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Chest Wall Implants: Their Use for Pectus Excavatum, Pectoralis Muscle Tears, Poland's Syndrome, and Muscular Insufficiency

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Abstract. Solid customized and prefabricated silicone implants have been used by the author for 15 years in a wide range of chest wall deformities. Chest wall implants are often used in males seeking to augment a muscularly deficient or underdeveloped chest; however, their greatest use has come in a variety of deformities both congenital and acquired, such as pectus excavatum, Poland's Syndrome, and pectoralis muscle tears. The implants can be either customized using a moulage technique or are prefabricated, manufactured implants which can be modified on the operating table to repair the contour deformity. The immediate postoperative problem of seroma and subcutaneous implant ''show'' has been minimized by careful planning, gentle technique, deep insertion, improved patient positioning on the operating room table, and the use of oral anti-inflammatory medications. The long-term results of these implants seem very satisfactory. The patients are usualy physically active, and the implants show no long-term sequelae such as seroma, infection, displacement, or rupture.

Key words: Chest wall—Silicone prefabricated implants—Pectus excavatum—Poland's syndrome—Pectoralis muscle tears—Under developed male chest contours

An adequate chest wall is psychologically very important for males. Well-developed chests denote fitness, strength, and power. The psychological problems of gynecomastia and pectus excavatum are well recognized by the medical profession as a form of embarrassment and social exclusion. The exposure of the male body in media advertising, especially the upper torso which features large and well-defined ''pecs'' make the latter highly desirable as an ideal standard. It is perhaps due to media attention, that ''pecs'' are becoming as important to males as breasts are to females. Many patients have attempted body building and weight lifting as well as dietary supplementation in order to try and improve their physique. Some patients have ingested anabolic steroids and may have associated gynecomastia. Patients with Poland's Syndrome or Pectus Excavatum usually consult because of the social embarrassment experienced when revealing the upper torso at sporting events. They retract from participation in swimming carnivals, such sports as basketball, and going to the beach, for example.

Evaluation of a Chest Wall

Chest wall evaluation is an essential component in the initial assessment of a patient with a torso deformity or a patient seeking a body contour procedure of the anterior chest. Chest wall asymmetries should be assessed and the skeletal and muscular development around the chest evaluated. The fatty distribution on the anterior and posterior aspect of the chest wall, especially along the lateral pectoral sweep, should be assessed. A systematic evaluation will ensure the surgeon does not fail to recognize the skeletal and muscular elements contributing to a chest wall deformity.

The Skeletal Evaluation

A skeletal evaluation initially consists of having the patient stand in front of a three-way mirror to observe the symmetries of the shoulder, rib cage, and sternum. The surgeon then observes the scapula and the cervicothoracolumbar spine from the posterior view. Slight scoliosis is commonly present as are anterior costocartilaginous prominences and asymmetries.

Muscular Evaluation

To evaluate the muscular structure, the surgeon begins by observing the pectoralis muscles and palpating them on relaxation and forced contraction. The pectoralis muscle has clavicular, sternal, and costal components which combine and coalesce to form the tendon inserting into the humerus (Fig. 1). The costal head is often asymmetrical, and it should be noted that the medial extension of the sternal head is not only variable but may be quite asymmetrical. Patients often seek exaggeration of the midline cleavage between the sternal heads and this can be limited by or not attainable because of a displaced sternal origin of that portion of muscle. The latissimus dorsi should be evaluated in relaxation and forced contraction providing the observer with an assessment of the overall development of the upper torso, anteriorly and posteriorly. Finally, the status of the skin and subcutaneous tissues including fat or adipose tissue are assessed. Acne and acne scarring are common in patients who have ingested anabolic steroids. Subcutaneous fat may be deficient particularly in a serious body builder who has recently competed or is considering competition.

Patient Expectations

Ideal communication of the patient's desires may require referral to popular sports or muscle and fitness magazines which then act as a reference for the desired development and shape of the pectoralis major muscles. For those patients wanting augmentation because of deficient muscularity, two types of implants are available. The Aiache implant[1] is a solid lozenge-shaped silicone implant which mainly augments the lower two-thirds of the muscle. The Novak implant[1] is similar but has a clavicular extension and is more square-shaped. Puny or underdeveloped men are usually satisfied with a lower two-thirds augmentation, whereas body builders often wish for more subclavicular prominence. Most patients prefer a fuller medial cleft, which, as mentioned, may be limited by the development of the sternal head.

Pectus Excavatum

Pectus excavatum is rarely associated with the physiological sequelae of restricted lung capacity; hence, patients who seek correction of this embarrassing deformity are seeking it almost exclusively for cosmetic reasons. Extensive thoracic procedures such as the Ravich operation [9] may be performed in order to achieve the desired contour of the sternum; however, a midline scar detracts from the final result, and the procedure is fraught with the risk of serious complications [6].

