Joint replacement

Recent advances in shoulder arthroplasty

H. G. Zadeh, P. T. Calvert

SUMMARY. Prosthetic shoulder arthroplasty is becoming increasingly popular. The most widely reported procedures are hemiarthroplasty and unconstrained total arthroplasty using the Neer II prosthesis, which involves insertion of a press-fit or cemented humeral component and a cemented polyethylene glenoid implant. Long-term studies show that excellent or good results are achieved in over 90% of cases, with 87% probability of implant survival at 15 years. Metal backing of cemented glenoid components has yielded disappointing results. In total shoulder arthroplasty, the use of cement on the humeral side is recommended but, in hemiarthroplasty, press-fit fixation remains acceptable.

The current indications for hemiarthroplasty are: normal glenoid surface, traumatic four part fracture dislocation of the shoulder joint, massive cuff tear arthropathy and severely eroded glenoid process. Total shoulder arthroplasty appears to achieve superior and more predictable results in rheumatoid patients. In osteoarthritis, the choice between hemi- and total shoulder arthroplasty remains controversial. In juvenile rheumatoid arthritis, both procedures appear to be equally effective.

Fully constrained/fulcrum devices have been the focus of much adverse publicity. However, they may still have a role to play in the treatment of severe cuff tear arthropathy or revision surgery for persistent prosthetic instability.

Recent years have witnessed the introduction of numerous uncemented prostheses. Early results are encouraging but long-term follow-up studies are lacking. Other recent innovations include complex modular systems, bioactive implant surfaces, variable humeral head alignment, non-conforming articular surfaces and surface arthroplasty. Their superiority over the more traditional and tested Neer II system with fully conforming articulating surfaces remains unproven. Until further evidence becomes available, the cemented Neer II prosthesis with an all polyethylene glenoid component should be considered as the gold standard.

INTRODUCTION

Prosthetic shoulder arthroplasty is becoming increasingly popular. Over 5000 shoulder arthroplasties were performed in the USA from 1990 through 1992, representing the third most common type of arthroplasty after hip and knee joint.1 The annual demand in the UK is unknown but probably rising. In parallel with other types of arthroplasty, there have been numerous innovations and advances in this field, and these will be the focus of this review. As highlighted recently, the average follow-up period of most of the reports in the literature regarding shoulder arthroplasty is only 3.5 years. There is also a distinct lack of long-term randomized prospective studies. These factors make it difficult to derive definitive conclusions in respect of many of the technical and clinical aspects of shoulder arthroplasty.
HISTORICAL REVIEW

While the French surgeon Jules Emile Pean is widely credited with carrying out the first shoulder replacement in 1893, the pioneering work of another French surgeon, Themistocles Gluck, should not be ignored. It is not clear whether Gluck personally performed a prosthetic shoulder replacement but his original ideas and implant designs inspired Pean’s future work. Most of the implants designed by Gluck were made out of ivory, but Pean felt this material was not strong enough for a shoulder prosthesis, and chose to construct his implant from platinum and rubber. This prosthesis was inserted into a man with tuberculous arthritis of the shoulder joint. The early result of this operation was encouraging but the implant had to be subsequently removed because of recurrent infection.

The next report of shoulder prosthetic arthroplasty appears to have been made by Kruger in 1951. He used a custom-made vitallium prosthesis in a patient suffering from osteonecrosis of the proximal humerus. In 1952, Richard, Judet and René reported the use of an acrylic prosthesis to replace the proximal humerus. The first series of prosthetic shoulder arthroplasty was reported by Neer in 1955. He described a press-fit cobalt chrome humeral prosthesis in the treatment of four-part fracture dislocations of the upper humerus. His principal idea was to recreate normal anatomy.

