and bone growth. These materials are already extensively used in orthopedic and maxillofacial surgery with very good results. The main limitation of bone autografts concerns the amount of bone that can be harvested and thus implanted in the thoracic site of reconstruction. In the last years, a large numbers of case reports described the use of bone allografts also for chest wall reconstruction **(16).**

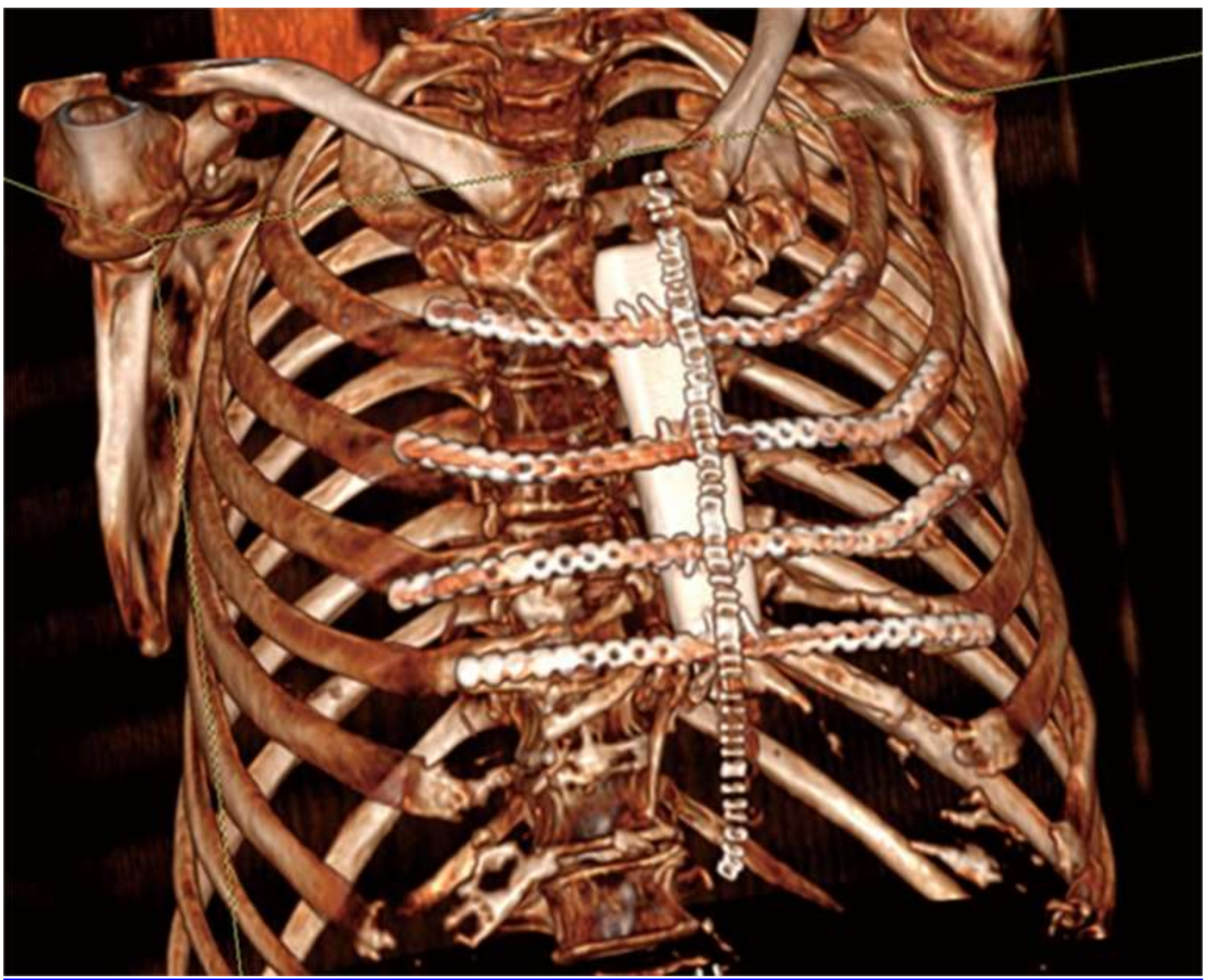

Fig. (7):Sternal reconstruction using fibula allograft for complete sternal destruction after median sternotomy **(8).**

