The Anatomic Stemless Humeral Prosthesis

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Nael Hawi and Peter Habermeyer

Introduction

Since 1951, early applications of shoulder arthroplasty underwent a complete transition in the development of humeral and glenoidal components, towards a more anatomical, modular, revisable, or convertible design (Figs. 25.1 and 25.2). The very first stemless humeral head prosthesis was implanted in 2004. Currently, most manufacturers offer stemless prostheses. The anchorage is cementless and metaphyseal. Thus, one can differentiate between a purely metaphyseal press fit anchorage and a metaphyseal press fit combined with epiphyseal bracing with a compression screw and a collar-bearing baseplate (trunion), to maintain additional primary stability. The advantages of this technique are that it saves intraoperative time, employs a stemless implant, produces less blood loss, incurs less trauma to the humeral shaft, and carries a lower risk of periprosthetic fracture. Additionally the access to the glenoid is compared to resurfacing arthroplasty much easier.

The stemless prosthesis design is applicable even to post-traumatic cases with existing deformities. Moreover, when revision surgery is necessary, this type of prosthesis is much easier to explant than a stemmed prosthesis. After

Fig. 25.1 Anatomic stemless prosthesis (Eclipse, Arthrex Inc.)

Fig. 25.2 Metalback convertible socket (Universal, Arthrex Inc.)

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explantation, it is possible to use a standard-sized, stemmed prosthesis.

Indications and Contraindications

The indication is basically the same for a stemless prosthesis and for the usual stemmed prosthesis. Contraindications are the presence of space-occupying cysts at the metaphysis, osteopenia, osteoporosis, or other metabolic bone disorders. It should be noted that, to date, we lack an objective tool for measuring bone quality, either pre- or intra-operatively. Other contraindications are fresh fractures and a history of epilepsy.

Preoperative Planning

Biomechanical Principles

Understanding normal three-dimensional anatomy provides the basis for successful joint replacement. In addition, changes in soft tissues, with respect to limb shortening, must be included in the planning. Upon implantation of the metaphyseal anchored prosthesis described here, attention must be focused on placing the baseplate (trunion) utmost anatomical by fitting it to the circular cortical rim for stable fixation. Proper positioning can minimize the load at the cap-trunion-bone-interface and forestall migration of the prosthesis. In addition, contact between the fixing hollow screw and the lateral cortex should be avoided to reduce bending stress on the hollow screw and to achieve uniform loading at the cap-bone interface.

Pathomechanics

Osteoarthritis of the Humeral Head

This condition causes loss of sphericity, with:

- disturbance of the rolling-sliding mechanism
- medialization of the center of rotation
- shortening of the lateral humeral offset
- development of caudal osteophytes, with growth rates according to the stage (classification according to Samilson and Prieto)
- Tensioning of the inferior capsule by bulging osteophytes
- reduction of the articular surface angle, which limits the range of motion
- shortening of the M. subscapularis and increased capsular tension with increasing dorsal decentering of the humeral head

Osteoarthritis of the Glenoid

This condition causes the following:

- medialization of the glenoid surface
- retroversion of the glenoid by posterior/inferior glenoid wear
- inferior tilt of the glenoidal inclination angle; the type of inclination depends on the stage (classification according to Habermeyer)
- enlargement of the glenoidal surface by osteophytes

Course of Primary Humeral Osteoarthritis

The typical course of primary humeral omarthrosis can be divided into three stages, as follows:

Stage 1

The initial shape of the humeral head in the coronal plane remains round and spherical. No substantial decentralization of the apex of the humeral head can be detected in the transverse plane. The cartilage wear primarily takes place in the inferior portion of the humerus. There is no posterior decentering of the humeral head. At this stage, osteophytes are generally shorter, though all stages according to Samilson and Prieto can occur. Regarding the glenoid morphology at this stage in the coronal plane, an inclination of 0–1 according to Habermeyer is mainly observed.

Stage 2

At this stage, there is a flattening of the humeral head in the coronal plane. Furthermore, an increasing deformation can be observed in the transverse plane, with displacement of the apex, primarily posteriorly. An extension of cartilage wear occurs superiorly. In addition, an incipient posterior subluxation can be observed. Moreover, there is growth of caudal osteophytes and an increase in the glenoidal type of inclination.

Stage 3

At this stage, an aspherical humeral head is observed in the coronal plane, and a decentered apex is observed in the transverse plane. Extensive cartilage damage extending superiorly is apparent. The humeral head is subluxated dorsally. In addition, caudal osteophytes and glenoidal inclinations are primarily higher grade.

Medical History

The patient history should cover the overall situation of the patient, including all medical, psychological, and social aspects (social environment). The medical aspects should include information on major complaints, typical pain symptoms, restrictions in the range of movement, and loss of strength.