[1]Aiache and Novak Design implants are available from A.B.T., 9576 Ridgetop Boulevard, Silverdale, Washington 98383, U.S.A.

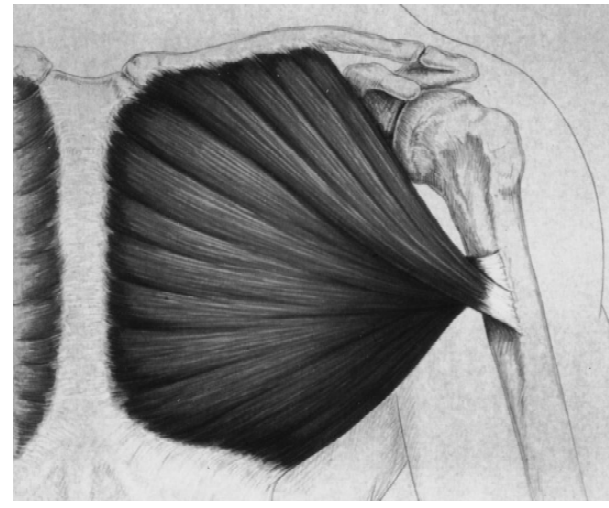

Fig. 1. The pectoralis muscle. The clavicular sternal and costal origins should be evaluated in relaxation and isometric contraction.

Early reports of the successful camouflage of a deformity with solid implants required the prefabrication of a papier mâché moulage [11]. Subsequently, the customized implant was sterilized and inserted through a substernal incision into the defect. The main problem with this technique was implant ''show'' due to the lack of subcutaneous tissue in a presternal area which was a source of patient and surgeon dissatisfaction [5]. Avoidance of unwanted subcutaneous ''show'' of the implant is achieved by careful moulage production and thinning of the edges of the implant. Subcutaneous positioning and ''show'' of an implant, which is usually unacceptable, can actually be used to advantage in some cases by simulating costal or xiphoid cartilages which may be deficient in pectus excavatum cases (see case study 2).

Moulage Preparation

Papier mâché kits are available (McGhan)[2] though faster-setting synthetic plastic kits (A.B.T.)[1] are used when a moulage preparation is required. The surgeon should seek the cooperation of the patient when choosing the correct size and shape of the moulage. The moulage to solid silicone implant requires transmission to the manufacturer of such specific requirements as suture tabs, density, and flexibility of the solid silicone. The implants are usually manufactured as smooth implants in solid silicone of either grade 4 or 5. The implant can be modified on the operating table with large scissors as required. A moulage can be useful for carving prefabricated implants on the operating table. Set on the back

[2]McGhan Medical Corporation, 700 Ward Drive, Santa Barbara, CA 93111, U.S.A.

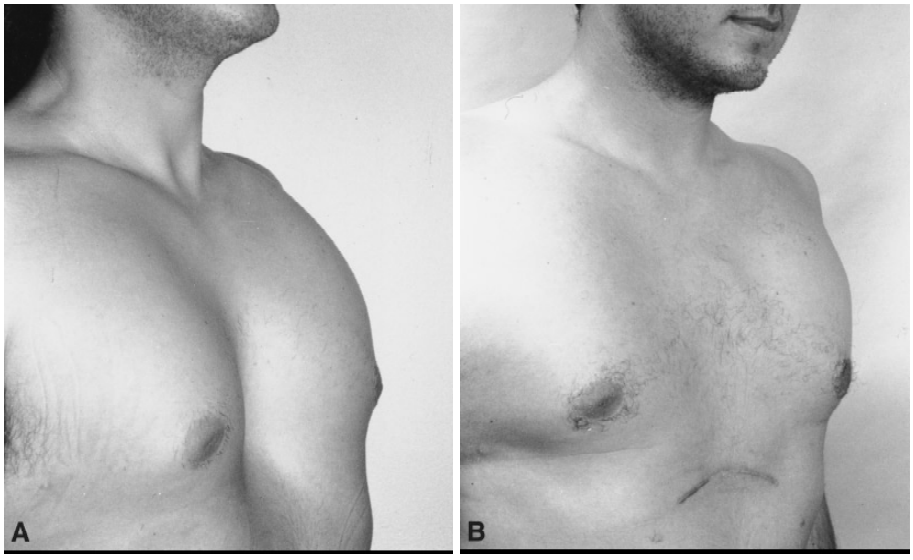

Fig. 2. (A) Before and **(B)** 3 months after customized solid silicone implants for pectus excavatum.