The graft, conserved in tissue bank, undergoes a 72-hours washing in sterile saline solution added with antibiotics and then it is irradiated and stored at –80 °C. The day before the surgical procedure, the graft is defrosted at 4–6 °C for 12 hours and is immersed in sterile NaCl 0.9% solution added with antibiotics and collected at 4–6 °C until used. The reconstruction of the anterior chest wall after partial or complete sternectomy using a sternal allograft is simple, using the preoperative CT scan of the recipient and an allograft radiograph to measure the longitudinal and transverse diameters of the patient and allograft sternum at the level of the sternal clavicular junction, manubrium and the sternal body, to guarantee the correct matching between the donor and recipient sterni. Intraoperatively, the presence of any discrepancy between the allograft and the surgical site of implantation can be easily corrected by, tailoring the bone allograft with a saw and rasp. Recently, new technologies such as 3D-printers and computed based navigation surgery appear to be very promising in preoperative planning and simplification in matching the allograft bone and the recipient's chest wall. At the end of the operation, a quick, safe and efficient stabilization of the transplanted bone is achieved with titanium plates and screws, usually placed between the allograft and the ribs. Whenever possible, a pectoralis muscle flap must cover the allograft, to further reduce the infective risk and to prevent the cutaneous decubitus of titanium bars **(14).**