Clinical Findings

The clinical examination should include evaluations of the following parameters:

- efflorescence of the skin
- signs of an infection
- swelling
- atrophic changes
- active and passive movements
- functionality of the rotator cuff
- neurological function (optionally extended neurological examination)
- increases in function scores (Constant-Murley Score)
- in case of a metallosis, perform a skin test

Instrument-Based Diagnostics

Diagnostic assessments tools:

(i) ***Sonography (use standard sonographical section planes)***
- Assess the rotator cuff, including effusion

(ii) ***Radiography/X-Ray (true antero-posterior (AP), axial)***
- Assess narrowing of the joint gap
- X-Ray AP: Assess the humeral head curvature, the caudal humeral osteophyte (according to Samilson and Prieto), centering, lateral humeral offset, medial glenoidal protrusion, and the type of glenoidal inclination (according to Habermeyer). Estimation of bone density and cyst formation.
- X-Ray AXIAL: Assess flattening of the humeral head, concentric or eccentric glenoidal wear, humeral centering, and the constellation of osteophytes

(iii) ***Computed tomography:***
- Assess the posterior subluxation-position (according to Walch) and glenoidal inclination and wear
- Assess any atrophic changes and determine the presence of any fatty infiltrations in the rotator cuff
- Preferably use 3 D reconstruction and software planning in order to measure retroversion- and inclination angles and determine if glenoid bone stock is sufficient to guarantee 80% of glenoid component bone contact and a retroversion angle <15°.

(iv) ***Magnetic resonance tomography:***
- Assess the rotator cuff, fatty infiltrations, or muscular atrophies
- Assess glenoidal and humeral morphology

Surgical Technique

Patient Positioning

The patient is placed in a flat beach chair position (30°). The head and neck are secured with a ring headrest, which is helpful for maintaining the head and neck in the correct position throughout the procedure. The upper body is brought to the lateral edge of the operating table to allow full extension of the arm, which is essential for exposure of the proximal humerus. The arm is positioned on an additional hand table, which is adjustable in height. The shoulder and arm are prepared in sterile conditions, and the body is draped appropriately, to allow full exposure and free movement of the entire limb (Fig. 25.3).

Approach

The deltopectoral approach requires an incision, which starts above the coracoid process and terminates above the insertion of the pectoralis major on the humeral shaft. The skin incision often lies directly over the course of the cephalic vein, between the deltoid and pectoralis major muscles. After ensuring preservation of the cephalic vein, the clavipectoral fascia is split. This allows visualization of the pectoralis major muscle (Fig. 25.4).

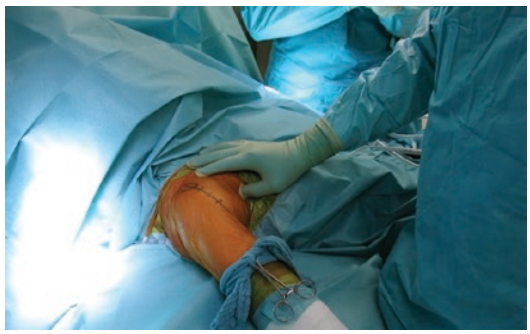


Fig. 25.3 Flat beach-chair position. The patient is draped in that way to allow free intra-operative mobility of the upper extremity

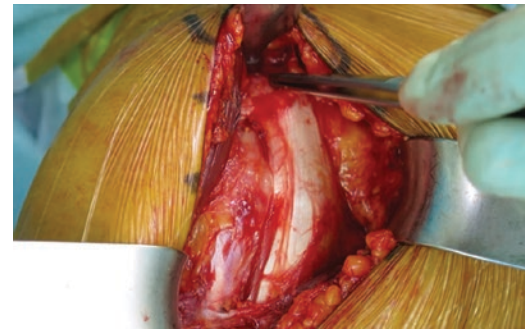


Fig. 25.4 The deltopectoral approach. The incision to expose the humeral shaft starts at the coracoid process and ends at the insertion of the pectoralis major. The forceps point to the surface of the coracoid process; directly below, the conjoint tendon extends vertically; at the lower edge of the image, the tendon of the M. pectoralis major crosses transversely

Next, the subfascial preparation of the proximal humerus beneath the fornix humeri is performed. When severe subacromial and subdeltoid bursitis is present, it is necessary to perform a resection of the bursae. The rotator cuff is preserved. Existing adhesions are removed. Then, tenolysis is performed to release the supraspinatus and infraspinatus tendons. To restore adequate gliding, the entire rotator cuff is mobilized. Furthermore, tenolysis of the subscapularis tendon is performed to release it from adhesion beneath the conjoined tendon. Here, due to the proximity of the posterior axillary gap, it is important to pay particular attention to the safety limits of the axillary nerve. In cases of nerve adhesions, a neurolysis should be performed.

Tenodesis of the Long Head of the Biceps Tendon

During tenodesis of the subpectoral biceps tendon, tension is maintained on the long head of the biceps tendon; also, two inverse U-stitches must be placed at the tendon edge of the pectoralis major, at the crista humeri. After capsular release, the intra-articular portion of the long head of the biceps tendon is completely excised, back to the level of the sulcus intertubercularis (Fig. 25.5).