The early 1970s saw the introduction of glenoid resurfacing, the use of bone cement for implant fixation and the indications for shoulder arthroplasty were diversified to include other conditions such as rheumatoid arthritis and osteoarthritis. During this period, the original Neer prosthesis was further modified. Various fixed fulcrum total shoulder replacement prostheses were developed for treatment of more severe shoulder arthropathies in the mid 1970s and early 1980s. Despite early encouraging results, most systems have now been abandoned as a result of a high incidence of complications.

The 1980s and 1990s saw the introduction of a number of uncemented prostheses employing bioactive surfaces to achieve biological fixation. Increasing modularity is a common feature of most current implant designs. The value of more recent innovations remains unclear.

TYPES OF SHOULDER ARTHROPLASTY

There are many types of shoulder arthroplasty (Table 1). The terminology used for prosthetic total shoulder arthroplasty (TSA) is often confusing and contradictory. Most authors subdivide TSA into three groups: unconstrained, semiconstrained and fully constrained/fixed fulcrum. However, a comprehensive classification system should take into account the degree conformity and constraint of the articulating surfaces. Currently, the two most popular types of TSA are prosthetic hemiarthroplasty (HA) and unconstrained TSA.

ANATOMICAL AND BIOMECHANICAL CONSIDERATIONS

Most current TSA systems adopt Neer’s original concept of recreating normal anatomy and biomechanical environment. The recognition and application of these principles is paramount in achieving a successful arthroplasty.

Table 1 Types of shoulder arthroplasty

<table>
<thead>
<tr>
<th>Hemiarthroplasty</th>
<th>Total shoulder arthroplasty</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>Unconstrained</td>
<td>Excisional arthroplasty</td>
</tr>
<tr>
<td>Bipolar</td>
<td>Semiconstrained</td>
<td>Allograft / Alloprostheses</td>
</tr>
<tr>
<td>Surface replacement</td>
<td>Fully Constrained / Fixed Fulcrum</td>
<td>Interpositional Arthroplasty</td>
</tr>
</tbody>
</table>
Fig. 3 The three main types of total shoulder arthroplasty: (A) unconstrained; (B) semi-constrained; (C) fully constrained/ fixed fulcrum (From Cofield RH. The shoulder and prosthetic arthroplasty. In: McCollister Evarts C (ed) Surgery of the Musculoskeletal System, 2nd edn. Edinburgh: Churchill Livingstone, 1990: 1571–1591, with permission)

Fig. 4 Implant types may be further sub-classified according to articular surface conformity and constraint (From Severt R, Thomas B, Tinter M, Amstutz HC, Kabo JM. The influence of conformity and constraint on translational forces and frictional torque in total shoulder arthroplasty. Clin Orthop 1993: 292: 151–158, with permission).

Fig. 5 The angle of retroversion is highly variable, but must be taken into account during surgery to avoid postoperative instability (From Neer CS. Glenohumeral arthroplasty. In: Neer CS (ed) Shoulder Reconstruction. Philadelphia: WB Saunders, 1990: 143–271, with permission).

Glenohumeral geometry is closely approximated by hemispheres with the radius of curvature of the glenoid larger than the humeral head by less than 0.1 mm. The radius of curvature of the humeral head is 25–28 mm in males and 22–25 mm in females. The humeral head is inclined relative to the humeral shaft by 130–150°. The angle of retroversion is highly variable, ranging from 10° to 55° (Fig. 5). In a recent cadaveric study by Tillett and co-workers, a useful guide for accurate reproduction of humeral head retroversion during TSA was to place the lateral fin of the humeral component 9 mm postero-lateral to the bicipital groove (Fig. 6). The centre of rotation of the humeral head is also displaced by 6 mm medially and 3–5 mm posteriorly relative to the axis of the humeral shaft. Most of the current shoulder replacement systems do not account for the posterior offset (Fig. 7).

Fig. 6 The relationship between the central axis of the humeral head (angle of retroversion) and the bicipital groove (From Tillett E, Smith M, Fulcher M, Shanklin J. Anatomic determination of humeral head retroversion: the relationship of the central axis of the humeral head to the bicipital groove. J Shoulder Elbow Surg 1993; 2: 255–256, with permission).