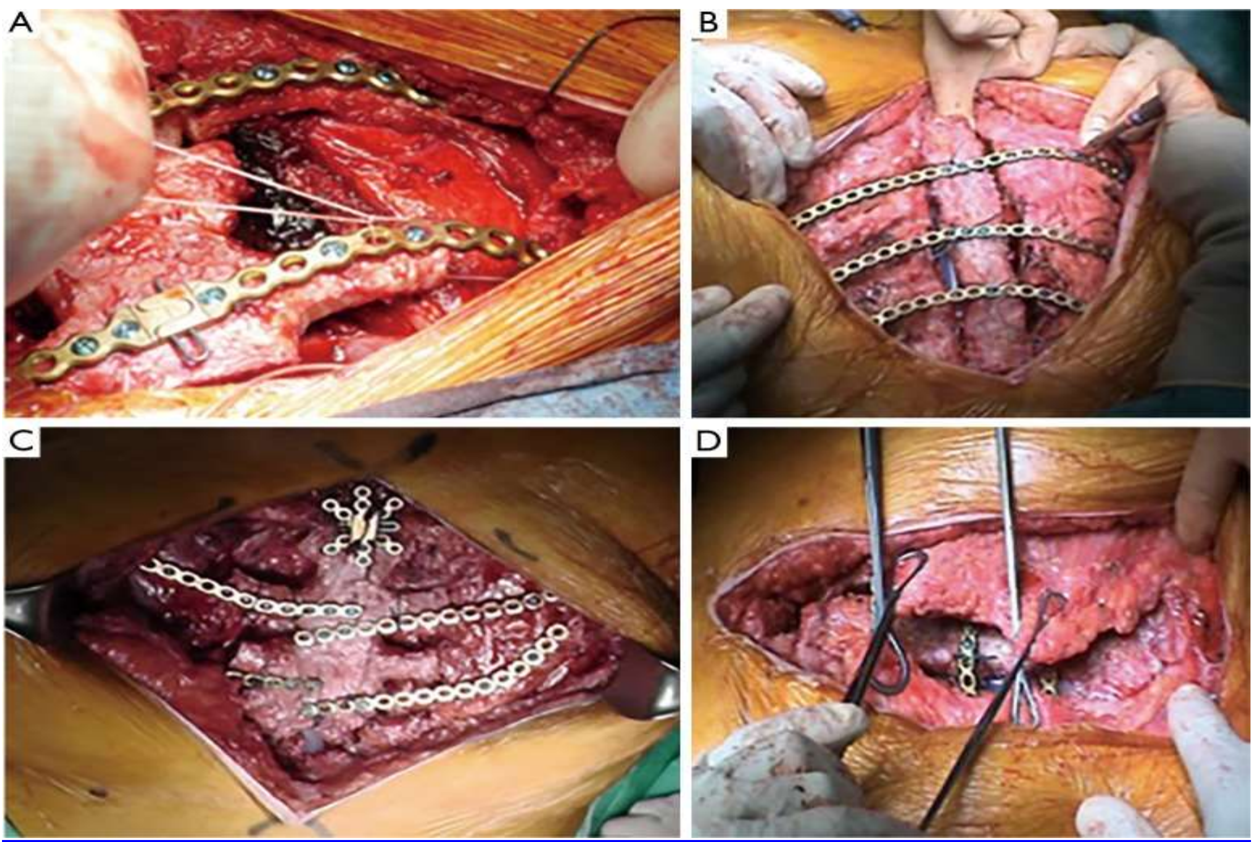

Fig. (8):Intraoperative view. (A) stabilization of the transplanted bone with titanium plates and screws placed between the allograft and the ribs; (B) complete sternal replacement; (C) partial sternal replacement; (D) pectoralis major muscle flap covering of the implanted graft **(8).**

Soft tissue coverage

Regardless of the technique used to establish skeletal stability, full tissue coverage of the prosthesis is mandatory, using direct suture, skin grafts, local advancement flaps, pedicled myocutaneous flaps or free flaps. There are various techniques available for chest wall reconstruction, including local tissue transfer, muscle flaps, and free flaps. The choice of technique depends on the size and location of the defect, need for prosthetic material or viscera coverage, and whether additional tissue bulk is required to fill a dead space void. One option is the latissimus dorsi flap, which is considered the workhorse in chest wall reconstruction. It can cover anterolateral and posterior wall defects or be passed between the ribs to fill a significant amount of intrathoracic space **(17).**

The pectoralis major flap is another option, which is used for sternal and anterosuperior chest wall defect coverage. The rectus abdominis flap is well-suited for covering large longitudinal chest wall defects, such as after total sternectomy. Free flaps may be indicated if local muscle groups have been resected, previously injured, or irradiated. The advantages of these techniques include reliable coverage, versatility of skin island design, and potential for primary closure at the donor site. However, they also carry risks of complications, such as seroma formation, functional disability, abdominal hernias, and donor-site morbidity. The omentum majus flap is another option for repairing defects in the anterior chest wall, in case other techniques fail or are not suitable. It can be lifted virtually to any chest wall location via a laparotomic or laparoscopic procedure, but it should be raised only by experienced surgeons **(18,19).**

Complex Chest Wall Reconstruction

Proline mesh

Proline mesh is a synthetic, non-absorbable polypropylene material commonly used in reconstructive surgeries for decades due to its biocompatibility and durability. Proline mesh is a type of surgical mesh that is commonly used in a variety of surgical procedures, including hernia repairs, abdominal wall reconstruction, and chest wall reconstruction. In the context of the chest wall, Proline mesh can be utilized to provide support and stability to damaged or defective areas of the chest wall **(20).**

- **Indications for Proline mesh**

The indications for using Proline mesh in chest wall reconstruction are diverse and include the management of trauma, tumor resection, infection, and congenital abnormalities. Chest wall trauma may cause damage to the ribs, sternum, or intercostal muscles, resulting in flail chest, paradoxical movement, and respiratory insufficiency. In such cases, Proline mesh can be used to stabilize the chest wall and restore its structural integrity. Tumor resection in the chest wall may result in large defects that require reconstruction to prevent chest wall instability and respiratory compromise. Proline mesh can be used to bridge the defect and provide support to the chest wall. Similarly, infection of the chest wall can cause tissue damage and structural instability, and Proline mesh can be used to facilitate reconstruction **(17).**