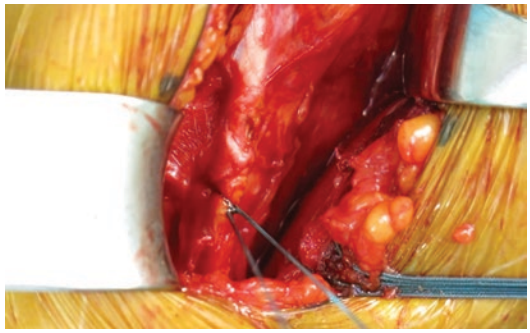


Fig. 25.5 Performing tenodesis of the long head of the biceps with inverse U sutures (upper suture). The insertion of the M. pectoralis major was incised, in this case, at its proximal end, and it has been reinforced with sutures to refix (lower right corner)

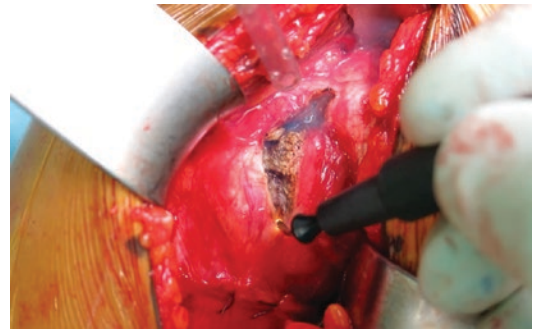


Fig. 25.6 The detachment of the tendon of the subscapularis takes place at the tuberculum minus (lesser tuberosity of the humerus), leaving a tendon stump to repair

Preparation of the Subscapularis Muscle

The rotator cuff interval is opened to perform the tenolysis. Thus, the coraco-humeral ligament is cut, at its base, at the coracoid process. Synovial fluid may be observed. Detachment of the subscapularis muscle tendon is performed at the tuberculum minus (lesser tuberosity of the humerus; Fig. 25.6). Upon detachment, a tendon edge remains attached to facilitate reattachment. Next, the humeral circumflex artery and vein are ligated. Then, a sharp dissection is performed to separate the muscular portion of the subscapularis muscle from the humeral calcar. Special attention should be paid to the safety limits of the axillary nerve. Next, the subscapularis muscle is completely dissected to the height of the latissimus dorsi muscle, and subsequently, it is reinforced with holding threads, in a modified Mason-Allen suture technique (Fig. 25.7).

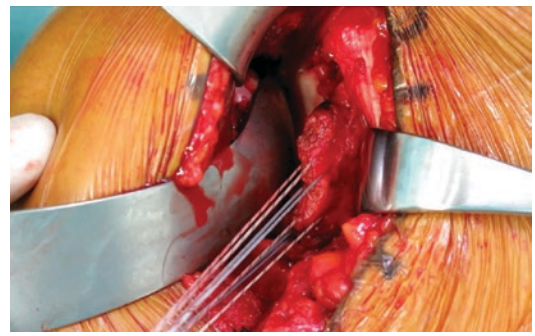


Fig. 25.7 Preparing reinforcement of the subscapularis tendon. Holding threads are placed in a modified Mason-Allen suture technique

Preparation of the Glenohumeral Joint Capsule

First, an inferior humeral capsulotomy is performed. The humeral capsule attachment must be completely cut at the anatomical neck, in a semicircular manner, from antero-superior to postero-inferior. Here also, attention must be paid to the safety limits of the axillary nerve.

Next, a retractor is inserted into the joint space, and the space must be opened until the ventral joint capsule and the subscapularis muscle can be visualized. In cases of subscapularis shortening, a tendon lengthening procedure must be performed, with a 270° release, according to Matsen. Next, a juxta-glenoidal capsulotomy is performed, with release of the subscapularis muscle. Further preparation of the subscapularis muscle up to the coracoid process, keeping the safety limits of the nerval structures in mind.

Preparation of the Humeral Head

A gentle dislocation of the humeral head is necessary. During this procedure, the arm is adducted and externally rotated (Fig. 25.8). A retractor is inserted to visualize the humeral

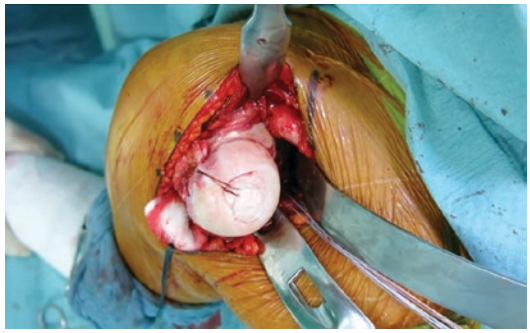


Fig. 25.8 Cautious dislocation of the humeral head, The upper arm is adducted and externally rotated, with the aid of a side table

