Analysis of a retrieved Delta III total shoulder prosthesis

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A reversed Delta III total shoulder prosthesis was retrieved post-mortem, eight months after implantation. A significant notch was evident at the inferior pole of the scapular neck which extended beyond the inferior fixation screw. This bone loss was associated with a corresponding, erosive defect of the polyethylene cup. Histological examination revealed a chronic foreign-body reaction in the joint capsule. There were, however, no histological signs of loosening of the glenoid base plate and the stability of the prosthetic articulation was only slightly reduced by the eroded rim of the cup.

The Delta III total shoulder (DePuy International Ltd, Leeds, England) is a reversed, semi-constrained prosthesis, which is recommended for the treatment of painful glenohumeral arthritis associated with an irreparable rotator cuff tear. This prosthesis transposes the shapes of the scapular and humeral joint surfaces in order to medialise the centre of rotation of the joint. The aim is to increase the length of the lever arm of the deltoid muscle and to improve the stability of the implant. The glenoid component consists of a convex metallic hemisphere (glenosphere) with a diameter of 36 or 42 mm fixed on a hydroxyapatite-coated base plate (metaglene) which is anchored to the glenoid by a central plug and four diverging screws. The modular humeral component has a conical stem with a metaphyseal component which accommodates a concave polyethylene bearing-surface (epiphysis).

Good short- and mid-term results for pain relief, active elevation and patient satisfaction have been reported. There is, however, concern about the rate of complications and the durability of the fixation of this prosthesis. The presence of a bony defect or notch at the inferior part of the scapular neck is a common radiographic finding at early follow-up. Component loosening, component dissociation, instability and fatigue fractures of the acromion have also been described. It is not clear if the bone loss at the inferior scapular neck is progressive or whether it is necessarily associated with loosening of either the glenoid or humeral components due to polyethylene particulate disease. The purpose of the current report is to present the post-mortem and histological findings regarding notching, fixation and stability of a reversed Delta III total shoulder prosthesis (DePuy International Ltd) retrieved eight months after implantation.

Materials

A fresh frozen left shoulder specimen of a 91-year-old man, who died following a severe brain injury after a fall was examined post-mortem. The glenohumeral joint had been replaced by a Delta III shoulder prosthesis (DePuy International Ltd) eight months before death. The operation was performed because of a painful, pseudoparalytic shoulder with an irreparable rotator cuff tear. Pre-operative radiographs showed superior subluxation of the humeral head and mild degenerative changes with osteopenia of the glenoid (Fig. 1a). A Delta III prosthesis (humeral epiphysis size 1, lateralised humeral cup and glenosphere of 36 mm diameter) was inserted using the standard technique. Radiographs six weeks post-operatively showed a small notch at the lateral border of the scapula and a radiolucent line on the posterior aspect of the glenoid component (Fig. 1b). At the latest follow-up three and a half months post-operatively the patient was almost pain free. Both active forward elevation and abduction of the arm were to 90° but with only little abduction strength.

Results

Gross inspection. Macroscopic examination revealed an intact deltoid muscle. The supraspinatus tendon was replaced by thick scar tissue firmly adherent to the acromion and the muscle, which was atrophic. The subscapularis...
tendon was attached to the lesser tuberosity with non-resorbable sutures, and the muscle was of normal appearance. The infraspinatus tendon was thin but in continuity; the muscle was atrophic. The teres minor was normal.

**Radiographic findings.** True anteroposterior radiographs were taken under fluoroscopic control with the proximal humerus in adduction and neutral rotation and revealed a small radiolucent line of less than 1 mm between cement and bone of the humeral shaft. On the scapular side a 1 mm thick radiolucent line was evident behind the fixation plate of the glenoid component. There was also a large inferior scapular notch with erosion of the bone beyond the inferior fixation screw, corresponding to a grade 4 notching on the radiographic scoring system proposed by Valenti et al⁷ (Fig. 1c). This classification system has five grades: grade 0, no notch; grade 1, small notch; grade 2, notch with condensation; grade 3, erosion up to the inferior screw; grade 4, erosion over the inferior screw with extension under the base plate.

**Intra-articular findings.** The synovium was of a normal colour and the capsule was thick and hard, especially posteroinferiorly and superiorly. A biopsy of the capsule
was fixed in 10% buffered formalin before embedding, sectioning and staining with haematoxylin and eosin. Light microscopy showed granulomatous tissue containing multinucleate giant cells, macrophages, bone debris and polyethylene fragments (Fig. 2).

The inferior pole of the glenoid and the scapular neck were eroded, corresponding to the radiographic notch on the lateral border of the scapula. The posteroinferior part of the glenoid component was denuded of bone as was the inferior fixation screw, except at its tip. The inferior rim of the lateralis polyethylene cup was worn down to the metal epiphysis of the prosthesis (Fig. 3). The defect enclosed an arc of 120° of the circumference of the cup. Examination with low-power magnification revealed a very rough surface with deep scratches on the defect but no further damage to the articular surface. The metallic rim of the epiphysis and the inferior screw were not damaged.