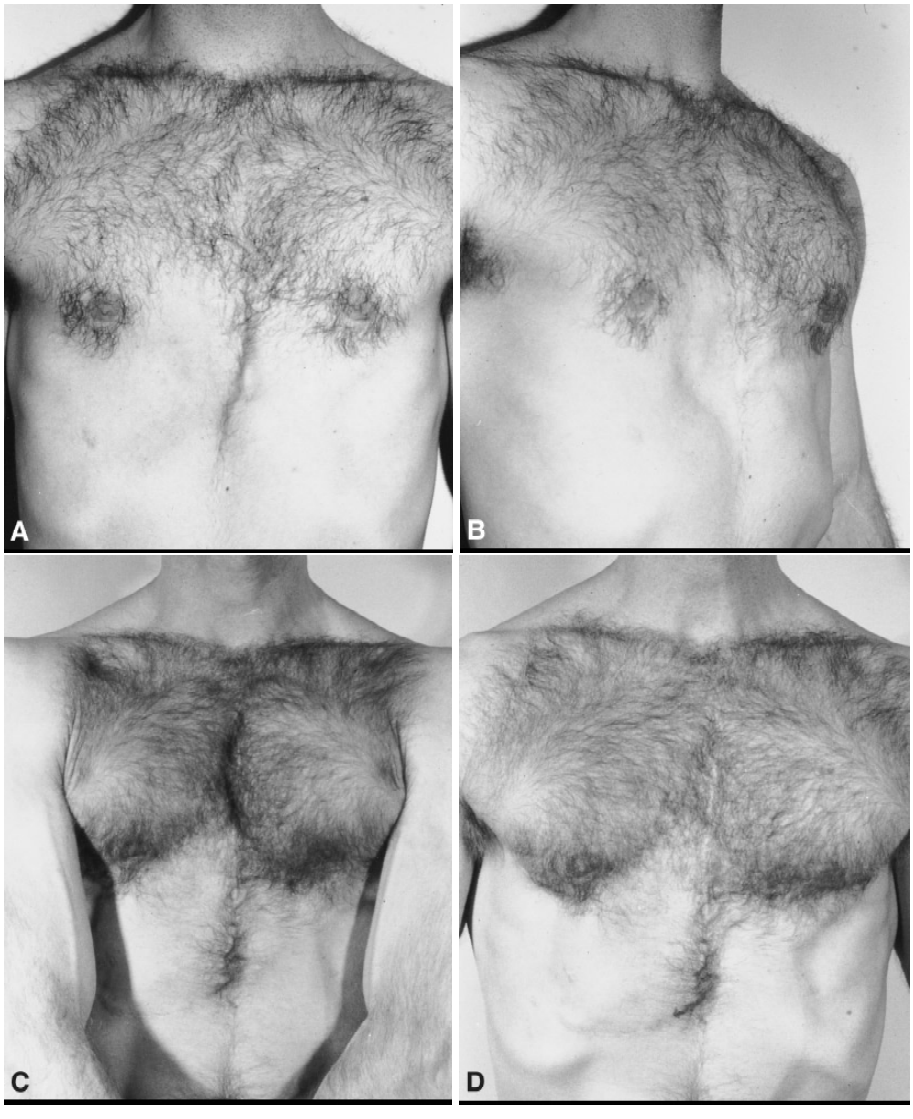

Fig. 3. (A, B) Residual pectus excavatum and loss of right sixth to eighth costal cartilages post-Ravich procedure for correction pectus excavatum. **(C, D)** Eleven years postinsertion of two customized chest wall implants for contour correction of the pectus costal cartilage deficit and also the origin of the sternal component of the right pectoralis major muscle.