Congenital abnormalities such as pectus excavatum or Poland syndrome may also require chest wall reconstruction. Pectus excavatum is characterized by a concave chest wall and may cause respiratory compromise, while Poland syndrome is a rare congenital disorder that results in chest wall asymmetry and may require reconstruction for both cosmetic and functional reasons. During chest wall reconstruction using Proline mesh, the mesh is usually placed over the defect and secured in place with sutures or staples. The surrounding tissues grow into the mesh over time, creating a sturdy, natural structure **(18).**

- **Surgical Technique**

Chest wall reconstruction using a proline mesh involves several steps. First, the patient is placed under general anesthesia and positioned appropriately for the procedure. An incision is then made in the chest wall, and the tissue is dissected to expose the chest wall defect. The edges of the defect are then trimmed to create a clean, even edge. Next, the proline mesh is cut to the appropriate size and shape to fit the defect. The mesh is then positioned over the defect and sutured in place (The mesh is typically secured to the surrounding tissue with non-absorbable sutures. Care is taken to ensure that the mesh is properly positioned and tension-free to avoid any complications. Once the mesh is in place, the tissue is closed with sutures, and a sterile dressing is applied. The patient is then closely monitored for any signs of complications, such as bleeding or infection. Postoperative care typically includes pain management, wound care, and physical therapy to help the patient regain strength and mobility. The underlying lung ventilated with positive end-expiratory pressure and normal tidal volumes to restore the natural shape of the chest wall. Soft tissue coverage was then performed with soft tissue, and the cosmetic appearance of the chest wall reconstruction with Prolene mesh is shown in. Prophylactic antibiotics given for 48 h postoperatively. All sutures were cut in 10–12 days **(19).**

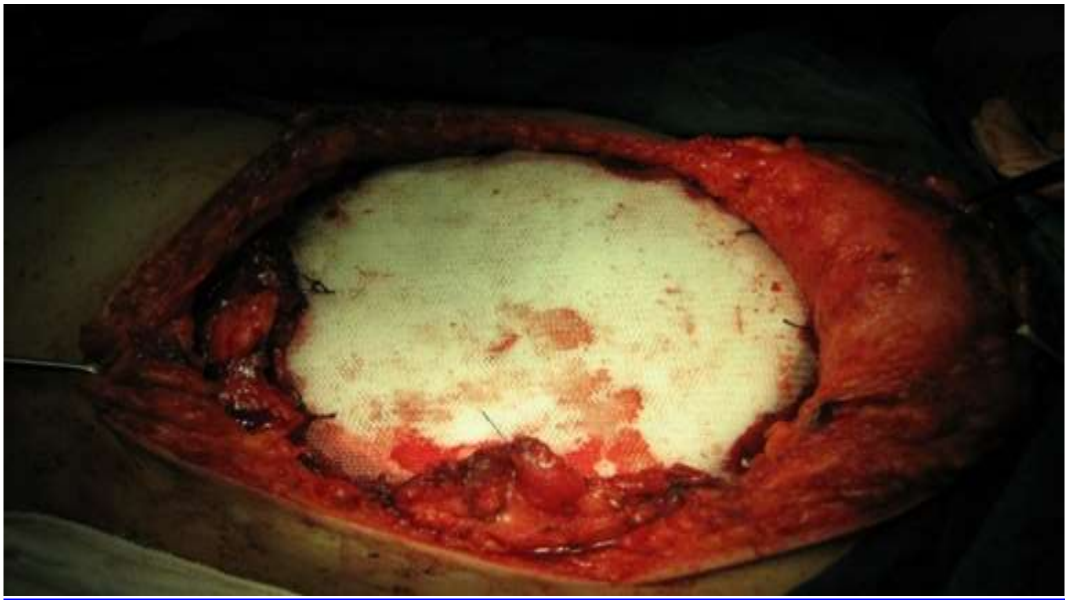

Fig. (9):Reconstruction of the chest wall with two layers of Prolene mesh was performed in a 45-year-old female with chest wall cancer; four ribs, the latissimus dorsi and stratus muscles were resected **(21).**