Fig. 7 (A) Most of the current shoulder replacement systems do not account for the posterior offset of the humeral head. (B) Asymmetrical humeral head components are occasionally required to achieve an anatomical restoration of the articular surfaces (Reproduced courtesy of Biomet Ltd, UK).
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Fig. 8 The 'rocking horse glenoid'. Humeral head translation and eccentric glenoid loading is present in normal shoulders, but the effect becomes more marked in shoulder instability and rotator cuff dysfunction (After Harryman DT, Sidles JA, Harris SL, Lippitt SB, Matsen FA. The effect of articular conformity and the size of the humeral head component on laxity and motion after glenohumeral arthroplasty. J Bone Joint Surg 1995; 77-A: 555–563, with permission).

During shoulder abduction to 90°, the joint reaction force within the glenohumeral joint is 0.89 x body weight. The shear force generated across the glenoid at 60° of abduction equals 0.42 x body weight. Shoulder abduction also results in translation of the humeral head on the glenoid surface, this being a maximum of 1.5 mm for every 30° of abduction in normal individuals. In pathological shoulders, especially in the presence of rotator cuff deficiency, humeral head translation exceeds this value. The eccentric loading of the glenoid, which is caused by the translation of the humeral head during shoulder abduction, is referred to as the 'rocking horse glenoid' (Fig. 8). This phenomenon, and the inherent weakness of glenoid fixation due to the shape and the quality of the bone, make glenoid fixation the weakest link in TSA.

OPERATIVE PRINCIPLES

In prosthetic TSA, the extended deltopectoral approach is favoured by most surgeons. However, superolateral and posterior approaches have also been described. The superolateral approach gives good access to the glenoid and is useful in traumatic cases as the fixation of the fractured tuberosities becomes easier, but care needs to be taken when exposing the humeral shaft to avoid circumflex nerve injury. The posterior approach may rarely be required in cases with locked posterior dislocation of the shoulder or certain implant types.

Success in TSA is dependent on a number of factors. These include correct patient selection, meticulous surgical technique and intensive postoperative rehabilitation. The surgical technique must ensure accurate alignment of the implants, secure fixation of the components, accurate reconstruction and tensioning of the surrounding soft tissue, particularly the rotator cuff (Fig. 9). Procedures not adhering to these principles will yield poor results.

Selection of the correct humeral head size is crucial. Larger head sizes improve stability and soft tissue tension, but reduce the range of movement and make rotator cuff repair more difficult. The humeral head must extend slightly above the level of the tuberosities to avoid impingement.

Shoulder joint arthropathy frequently results in soft tissue contractures, notably in the anterior structures. This is certainly the case if the arthropathy is secondary to previous overzealous repair of anterior glenohumeral instability. Soft tissue balancing is essential to avoid postoperative instability and asymmetrical glenoid wear. Restoring external rotation is necessary to achieve adequate abduction.

In traumatic cases, the main problems are achieving the correct angle of retroversion, humeral head
Fig. 10  Isoelastic humeral prosthesis (Reproduced courtesy of Mathys Ltd, Switzerland).

Fig. 11  The Bi-Modular® humeral prosthesis consists of a porous coated titanium stem for uncemented fixation, with a cobalt chrome modular head to improve wear characteristics (Reproduced courtesy of Biomet Ltd, UK).

Fig. 12  Metal-backed and all polyethylene Neer II glenoid components (Reproduced courtesy of Biomet Ltd, UK).

height and reduction of displaced tuberosities. A retroversion angle of 30–40° is selected by most surgeons. Humeral head height could be best judged by inserting a trial prosthesis and applying traction on the arm. Normally, the humeral head should not displace inferiorly more than 50% of the length of the glenoid fossa. Displacement beyond this means that the prosthesis is too low. Lack of inferior displacement and subacromial impingement suggests the prosthesis is seated too high. The fractured tuberosities must be reduced below the level of the humeral head to avoid impingement and abductor weakness. The long head of biceps tendon is a useful guide to the relative position of the two tuberosities. Strong suture material rather than wires is preferred to fix the tuberosities as wires tend to cut out. The humeral component is generally cemented to avoid subsidence. Bone grafts may also be used.