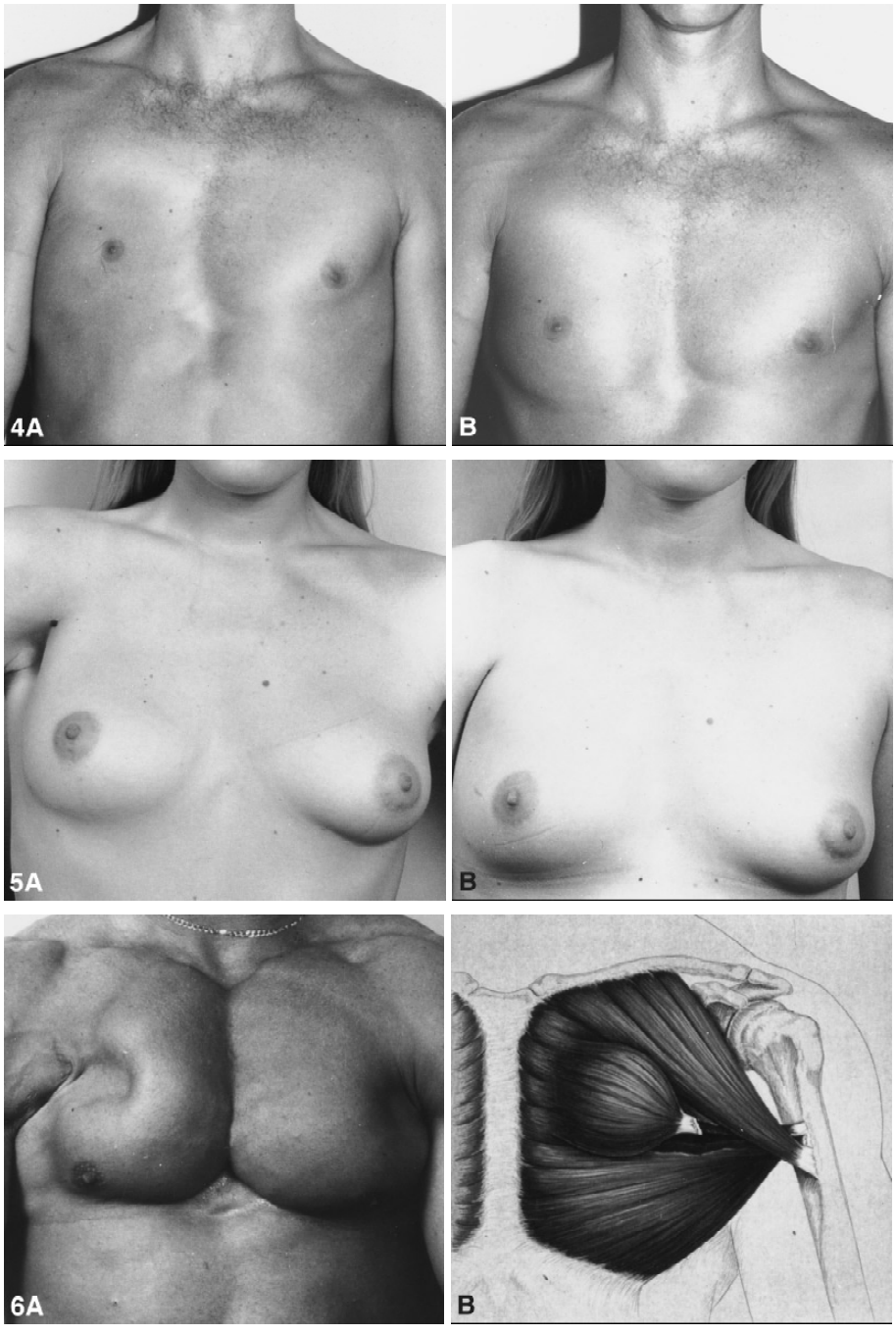

Fig. 4. (A, B) Customized implants for correction of right Poland's Syndrome in a 23-year-old surfboard rider.
Fig. 5. (A, B) Size 2-Aiache styled chest wall implant for correction of mild Poland's Syndrome right side.
Fig. 6. (A, B) Appearance of torn pectoralis major muscle noting medial bulge of sternal head and lateral groove.

table, the surgeon can modify the solid prefabricated implant more precisely by copying the shape of the moulage.

Operative Procedure

Under general anesthesia, a substernal curvilinear incision is made, and the deepest possible plane is developed at the perichondrium and periosteal level. If possible, some origins of the pectoralis muscle can be also elevated for further coverage of the implant. The origin of the pectoralis muscle is usually splayed apart in pectus excavatum and there may be a compensatory hypertrophy of the clavicular and costal heads leading to an exaggeration of the hollowing in the midline. The costal cartilages are often very prominent, and the medial dissection around these can be quite difficult. Fiberoptic retractors are essential, and the dissection needs to be both blunt and sharp to obtain the best fit for the solid implant obtained. The edges of the customized implant should be thinned or trimmed using large scissors in order to prevent ''show'' of the implant underneath the

Fig. 7. Preoperative moulage preparation of torn pectoralis major muscle defect.

subcutaneous tissue. To reduce the size of the incision, the implant can be curled in a circle and slipped into the pocket under a Deaver retractor, then unfurled so that the edges lie flat. A long, flat, spatula is used for this purpose.

Case Study 1

A 19-year-old boy presented with pectus excavatum. The patient had attempted body building, gained weight, and became frustrated because no change occured in his chest wall appearance. In fact, the chest wall appearance deteriorated with the body building due to the pectoralis muscle develpment. The pectoralis muscles on evaluation were well developed, but the patient had a 5 × 12 × 5 cm pectus excavatum deformity. A customized implant had been produced from a firm moulage plastic kit supplied by A.B.T. At surgery, a subxiphoid incision was made, the pocket developed, and the implant was inserted into the pocket. The final result was favorable, but there was a lateral displacement of the medial pectoralis muscle heads. Secondary sternal head implants were suggested which the patient declined as he was satisfied with the result (Fig. 2).