Advantages of Proline Mesh in Reconstruction of Chest Wall

Proline mesh has several advantages in the reconstruction of the chest wall. One of the most significant benefits is its ability to provide a strong and durable support structure for damaged or weakened areas of the chest wall. This can be particularly important in cases of chest trauma or tumor resection, where the integrity of the chest wall may be compromised, leading to respiratory insufficiency or other complications. Proline mesh can help to prevent these complications by providing stability and support to the chest wall. Another advantage of Proline mesh is its biocompatibility. The mesh is made of a synthetic material that has been extensively studied and tested in medical applications, and it has a proven track record of safety and effectiveness. When placed in the body, Proline mesh is well-tolerated and does not typically cause adverse reactions or immune responses. This makes it a reliable option for patients who require chest wall reconstruction **(16)**

Proline mesh is also relatively easy to implant and can be customized to fit the specific needs of each patient. The mesh can be cut to the appropriate size and shape and secured in place using sutures or staples. Over time, the body's tissues grow into the mesh, incorporating it into the natural structure of the chest wall. This allows for a seamless integration of the mesh into the patient's body, minimizing the risk of complications and ensuring long-term durability. Finally, Proline mesh is a cost-effective option for chest wall reconstruction. Because it is a synthetic material, it can be produced at a relatively low cost, making it an accessible option for patients who may not have the resources for more complex or expensive reconstructive procedures. This can be particularly important in cases where the chest wall has been damaged due to trauma or infection, as these patients may require urgent treatment to prevent further complications. By providing a safe, effective, and affordable option for chest wall reconstruction, Proline mesh can help to improve the quality of life for patients and reduce the burden on healthcare systems **(17).**

- **Disadvantages of Proline Mesh in Reconstruction of Chest Wall**

While Proline mesh has several advantages in chest wall reconstruction, there are also some potential disadvantages that must be considered. One of the main disadvantages is the risk of infection. Although Proline mesh is generally well-tolerated by the body, it is still a foreign material and can provide a surface for bacteria to grow. Infection of the mesh can lead to serious complications and may require removal of the mesh. Another potential disadvantage of Proline mesh is the risk of mesh migration or displacement. If the mesh is not secured properly or if there is not enough tissue growth into the mesh, it may shift or move out of position. This can cause pain, discomfort, and may require additional surgery to correct. There is also a risk of the body rejecting the Proline mesh. Although the material is generally biocompatible, some patients may have an allergic reaction or immune response to the mesh. This can lead to inflammation, tissue damage, and other complications **(22).**

Metallic Bar

Metallic bars are typically made of titanium or other lightweight metals, and are designed to provide stability and support to the chest wall after injury or disease. They can be customized to fit the unique anatomy of each patient and can be used in a variety of configurations depending on the extent and location of the damage. One of the main advantages of metallic bars in chest wall reconstruction is their high strength-to-weight ratio. Titanium is one of the strongest metals available and is also lightweight, making it an ideal material for use in chest wall reconstruction. The bars can be engineered to provide support and stability without adding unnecessary weight or bulk to the patient's body **(23).**

Another benefit of metallic bars is their biocompatibility. Because they are made of metal, they are generally well-tolerated by the body and do not typically cause adverse reactions or immune responses. However, it is still important to carefully select the appropriate material and to sterilize the bar to prevent the risk of infection. Metallic bars can also be used to stabilize fractures or other injuries to the ribs. This can help to reduce pain and promote healing, as well as improve respiratory function. The bars can be placed in a variety of configurations, depending on the specific needs of the patient, and can be adjusted over time as the patient heals. However, one of the risks associated with the use of metallic bars in complex chest wall reconstruction is infection. The presence of a foreign body can increase the risk of bacterial colonization and infection. In addition, the placement of the metallic bar may cause damage to surrounding tissues, which can also increase the risk of infection. Other potential risks include the bar shifting or moving out of position, causing pain, discomfort, or the need for additional surgery **(1)**