BIOMATERIALS

Humeral components

On the humeral side, the most widely used biomaterials are cobalt chrome, titanium and stainless steel. Other more unusual biomaterials are polyethylene in reversed ball and socket fixed fulcrum prostheses, polyacetal resin (isoelastic prostheses) (Fig. 10), and allografts. Hydroxyapatite coating is also added to certain types of implants to improve osseointegration. Due to its high wear resistance, cobalt chrome is the biomaterial of choice for the manufacture of modular articulating humeral heads (Fig. 11). Titanium should be avoided for this purpose as it has poor wear characteristics.

Glenoid components

On the glenoid side, polyethylene is the biomaterial most widely used. A new variant of polyethylene, ‘Hylamer®’ (Depuy Inc., Warsaw, Indiana, USA), is claimed to have superior mechanical properties, and has recently been promoted. However, an improved clinical outcome has not yet been substantiated in long-term studies.

The original glenoid components were made out of polyethylene. Metal backing was introduced later (Fig. 12). In the cemented type, the metal backing was added to enhance the fatigue strength of the glenoid component. In the uncemented variety the purpose of the metal backing was to allow biological fixation. Some manufacturers have also added hydroxyapatite coating to further enhance osseointegration (Bayley JIL 1997, personal communication). All metallic glenoid components are generally only used in fixed-fulcrum prostheses. Polymethylmethacrylate remains the bone cement of choice for fixation of both the humeral or glenoid components. Although used infrequently, osteochondral allografts are used in special situations such as tumour surgery or reconstruction of large humeral head defects as occur in chronically locked posterior shoulder dislocations. Interpositional arthroplasty with silastic implants, polyethylene, (Bayley JIL 1997, personal communication), joint capsule, fascia lata and lyophilized dura have been described.

IMPLANT FIXATION

Humeral component fixation

Regardless of the mode of humeral component fixation, aseptic loosening remains remarkably uncommon in this interface. The original Neer humeral
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The Randelli® shoulder replacement system offers a variety of stem designs including a threaded variety for uncemented fixation (Reproduced courtesy of Lima-Lto Medical Systems, Italy).

Glenoid component fixation

As mentioned previously, glenoid fixation remains the weakest link in TSA. Overall, the revision rate for the glenoid component is 3.2% compared with 1.8% for the humeral component. Most glenoid components are fixed with bone cement and may be either all polyethylene or metal backed, although the former is more commonly used. Glenoid lucent lines and aseptic loosening remains a major concern regardless of type of fixation. The incidence of lucent lines for the cemented implants ranges from 22 to 100% in various studies. It is now recognized that the majority of glenoid lucent lines are present from the immediate postoperative period and indicate flaws in the cementation techniques. Although most glenoid components with lucent lines are clinically stable and do not progress, every effort must be made to avoid their occurrence. Advanced cementation techniques, including the use of pulse lavage, cement pressurization and drying of bone surfaces prior to cement insertion are recommended.

Cemented metal-backed glenoid components have certainly not stood up to expectations. Although potentially offering superior mechanical properties, their use has been associated with higher rates of revision. The best result to date achieved with a cemented metal-backed glenoid component has been using a custom design implant. Due to its custom-fit and the use of compression screws during implantation, the authors claim that cement pressurization can be achieved at the cement-glenoid interface. Overall, the value of metal-backed glenoid components over the original all polyethylene variety, remains unclear.

Uncemented metal-backed glenoid components were developed to counteract some of the problems...
Fig. 15 The cement mantle on the glenoid side must remain contained within cortical bone, otherwise cement breakage followed by glenoid component failure will be an inevitable complication (From Rodosky MW, Bigliani LU. Indications for glenoid resurfacing in shoulder arthroplasty. J Shoulder Elbow Surg 1996; 5: 231-248, with permission).