Case Study 2

An 18-year-old boy underwent surgical correction of pectus excavatum by a thoracic surgeon. The operative procedure, using a midline sternal approach, was complicated by infection. After the infection resolved, there was a residual deformity due to the absence of the cartilaginous xiphoid and right sixth to eighth costal cartilages, secondary to necrosis. The pericardium with the heart beating was visible beneath this deformity, and the patient and his parents were concerned for fear of cardiac injury (Fig. 3A, B).

To correct this asymmetrical deformity, a customized silicone implant was fabricated and inserted into a subcutaneous pocket after dissection over the pericardium and right subcostal flattened chest wall. Although complicated by seroma, which required repeated aspiration, the implant remained fixed with no objectionable edges showing. The implant's subcutaneous ''show'' resolved the cartilaginous chest wall deformity simulating the deficient costal margin and covered the pulsating pericardium simultaneously correcting the residual pectus excavatum.

The patient was very satisfied with the appearance and began rigorous weight training at a local gymnasium. The weight training led to enlargement and greater definition of the left pectoralis muscle. This definition revealed that the origin of the right pectoralis muscle from the mid and upper costosternal junction was deficient, and, subsequently, the patient sought further correction of this deformity. The deficiency was corrected by a second customized implant (Dow Corning) placed submuscularly to simulate the bulk of the medial pectoralis muscle and provide symmetry with the normal pectoralis muscle. The implant was inserted through a lateral incision at the free border of the right pectoralis major muscle. The patient has continued his body building and now enjoys muscular symmetry 15 years after this implant was inserted (Fig. 3C, D).

Poland's Syndrome

Severe Poland's Syndrome is rare. Most commonly, Poland's Syndrome patients present with a discernible skeletal and pectoralis major muscle deficiency usually in the middle third of the chest wall and a loss of the lateral pectoralis sweep. An associated nipple or breast deformity is present except in the most minor presentation of Poland's Syndrome. Minor deformities can be corrected by the use of customized or prefabricated solid silicone implants. A pectoralis implant cannot correct the lost lateral sweep of the muscle, but *can* repair the anterior chest wall skeletal and muscular deformity. Only if there is sternal rotation and very prominent projecting costal cartilages should thoracic surgical repair be considered [10]. Latissimus dorsi muscle transposition should be considered if the pectus sweep to the humerus is the most significant aesthetic deficit; however, this is rare. The back scar and failure of the operative procedure due to muscle contracture detract from its appeal.

Case Study 3

A 26-year-old male surfboard rider and construction worker presented with Poland's Syndrome with loss of the central sternal head of the pectoralis muscle and the lateral sweep of the muscle. He had an associated 3-cm nipple elevation on the affected side. The customized implant was utilized after a moulage was constructed, and at surgery, the implant was inserted through an ax-

Fig. 8. (A) Before and **(B)** after customized solid silicone implant for old pectus muscle tear.

illary incision into a deep supraperiosteal position above the ribs (Fig. 4).

Initially, the patient developed a seroma, which required multiple syringe drainages, and, eventually, the implant was removed. The implant was reinserted approximately 3 months later. Three years later the result remains stable with an acceptable correction of the anterior and lateral chest wall deformity. A lowering of the nipple–areolar complex along with expansion of the chest wall skin has improved the overall appearance of the chest wall.

Case Study 4

A 24-year-old female presented with a concavity of the right mid-chest wall secondary to a deficiency of the sternal head of the pectoralis muscle; she also had an associated loss of the lateral sweep of the muscle. There was no mammary hypoplasia on the affected side. She was a successful model, and her main concern was her upper chest asymmetry which she camouflaged by wearing long hair, styled to cover her upper chest. At operation, a slightly modified size-2 Aiache solid silicone implant was inserted through an axillary incision filling the central third muscular defect. The patient accepted the residual deformity of the lateral sweep of the pectoralis muscle and was delighted with this relatively uncomplicated approach to the anterior chest wall deformity. The result is stable 2 years postinsertion of the implant (Fig. 5).