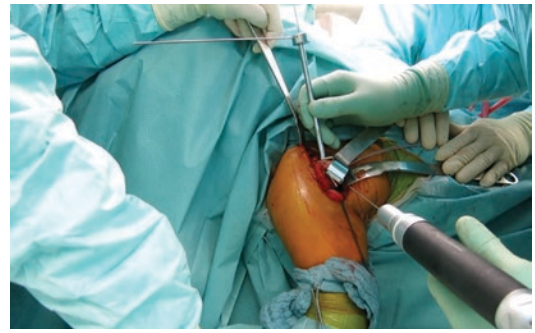


Fig. 25.10 The targeting instrument is fixed, and two K-wires are inserted into the anatomic neck

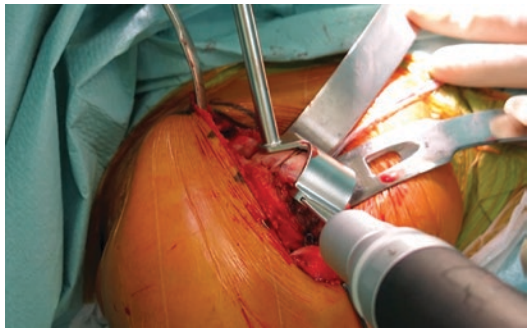


Fig. 25.9 The target instrument is placed to guide resection of the humeral head. The original anatomical neck of the humerus serves for orientation

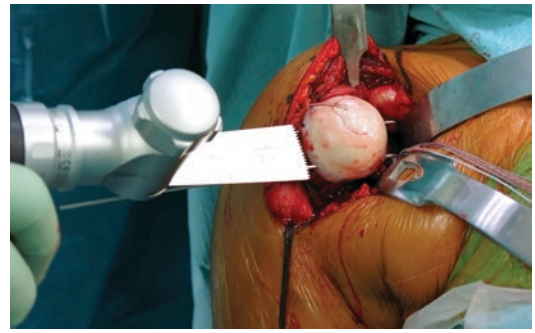


Fig. 25.11 The osteotomy is performed across the anatomical neck with an oscillating saw. The K-wires serve to guide the saw angle

joint surface, with osteophytes. Using a chisel, the antero-inferior and postero-inferior osteophytes along the anatomical neck are carefully removed. This allows visualization of the anatomical neck.

Humeral Head Resection

The target instrument is placed to guide resection of the humeral head (Fig. 25.9). The metaphyseal axis is marked. The retrotorsion is oriented along the anatomical neck. Under pre-drilling of two K-wires, the target instrument is attached in the area of the anatomical neck (Fig. 25.10). Then, the drilling jig is removed, and an osteotomy at the anatomic neck is performed with an oscillating saw. The saw orientation is guided by the K-wires (Fig. 25.11).

The resected humerus head cap is measured to determine the AP diameter and resection height (Fig. 25.12). The size of the baseplate (trunion) is determined with a template, placed directly on the resected anatomical neck. This should sit on the circular face of the resected humerus, flush with the cortical bone (Fig. 25.13).

A crown cutter is placed inside the drilling jig to prepare the thread for receiving the hollow screw (Fig. 25.14). To determine the length of the hollow screw, an insertion device is placed in the drilling jig, and a laser-marked drill wire is used as a depth gauge for drilling to the lateral cortex (Fig. 25.15). Caution: The opposite cortex should not be pierced. If the measured length lies between two laser markings, the shorter screw length should be selected. Finally, the drilling jig and insertion device are removed. A resection

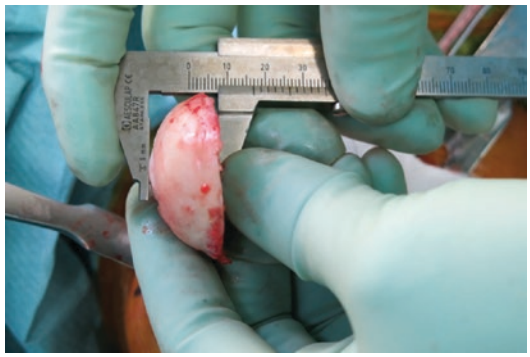


Fig. 25.12 The resected humerus head cap is measured to determine its AP diameter and the height of resection

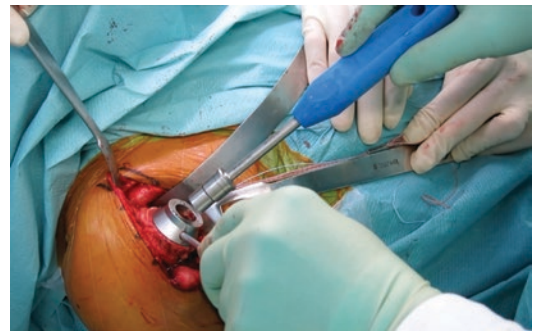


Fig. 25.14 Using the crown cutter, the thread is prepared to receive the hollow screw

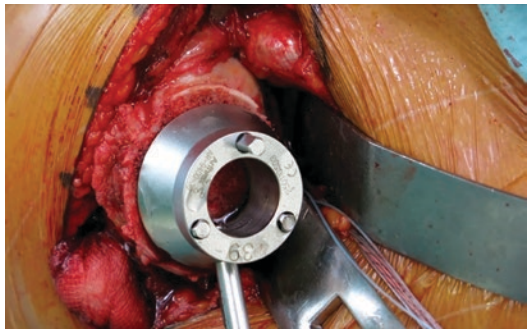


Fig. 25.13 The size of the trunnion (baseplate) is determined directly at the resected anatomical neck with a template