Fig. 16 The Cofield metal-backed glenoid component (Smith & Nephew Richards, USA) with a porous ingrowth surface and screws for uncemented fixation (From Cofield RH, Daly PJ. Total shoulder arthroplasty with a tissue-ingrowth glenoid component. J Shoulder Elbow Surg 1992; 1: 77-85, with permission).

Fig. 17 The Kirschner® integrated shoulder system is based on the original Neer II system. The added features include: modularity and plasma sprayed humeral and metal backed glenoid components for uncemented fixation (Reproduced courtesy of Biomet Ltd, UK).

Fig. 18 The Kessel® prosthesis (Biomet Ltd, UK). This prosthesis is composed of a polyethylene humeral component which is fixed with bone cement and an uncemented stainless steel glenoid screw.

Fig. 19 Radiographs of a shoulder arthroplasty using a Bi-Modular® humeral component with a Bayley glenoid screw (Reproduced courtesy of Biomet Ltd, UK).

Fig. 19 Radiographs of a shoulder arthroplasty using a Bi-Modular® humeral component with a Bayley glenoid screw (Reproduced courtesy of Biomet Ltd, UK).

In the Kessel glenoid component, fixation was achieved by the use of a single large screw which was inserted without cement into the glenoid medullary cavity (Fig. 18).28 This form of fixation appears to enjoy long-term durability with a low incidence of loosening or revision (Bayley JIL 1997, personal communication). This principle has been adopted by the Bayley and Bayley-Walker® (Stanmore Implants World Wide Ltd, Stanmore, Middlesex, UK) shoulder replacement systems, which are currently in use at our institution (Figs 19 & 20) (Bayley JIL 1997, personal communication). Of course, not all uncemented glenoid components are metal backed. The all-polyethylene glenoid component of the Roper-Day® system (Corin Medical Ltd, Cirencester, Gloucestershire, UK) can be fixed with or without cement.

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Fig. 20 The Bayley–Walker® total shoulder replacement system (Stanmore Implants Worldwide Ltd, UK). This is an upgraded version of the original Kessel design. The glenoid component is composed of a hydroxyapatite-coated titanium screw with a cobalt chrome articulating head and is inserted without cement. The humeral component has a titanium stem with a polyethylene-lined socket and is cemented in place.

MODULARITY

Modular systems are now becoming increasingly popular. For example, the Neer II system is available in both conventional and modular versions (Fig. 17). Most implant manufacturers nowadays provide a selection of interchangeable humeral head sizes, stem lengths and diameters in their range of shoulder replacement systems. There are a number of advantages with modular systems. The flexibility afforded makes adjustment of soft tissue tension, rotator cuff closure, implant fixation and stability easier to achieve. At times, revision surgery is also made easier by retaining a well-fixed humeral stem. There has been a trend in recent years towards more complex modular systems. For example, the Aequalis® (Forth Medical Ltd, Newbury, Berkshire, UK) (Fig. 21A), Nottingham® (Biomet Ltd, Bridgend, South Glamorgan, UK) (Fig. 21B) and Randelli® (Lima-Lto Medical Systems, Casiacco, Italy) systems allow setting of the humeral head offset in various directions. The Biangular® system (Biomet Ltd, Newbury, Berkshire, UK) allows the anteversion of the humeral component to be adjusted individually. The Delta (Grammont)® (Medinov, Roanne, France) shoulder system has options for having the ball and socket part of the prosthesis in either anatomical or reversed orientation (Fig. 13). The Eska® modular® (Eska Implants GmbH & Co., Lübeck, Germany) (Fig. 22) and RPS® shoulder systems (Lima-Lto Medical Systems, Casiacco, Italy) accommodate various lengths of upper humeral bone loss by using interchangeable lengths of metal spacers.