Pectoralis Muscle Tears

There is a common incidence of pectoralis muscle tears in high-impact sports, motorcycle racing, weight lifting, and body building, especially during bench press exercises [8]. Usually, the sternal origin detaches from the common pectoralis tendon laterally [2]. Injuries, such as pectoralis muscle tears, are initially suspected after a high-impact sporting incident which may often be accompanied by the sound of the muscle breaking and a large hematoma forming in the chest wall. Occasionally, orthopaedic surgeons repair these tears early, although patients often present at a later stage when the deformity becomes obvious on muscular contraction [4]. On forced contraction of the muscle, the medial muscle head bulges and there is a lateral groove which forms toward the muscle insertion. The bulge of the medial muscle head protrudes above the rest of the pectoralis muscle forming an asymmetry, especially on forced contraction. This asymmetry can lead to an aesthetic deformity which is unacceptable by competitive bodybuilders (Fig. 6). Late presentation is accompanied by a hollowing and visibility of the sternal costal cartilages on contraction of the pectoralis muscle. The bulging groove has been corrected by the author by direct surgical excision of the wedge of the protuberant muscle and suture repair of the groove [3]. When the late repair is impossible, the defect is better camouflaged by a customized implant and prefabricated solid silicone implant inserted through an axillary incision.

Case Study 5

A 24-year-old recreational bodybuilder has torn his right pectoralis major muscle when wrestling at high school. No surgical repair or therapy was carried out and the deformity had become increasingly obvious the more he tried to build up the muscle with weight training. Examination revealed lack of muscular origin of the right sternocostal region, with exposure of the third, fourth, and fifth ribs. There was no associated bulge ofthe pectoralis major muscle laterally on contraction of the muscle.

A moulage was made of the muscular defect (Fig. 7) and the customized silicone implant was inserted submuscularly to camouflage the defect. The insertion was made through a low axillary incision in the submuscular plane with no fixation other than external compression being used. The implant remains in good position with nonpalpable edges 6 months after insertion. The patient had recommenced recreational bodybuilding (Fig. 8).

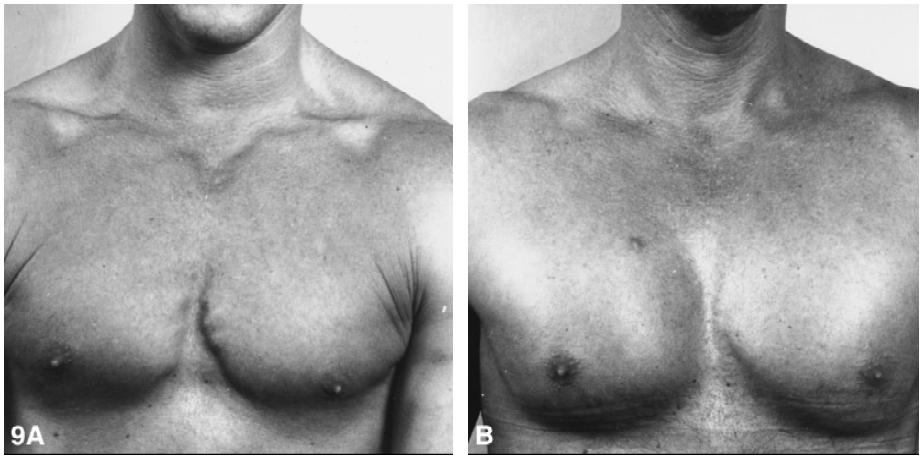

Fig. 9. (A) Before and **(B)** after size-4 Aiache implant for deficiency of pectoralis muscle.

Muscle Insufficiency

Bodybuilding is a rapidly growing sport for both men and women. In the male bodybuilder, both amateur and professional, well-developed pectoralis major muscles are an essential constituent to achieving the ideal wedge from shoulder to waist and chest wall projection in lateral poses. The pectoralis major muscle has three components—clavicular, sternal, and costal—which cover the anterior chest. The tendons of the muscles course together and combine in the lateral sweep of the pectoralis muscle as it inserts into the humerus. Bodybuilders have individual preferences for the development of the pectoralis muscle. In the upper one-third, the pectoralis muscle should be well-developed below the clavicle and in the lower one-third, the muscle (the costal component) should have a drooping and globular shape. Bodybuilders uniformly desire as much medical cleft and symmetry of cleft as possible. When exercise alone fails to achieve the desired shape, volume, and development of the muscles, body builders often resort to taking either medically or nonmedically prescribed anabolic steroids.

There are two designs of pectoralis implants—the Aiache and the Novak [1]. The two designs have been developed to achieve volumetric displacement of the pectoralis muscle by placement in a subpectoral position to enhance male chest development. The Novak design provides more enhancement to the upper clavicular portion of the pectoralis muscle, whereas the Aiache implant augments the sternal and costal lower two-thirds of the muscle. Prior to these implants being commercially available, multiple lozenge-shaped implants were used; however, these were apt to dislodge resulting in subsequent deformity. Solid blocks of silicone were also meticulously carved to provide the appropriate volume and shape desired [7]. With the available prefabricated implants, most patients can be satisfied if the correct size and shape is determined preoperatively.