- **Complex Chest Wall Reconstruction with Proline Mesh and Metallic Bar**

The main technical principles of chest wall reconstruction are of a stable repair, compatibility of materials and meticulous surgical technique to minimize potential complications and the combination of available technologies. Apart from muscular or musculo-cutaneous flaps and omentum, the most commonly used materials for chest wall reconstruction are metal bars, various forms of plastic mesh, titanium mesh, cement and occasionally cadaveric bone **(1)**

The metal bars can used to recreate the anatomically acceptable shape of the chest wall. StraTos bars (MedXpert, Germany) could be quite useful, because it is possible to bend them to the required shape and to secure them normally or in the invert position if required. More frequently chest wall reconstruction is required for peripheral lung cancer invading lateral aspects of the chest wall. In this situation absent ribs also could be replaced by various forms of titanium bars, such as titanium Stratos bars which are available in different size and could be also trimmed according to the individual need If the muscle defect over the bars is significant, overlying Prolene mesh may be helpful to prevent lung herniation in the postoperative period **(19).**

Fig. (10):Right chest wall resection and reconstruction with StraTos titanium bars **(24).**

In cases where the defect of the chest wall is too large to be secured with metal bars, a combination of cement and natural flaps may be used as an ideal option, particularly after the resection of a primary malignant tumor. This approach commonly involves the use of methyl methacrylate bone cement in combination with a synthetic mesh applied to the defect, which is then covered with a latissimus dorsi muscle flap. This method has proven to be successful in chest wall reconstruction when metal bars cannot be used. Another approach to replace the defect after the resection of the sternum is to use a cadaveric sternum, which is put in place and secured with various forms of metal bars attached to the adjacent ribs. This method involves the use of specialized surgical techniques to ensure the proper placement of the cadaveric sternum and the secure attachment of the metal bars. This procedure is typically reserved for cases where the defect of the chest wall is significant and requires a more complex reconstruction approach **(25).**

Complex chest wall reconstruction is also indicated in patients operated for borderline pathology such as aggressive desmoid fibroma or other benign or borderline pathology of the chest such as fibrous dysplasia of the rib. The defect after resection may be very large because desmoid fibroma requires wide incision due to well-known tendency to grow deep onto the skeletal muscle so the defect could comparable to the defect expected after resection of a malignant tumour. In these cases, the implantation of a metal bar covered with Prolene Mesh would be ideal to resolve this problem Amongst the varieties of metal bars in place, it is preferable to use bars made from titanium because this metal is inert and rarely causing infective complications

(26).

Fig. (11):Resection of the left 6 rib with chest wall reconstruction using StraTos bar and Prolene mesh. Intra-operative view. The head end of the operating table is on the right **(24).**

Another area of chest wall reconstruction, which could be considered complex is the repair of congenital chest wall deformities such as pectus excavatum or pectus carinatum in young adults or occasionally in patients with a more advanced age. This surgery is performed via a transverse incision with a patent placed in a decubitus position. For this purpose, titanium bars are also ideal because they allow to maintain stability, but these bars require removal at a later stage, which is the down side of this procedure. The reconstruction may also be semi-rigid. As an example, the sternum may be secured with strips of Prolene Mesh positioned under the sternum and attached to the bony ends of the resected costal cartilages using non-absorbable sutures making them adequately tight after one end is properly fixed. This type of repair does not require a repeat procedure to remove the mesh **(27).**

Another area of complex and difficult surgery is operating on patients with complications of attempted repair of congenital chest wall deformities. The usual indications in this situation would be sub-optimal correction, retained metal constructions persistent pain and an unstable chest. For this kind of surgery, a wide surgical access is usually required. Even though a transverse incision is preferential, the old incision should be used, if previously a vertical incision was employed. An attempt to just perform a minimal procedure usually is not satisfactory because it does not lead to a desired result and does not allow to remove firmly embedded foreign material into the chest, so full exposure and complete reconstruction is required to achieve nearly normal anatomy and firm stabilization **(28).**

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