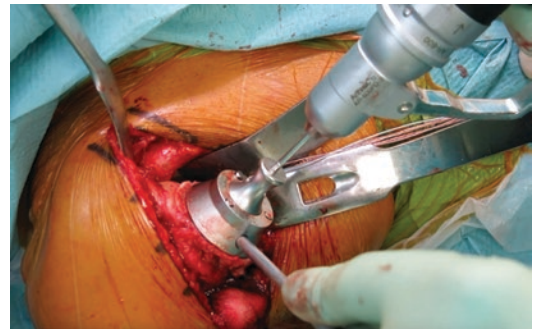


Fig. 25.15 Using the centering device and a graduated cage screw sizer, the length of the screw hole is determined by drilling the cage screw sizer until it reaches the lateral cortex

protection is placed during preparation of the glenoid.

Implantation of the Humeral Component (Eclipse, Arthrex)

The humerus is re-exposed, and the resection protection is removed. When necessary, the resection can be filled with cancellous bone and compacting it. The cancellous bone may be acquired from the resected humeral head. With the centering device in place, the baseplate is placed according to the predetermined location (Fig. 25.16). The impactor is placed over the centering device, and the baseplate is fixed by stiking the impactor to achieve a press fit (Fig. 25.17). Next, the centering device is removed, and the hollow screw, of

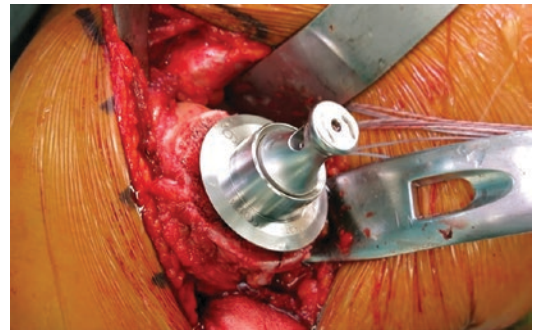


Fig. 25.16 The trunion (baseplate) is inserted over the centering device, in the predetermined location

the predetermined length, is inserted through the conus of the impactor (Fig. 25.18). The baseplate is pressed firmly against the resected bone to achieve adequate compression during screw fixation and to ensure primary stability. Next, a trial

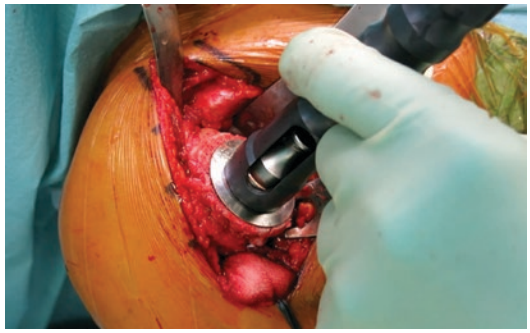


Fig. 25.17 The impactor is placed over the trunion (baseplate), and the impactor is struck to achieve a press fit

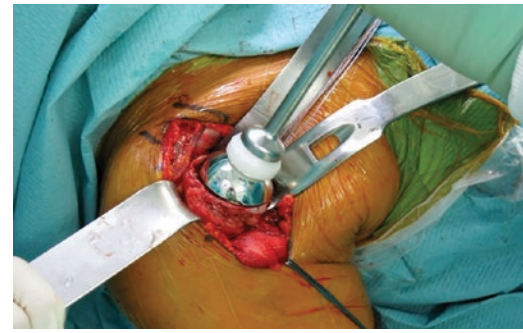


Fig. 25.20 The definitive humeral head prosthesis is struck with an impactor to achieve a press fit

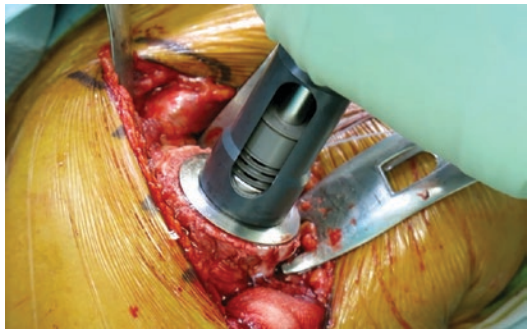


Fig. 25.18 The centering device is removed, and the hollow screw is inserted into to impactor, and screwed into the bone. In this case, the trunion (baseplate) is pressed firmly against the resected face of the proximal humerus

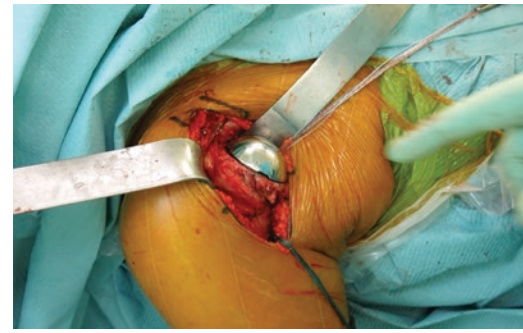


Fig. 25.21 After final implantation, the prosthesis is repositioned to observe "joint play"