The disadvantages of complex modular systems are increased cost, complexity and potential for technical errors at surgery. Increased wear debris production is more likely with a greater number of implant interfaces. Furthermore, component dissociation is a well-recognized complication.

Another important factor to take into account is that, for a given head size, the amount of articulating surface area available for the humeral component is larger in a one-piece implant as compared with the equivalent modular type. This is due to the space taken by the Morse taper and the humeral component collar in the modular version. Therefore, the maximum range of movement is potentially lower in modular as compared with the equivalent one-piece type (Fig. 23). Dissociation of modular humeral heads has been further investigated by Blevins and co-workers. They proposed that the most likely cause of this complication was contamination of the Morse taper by blood. They made the observation that as little as 0.4 ml of fluid can prevent proper seating of the taper (Fig. 24). Currently, there is little evidence to suggest that more complex modular systems offer significant long-term clinical benefit.

Fig. 21 (A) The Aequalis® system; (B) The Nottingham Shoulder®. Both offer variable humeral head offset. Humeral neck shaft angle may also be altered with the former system (Reproduced courtesy of (A) Forth Medical Ltd, UK; (B) Biomet Ltd, UK).

Fig. 22 Almost any length of humeral loss could be accommodated by the Eska® modular system (Reproduced courtesy of Eska Implants GmbH & Co, Germany).
**Fig. 23** The articulating surface area is reduced in modular systems as compared with the equivalent one-piece version.

**HEMIARTROPLASTY**

The original Neer shoulder arthroplasty system was a hemiarthroplasty. In subsequent years, there has been a trend towards TSA as it was noted that certain cases did not do well following an HA alone. TSA is a technically more demanding procedure than HA and exposes the patient to additional risks of glenoid component failure or polyethylene wear debris formation. Currently, there is considerable debate regarding the choice between HA and TSA.

In the following three situations, there is a general consensus of opinion that the result of HA is superior to TSA: (1) when the glenoid articular surface is normal; (2) when the glenoid is too damaged or eroded to allow satisfactory implant fixation and in irreparable rotator cuff deficient shoulders (cuff tear arthropathy). Neer himself considers it unwise to replace the glenoid if the articular surface is healthy and strongly recommends an HA as the clinical results are excellent in this situation. In traumatic cases, the glenoid surface is usually healthy and therefore HA is advocated. Of course, when the glenoid is too damaged, it will be technically impossible to achieve stable glenoid replacement. Rodosky and co-workers found that, in revision arthroplasty for a failed glenoid component with severe glenoid erosions, the results of simple glenoid removal were equivalent to revision to a new glenoid prosthesis. TSA in the presence of irreparable massive rotator cuff tears has been shown to be associated with a high incidence of glenoid component loosening or failure. A number of authors have found HA alone a satisfactory means of arthroplasty in rotator cuff-deficient shoulders. The choice between HA and TSA remains controversial when the glenoid is pathological and the rotator cuff is intact or repairable. To date, the study by Jonsson et al is the only randomized prospective study that has addressed this issue. A number of non-randomized studies have also been reported. Their conclusions should be interpreted with caution, as they are subject to patient selection bias. The results of these studies are summarized in Table 2.

Overall, for pain relief, the medium-term results of TSA appear to be superior and more predictable than HA in rheumatoid patients. In osteoarthritis, the choice between HA and TSA remains controversial. In juvenile rheumatoid arthritis, both procedures appear to be equally effective.

Other less conventional types of HA are surface replacement, bipolar arthroplasty and isoelastic implants. Two to five year follow-up studies of these implants appear to be comparable with the Neer HA. However, in the case of surface HA, Rydholm and Sjogren reported an incidence of