After excision of all soft tissues, it was evident that the superior screw was orientated towards the supraspinatus fossa and had perforated the cortex of the scapular neck. The posterior screw had perforated the cortex close to the base of the scapular spine (Fig. 4). The anterior screw was completely covered by bone.

Range of movement. The range of movement was tested after venting the joint and releasing the soft tissues. Maximum abduction in the scapular plane was 70° with respect to the plane of the glenoid component. Abduction was limited by abutment of the greater tuberosity against the subacromial scar tissue. In neutral rotation, adduction was limited by direct contact of the abraded polyethylene cup with the inferior fixation screw. In this position the proximal humerus formed an angle of 5° of abduction with respect to the plane of the base plate. The inferior rim of the cup rubbed on the denuded screw during flexion, extension and rotational movements in adduction, explaining the erosion of the polyethylene retrieved in this specimen.

Prosthesis-bone interface. The scapula was divided in the frontal plane through the centre of the glenoid component in order to assess the quality of bony ingrowth on its hydroxyapatite coated base. The cuts were stained with toluidine blue and examined under light microscopy. Incomplete seating of the base plate with good fixation of the central peg in the glenoid bone were found (Fig. 5). There was a small layer of connective tissue superiorly and a thin layer of cartilage on the inferior part. The inferior pole of the glenoid is eroded, the corresponding part of the prosthesis is not supported by bone. Thin trabeculae adhere to the hydroxyapatite coated central peg. The fixation screws have been removed before sectioning (toluidine blue, scale in mm).

Stability of the prosthesis. The eroded polyethylene cup was removed and subjected to stability tests. A glenosphere with a diameter of 36 mm was attached to the cross head of a
Subluxation force (N) and lateral displacement x 10 (mm)

Diagram depicting the lateral displacement multiplied by ten, and the subluxation force vs the translation towards the intact (left) and the defective rim (right). The compressive load was 50 N.

universal testing machine (Instron, High Wycombe, UK), with the equator oriented in a vertical position. The cup was aligned in front of the glenosphere and fixed to a frictionless loading frame mounted on the platform of the testing machine. A load of 50 N was applied to the loading frame using a pulley and a hanging weight to press the cup onto the glenosphere. The effective depth of the cup was determined by measuring the lateral displacement of the cup as the glenosphere was translated with a speed of 50 mm per minute from the intact rim through the deepest point of the cup towards the defective rim. The dislocation force was also recorded with a frequency of 10 Hz during this manoeuvre. The depth of the cup was 8 mm with respect to the intact rim and 4.1 mm with respect to the defective rim (Fig. 6). The stability ratio, which is defined as the relationship between dislocation force and compressive load, was found to be 1.69 in the direction of the intact rim and 1.51 in the direction of the defective rim (difference 10.7%).

The value of 1.69 corresponded well to the theoretical value of 1.67, calculated using the formula published by Anglin, Wyss and Pichora for a rigid ball and socket joint with a radius of curvature of 18 mm for the sphere, a cup diameter of 30 mm and a coefficient of friction of 0.05.

Discussion

The Delta III reversed shoulder prosthesis is recommended for use in older patients with irreparable rotator cuff tears and osteoarthritis. Earlier types of reversed total shoulder prostheses were withdrawn from the market because of a high rate of aseptic loosening of the glenoid component due to high eccentric loads. In the Delta III prosthesis the centre of rotation lies in the plane between the glenoid component and glenoid bone and theoretically there should be no eccentric loads. However, medialisation of the centre of rotation brings the humeral component closer to the scapula with the risk of impingement between the polyethylene cup and the inferior scapular neck. Repetitive contact between polyethylene and bone may result in polyethylene wear, chronic inflammation, osteolysis and loosening of the glenoid implant.

An inferior notch very often develops within the first months after the operation but may not progress thereafter. In this case, mechanical impingement between epiphysseal polyethylene and the inferior screw was present but it had not led to loosening of the glenoid component. Despite the lack of bony support and poor reaming of the glenoid bone, the component was not loose. We hypothesised that stability of the glenoid component depends mainly on the central peg and the two monoaxial screws placed in the frontal plane.

Perforation of the posterior cortex by the drill or the posterior screw may damage the suprascapular nerve at the base of the scapular spine (Fig. 4). A lesion of this nerve is only harmless if the infraspinatus tendon is torn or if the muscle is degenerated. If the infraspinatus is intact preoperatively, the nerve should be protected during surgery in order to preserve external rotation of the arm.

The lesion of the rim of the cup reduced its effective depth by 49%. The stability ratio, however, was only reduced by 11% under a compressive load of 50 N. The difference between these two values can be explained by the form of the defect and the degree of constraint of the design of the prosthesis. The intact portion of the rim enclosed the glenoid component like an open ring and provided good resistance against dislocation in the direction of the defect. This seems to be confirmed in clinical practice. To our knowledge a large inferior notch and wear of the polyethylene cup have not been reported to be associated with instability of the humeral component. Therefore, the risk of impingement of the polyethylene cup on the inferior glenoid may be reduced by using, either a polyethylene cup with an asymmetrical rim or a humeral component with a smaller neck-shaft angle. Positioning the glenoid component more inferiorly on the glenoid implant.

Further biomechanical studies are necessary to verify these hypotheses.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