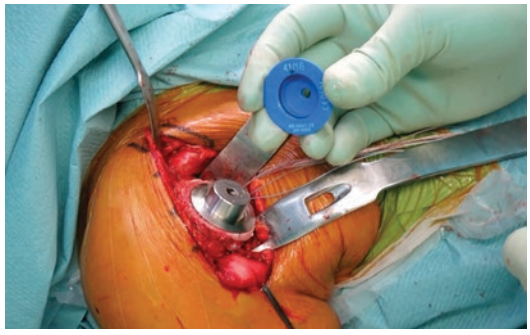


Fig. 25.19 Fitting a trial head for trial positioning

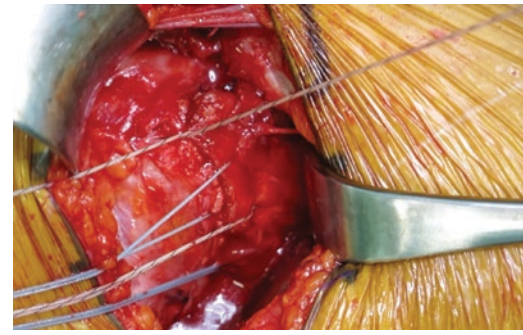


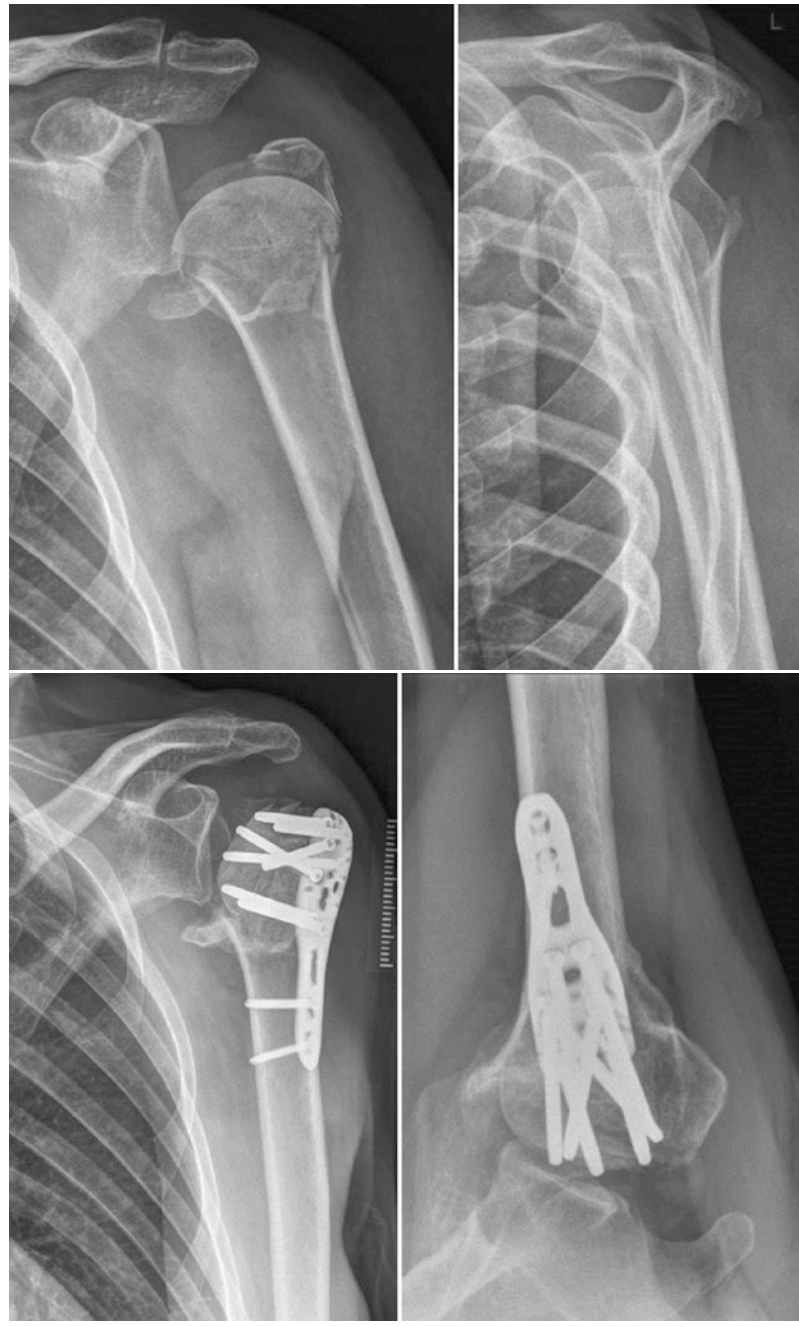
Fig. 25.22 Reattachment of the previously reinforced subscapularis tendon. A tension-free suture is recommended for the rotator cuff interval

positioning is performed with a trial head cap to confirm the correct size of the humeral head cap (Fig. 25.19). Finally, the prosthetic head cap is implanted. Therefore the head cap is chipped (Figs. 25.20 and 25.21).