Case Study 6

A 30-year-old amateur bodybuilder presented for chest wall augmentation as he was dissatisfied with his present exercise program, which had developed his latissimus and abdominal muscles to a high degree but had failed to increase the pectoralis muscles. He had not ingested anabolic steroids and adhered to a rigorous exercise program. One examination, all three components of his pectoralis muscle were present and developed; however, in relationship to the adjacent latissimus muscles, the pectoralis muscle was relatively inadequate. Immediately prior to the surgical procedure, the incision, the outline of the pectoralis muscle, and the torso were all marked. In an effort to define the pectoralis muscles further, some liposuction of the lateral pectoral sweep and the abdominal wall and flank area was performed in order to accentuate the ‘‘washboard’’ effect of the developed rectus abdominis muscles. Size-4 Aiache implants were inserted through an axillary incision (Fig. 9). The patient was continued on Brufen 200 mg (oral anti-inflammatory) every 6 hours for a week, immediately postoperatively, and avoided upper body exercises for 4 weeks. Two years after insertion, he continues as a serious amateur body builder.

Pectoralis Implants for Females

Female bodybuilders or powerfully muscled women are poor candidates for conventional subglandular or subpectoral insertions of saline implants. When the implants are in a subpectoral position, contraction of the powerful pectoralis muscles leads to significant unattractive displacement of the implant. When the implants are subglandular, because of the glandular and fatty depletion in these athletes, implant wrinkling so common with saline implants is often very obvious. As an alternative, solid subpectoral implants can be used if the patient has no ptosis of the breast and no desire for a very large augmentation. The technique for insertion is identical to that of a male, and the augmentation with a subpectoral implant gives the ‘‘hard-body look’’ and the simulation of a breast for the female by using the Aiache implant which is more accentuated inferiorly. If ptosis was present, a ptotic procedure could be performed at the same operation, repositioning the breast tissue over the augmented pectoralis muscles.

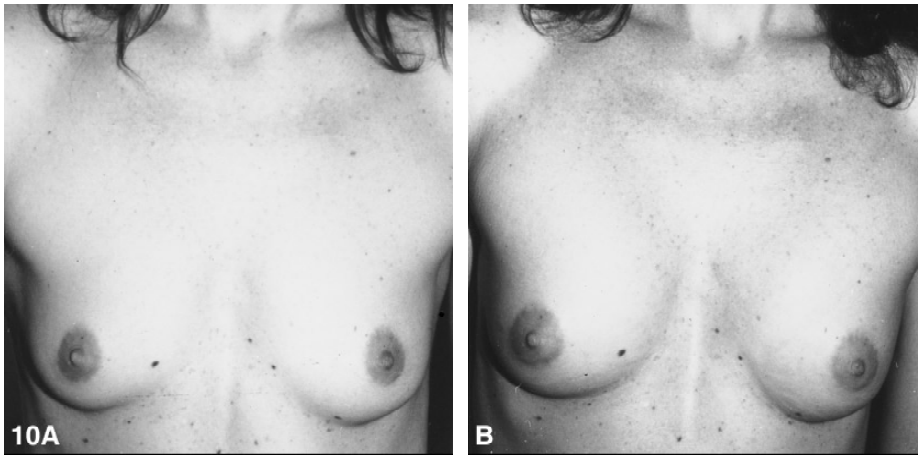

Fig. 10. (A) Before and **(B)** after size-2 Aiache implant in female competitive bodybuilder.

Case Study 7

A 31-year-old female requested breast enlargement. She was a serious recreational bodybuilder who had entered amateur competitions. She did not want implant ''show'' or a particularly large augmentation and accepted the suggestion of a subpectoral solid silicone implant. She did not want more than a B-cup and understood that the implant was placed solely to augment the pectoralis muscles and not to create a pocket for an implant that would simulate a breast. Six months after the size-2 Aiache implant was inserted through an axillary incision, the patient was satisfied with the result and no postoperative complications such as seroma or displacement of implant occurred (Fig. 10).

Technique of Insertion

The implants are inserted with the patient supine under general anesthesia, and both arms are held above the head at an angle of 15° behind the acromio–clavicular joint and secured on an ether screen. This maneuver brings the pectoralis muscles out of the chest wall and exposes the axilla where the incision is made for insertion of the implants (Fig. 11). The incision in the axilla should be approximately 5–6 cm in length and placed in the mid-hair-bearing area of the axilla, care being taken not to extend the incision past the pectoralis sweep and onto the anterior chest.

The incision should be marked preoperatively and the arm moved, abducted, and raised over the head in order to position the incisions correctly and make them as inconspicuous as possible. The surgical incision is deepened through the subcutaneous tissues to the lateral chest wall and a sharp dissection underneath the lateral pectoralis muscle allows the pectoralis muscle to be lifted more anteriorly from the chest wall. A blunt instrument is then inserted either with a large spatula or Agris dissectors in order to dissect the pockets. Enlargement of the inferior pocket must be cautiously undertaken to prevent detachment of the origin. This is quite *different* from that of the female subpectoral pocket of the breast implant. The aim is not to lower the inframammary fold; therefore, the dissection of the pectoralis muscle must *not extend* below the predetermined position of the lower border of the pectoralis major muscle. If the dissection of the pectoralis muscle is too extensive, then the implant is displaced inferiorly, which is a difficult deformity to correct secondarily. Similarly, the detachment laterally is limited, and the serratus anterior should generally be left intact. The cautious avulsion of the sternal head allows for medial displacement of the implant to achieve the desired medial clefting.

One must be aware of the deficiency of subcutaneous tissue in these patients and attempts to position implants subcutaneously can lead to unnatural ''show'' of the implant. The most likely concern is coverage of the implant laterally and superiorly. The tail ofthe implant may need to be excised or contoured to allow for coverage of the implant by the pectoralis muscle and the fascia of the muscle. This should be checked by movement of the arm and palpation of the implant in the axilla. To aid the insertion of the implant after contouring it on the table, the implant is rolled as a ''roulade'' and inserted through the incision. It is then unfurled with a large spatula under the pectoralis major, and the edges are carefully positioned using the spatula. Most recently, the pocket has been inspected with a 10-mm straight endoscope, and muscular bands have been incised with a specialized angled, curved cautery unit inserted through an axillary incision. Rough handling of the implant should be avoided as should manipulation of the posterior pectus muscle in an effort to insert a lager implant. Too much rigour probably leads to damage of the muscle and possibly seroma formation. Closure of the incision is made in three layers, through the pectoralis fascia, the subcutaneous tissues, and the skin. The chest wall is not usually drained, and the chest is bandaged firmly for 4 days. The patient abstains from exercise for 4–6 weeks and wears a tight singlet, T-shirt, or swim shirt during that time. If the latter are not available, then an Ace-bandage suffices in compression and stabilization and serves to reduce movement of the implant during the 6-week healing phase. Decadron, usually 8 mg intravenously, is

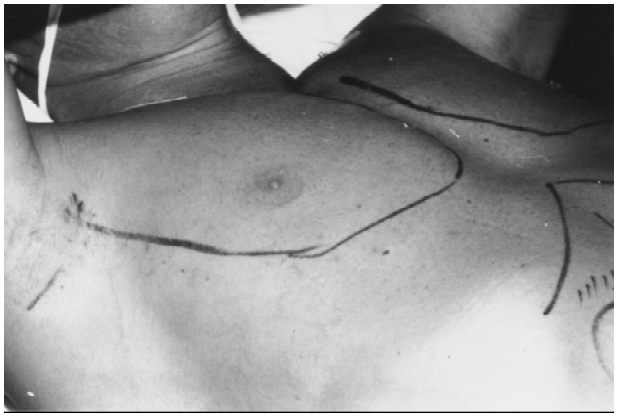

Fig. 11. On-table positioning for insertion of pectoralis implant through axillary incision.

given at the commencement of surgery, and the patient is commenced postoperatively on a 7-day course of oral anti-inflammatory medications.

Complications

Complications of seroma generally present 7–10 days postoperatively initially in about 30% of cases. As noted in the cases above, persistent seroma requires both the removal and reinsertion of the implant; however, by using the new positioning technique, the careful use of the pocket makers as well as the addition of oral anti-inflammatory medications, the incidence of seroma has dropped to nearly zero. Asymmetries of placement of the implant are due to overaggressive disinsertion of pectoralis origins, especially inferiorly and should be avoided. If the implant is too low, then it will likely need to be removed and reinserted several months later if taping techniques are unsuccessful. Following reinsertion, taping of the inferior border will again be reintroduced for 4–6 weeks to prevent inferior displacement of the implant. Infections have not occurred around the implant nor have long-term capsular contractions or distortion of the implant.

Summary

Chest wall enhancement is usually satisfactory with prefabricated Aiache or Novak type chest wall implants. For pectus excavatum, customized implants should be manufactured after a moulage of the defect has been completed. Pectoralis muscle tears can be acceptably camouflaged using these implants. In both male and female body builders, the implant provides a platform for the pectoralis muscle and enhances the appearance of the muscle. It also allows further development of a muscle above the implant if this is desired. The complication of seroma so commonly occurring in earlier patients, has been significantly reduced by improved on-table positioning, less traumatic techniques, and a further refinement of techniques using specialized instruments, dissectors, and the endoscope. The use of steroidal and nonsteroidal anti-inflammatory drugs is now routine and possibly contributes to the decreased rate of seroma formation.

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