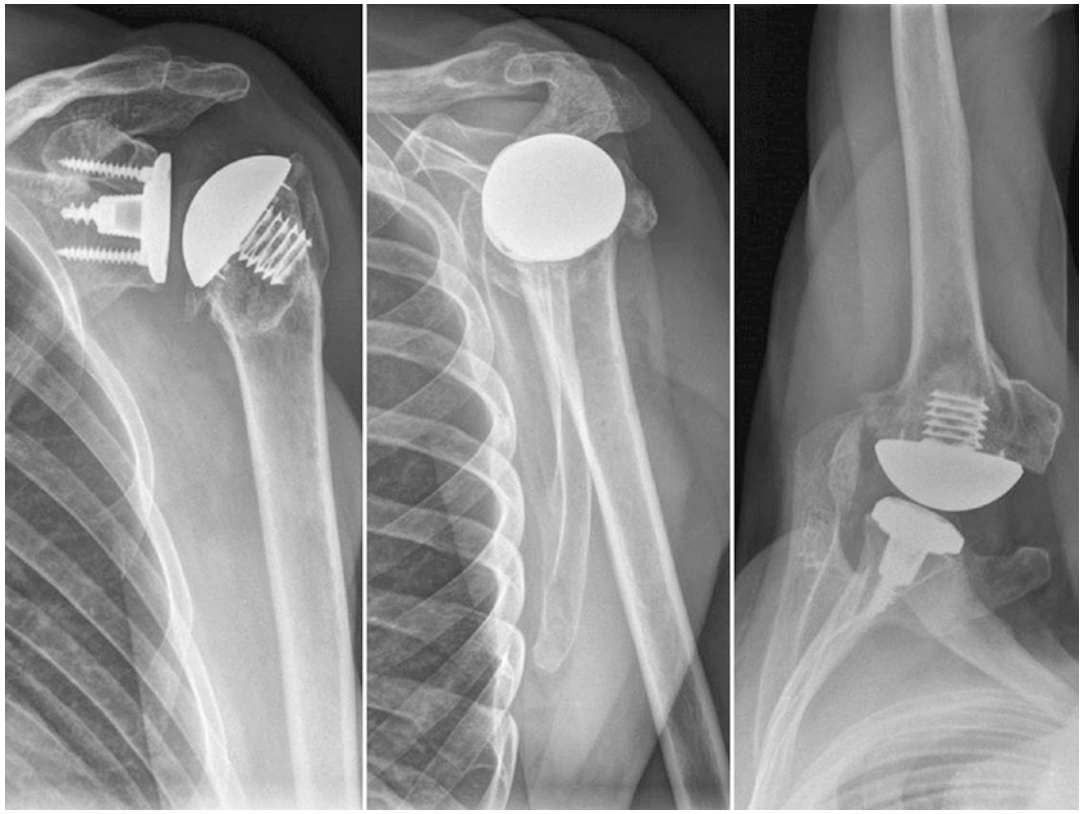
Next, the subscapularis tendon is reattached according to the Mason-Allen suture technique, with the stitches prepared prior to implantation (Fig. 25.22). A tension-free suture is advised for the rotator cuff interval. An

appropriate wound closure is performed, and a drain is inserted.

Figures 25.23, 25.24 and 25.25 show the 2-year follow-up after implantation of a stemless humeral head prosthesis in combination with a metal-back socket. The prosthesis was implanted to repair an avascular humeral head necrosis with deformity of the tubercles. These disorders occurred after a fixed-angle plate osteosynthesis was applied to repair a humeral



Figs. 25.23, 25.24, 25.25 Two-year follow-up after a stemless humeral head prosthesis was implanted, in combination with a metal-back socket. The prosthesis was implanted to repair an avascular humeral head necrosis with deformity of the tubercles. These disorders occurred after a fixed-angle plate osteosynthesis had been performed, in an attempt to repair a humeral head 4-segment-fracture



Figs. 25.23, 25.24, 25.25 (continued)

head 4-segment-fracture (Figs. 25.23, 25.24 and 25.25).

Postoperative Management

The major goal of therapy is to achieve a centralized humeral head. For the best possible integration into everyday life, the prosthesis should allow pain-free mobility, coordination, and the ability to exert sufficient and adequate force levels.

Phase 1 (1—3 Postoperative Weeks)

The arm is initially placed in a shoulder brace. The brace is maintained day and night, until the end of the third postoperative week. During the day a short-term positioning on a pillow is possible. The patient is given instructions on isometric exercises for the hand and elbow.

The shoulder is passively mobilized at the scapula level, in a pain-free manner. Mobilization is stopped gently, with a maximal flexion of 90°, abduction of 60°, internal rotation of 45°, and external rotation of 10°.

The adjacent joints are mobilized with instructions to perform gentle isometric centering exercises (joint-near only), under consideration of the scapula level. The scapula is mobilized gently, with assistance. Gentle detoning measures are performed in the areas of the shoulder and neck, with bilateral, assisted flexion, applied in the supine position. The patient is instructed in performing controlled passive pendulum exercises, with posture correction under scapula control. The patient

is trained to complete activities of daily life, including getting up, dressing, washing, self-reliance, and gently applying the shoulder brace.

Phase 2 (4—6 Postoperative Weeks)

After three weeks, the patient is advised to undergo follow-up inpatient rehabilitation for a period of 3 weeks.

Focus: mobilization and coordination training

Patients undergo passive mobilization in all planes of motion, painlessly. Mobilization should stop gently, at a maximum flexion of 90°, abduction of 70°, internal rotation of 70°, and external rotation of 20°. The patient should slowly transition to assisted mobilization. Exercises should be performed to strengthen the scapula-fixators (serratus anterior m. and trapezius m.). Light, painless, isometric measures should be applied to the rotator cuff with a small lever. Soft tissue techniques should be applied. A home plan or instructions for independent mobilization should be worked out.

After week 4, the patient should perform active-assisted mobilization.

Goal: 6 weeks post-operatively: painless crest grip and apron grip until the trochanter major.

Phase 3 (7—12 Postoperative Weeks)

Focus: Active mobilization, coordination training, and strengthening

Patients should perform terminal, passive, and active range of motion exercises. With respect to the pain threshold range of motion should be increased. To achieve glenohumeral centering and stabilization, patients should perform isometric and dynamic activity at the rotator cuff. The glenohumeral rhythm should improve at all joint positions. Active counterforce should be applied between the scapula and humerus for flexion, abduction, external rotation, and internal rotation.

Coordination and stabilization exercises for the scapula should be performed (in particular, they should receive training in recruiting the M. serratus anterior and M. lower trapezius). Patients should focus on posture correction.

The home plan should be expanded, and the arms should be integrated into daily life.

After the 9th week, patients should increase dynamic training of the rotator cuff, with both concentric and eccentric exercises at the scapula level. For example, they could employ a Thera band (yellow-red) and light weights (maximum 1 kg).

Patients should focus on improving coordination quality. They should perform complex activation of the shoulder muscles in closed chain movements. Later, they can perform the overhead position (wiping exercise), light lifting exercises, and resume professional activities that require low shoulder strain; typically, it is possible to drive.

Goal at 12 weeks post-op: Apron and crest grip.

Phase 4 (After the 12th Week)

Focus: strengthening and integration into everyday life

Patients should intensify muscular strengthening with closed-system devices. They should perform stabilized closed chain movements with higher intensity. Dynamic stabilization exercises should be performed with increasing loads, based on core stability. They should perform specific, progressive resistance exercises for the rotator cuff (particularly eccentric) and the other shoulder muscles. They should perform reactive exercises, with low intensity, below the shoulder level (supporting exercises, cable, Theraband, catching and throwing exercises). They should receive training in functional activities with increased loads. They can resume professional activities with increased loads.

Phase 5 (After the 21st Week)

Focus: resumption of sports and other active shoulder burdens

Patients should increase the intensity of the previous exercises, and perform power training, when appropriate. They should perform reactive exercises with higher intensity, and gradually increase movements to above shoulder height. They should resume professional activities with intense loads on the shoulders. They can perform independent athletic training, at a slowly increasing intensity, with occasional supervision from a therapist. Even in the late stages of rehabilitation, exercise can lead to overload responses; therefore, an accurate, symptom-based load control remains necessary in everyday life, work, and sports.

Results

The stemless arthroplasty of the shoulder joint is a relatively new concept. The currently available literature has reported 929 cases that employed stemless prostheses from different manufacturers. All authors described a significant improvement, and no cases reported loosening that required revision of the shaft. However, it must be noted that, currently, only two studies have reported results with follow-ups of more than 3 years. Our workgroup applied the described type of humeral prosthesis, and we included follow-ups of 6 and 9 years. We observed functional and radiological outcomes comparable to those achieved with third and fourth generation stem prostheses. Furthermore, in the available literature, comparative studies did not distinguish between stem and stemless prostheses in terms of the outcome.

Complications

Complications associated with the use of stemless prostheses were reported by Huguet et al. In 5 of 63 cases, they noted lateral cortical disruption in the immediate postoperative imaging, with the TESS prosthesis (Biomet). All those cases received conservative treatment. Consolidation was noted within 2 months. However, those cases were considered part of the learning curve.

Brunner et al. reported that one of 233 cases showed an extensive resorption-margin below the baseplate and around the screw in 24-month postoperative x-ray images. That case was evaluated as aseptic loosening, and it was treated conservatively (Eclipse, Arthrex).

The 6- and 9-year results from our workgroup did not show any loosening with the described prosthesis.

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