**Table 2** Clinical series comparing TSA with HA

<table>
<thead>
<tr>
<th>Study</th>
<th>No. cases</th>
<th>Diagnosis</th>
<th>Mean follow-up</th>
<th>Pain relief</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jonsson et al</td>
<td>17/16</td>
<td>Mixed</td>
<td>1 yr</td>
<td>TSA&gt;HA</td>
<td>TSA&gt;HA</td>
</tr>
<tr>
<td>Gschwend &amp; Bischof</td>
<td>56/24</td>
<td>Mixed</td>
<td>3 yrs</td>
<td>TSA&gt;HA</td>
<td>TSA&gt;HA</td>
</tr>
<tr>
<td>Clayton et al</td>
<td>15/7</td>
<td>Mixed</td>
<td>4.5 yrs</td>
<td>TSA&gt;HA</td>
<td>TSA&gt;HA</td>
</tr>
<tr>
<td>Boyd et al</td>
<td>226/76</td>
<td>RA/Others</td>
<td>3.6 yrs</td>
<td>TSA&gt;HA</td>
<td>TSA&gt;HA</td>
</tr>
<tr>
<td>Petersson</td>
<td>14/7</td>
<td>RA</td>
<td>3.5 yrs</td>
<td>TSA&gt;HA</td>
<td>TSA&gt;HA</td>
</tr>
<tr>
<td>Rozing</td>
<td>31/13</td>
<td>RA</td>
<td>3.6 yrs</td>
<td>TSA&gt;HA</td>
<td>TSA&gt;HA</td>
</tr>
<tr>
<td>Levine et al</td>
<td>24/6</td>
<td>JRA</td>
<td>10.6 yrs</td>
<td>TSA=HA</td>
<td>TSA=HA</td>
</tr>
<tr>
<td>Norris &amp; Iannotti</td>
<td>176/44</td>
<td>OA</td>
<td>NA</td>
<td>TSA&gt;HA</td>
<td>TSA&gt;HA</td>
</tr>
<tr>
<td>Pollock et al</td>
<td>11/19</td>
<td>CTA</td>
<td>NA</td>
<td>TSA&gt;HA</td>
<td>TSA&lt;HA</td>
</tr>
</tbody>
</table>

Abbreviations: CTA, cuff tear arthropathy; RA, rheumatoid arthritis; OA, osteoarthritis; JRA, juvenile rheumatoid arthritis; NA, not available.

**Fig. 24** Laboratory studies have shown that retained fluid within the Morse taper can prevent proper seating of the implant and result in humeral component dissociation (From Blevins FT, Deng X, Torzilli PA, Dines D, Warren RF. Dissociation of modular humeral head components: a biomechanical and implant retrieval study. J Shoulder Elbow Surg 1997; 6: 113–124, with permission).
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UNCONSTRAINED TOTAL SHOULDER ARTHROPLASTY

Currently this appears to be the most common type of TSA. The largest experience to date is with the Neer II system (Fig. 26). Neer advocates cementing the glenoid component, which may be either all polyethylene or metal backed. On the humeral side, the prosthesis may be fixed with cement or inserted in a press-fit fashion. There are now a number of studies with a mean follow-up of nearly 10 years or over, reporting good or excellent clinical outcome in over 90% of cases. In the long-term study by Torchia, Cofield and Settergren, the probability of implant survival was estimated to be 87% at 15 years.

Recently, there has been the introduction of surface arthroplasty and a number of uncemented systems. Most series report satisfactory outcomes in early-to-medium-term follow-up, comparable with the Neer II (Biomet Ltd, Bridgend, South Glamorgan, UK) system. Long-term results remain eagerly awaited.

One of the main points of controversy in unconstrained TSA is the ideal degree of articulating surface conformity. Advocates of fully conforming designs argue that the stable fulcrum afforded by this type of design enhances the leverage and stability of the rotator cuff which has been weakened by previous arthropathy. Furthermore, in fully conforming designs, the contact stresses are more evenly spread over the articulating surfaces, hence reducing the chances of point loading and polyethylene wear. The use of stiffer polyethylene has the effect of increasing contact stresses in non-conforming designs as there will be less deformation for a given load. Fortunately, biomechanical studies show that the effect of increased stresses was smaller than the increase in material strength. It is not yet known whether the long-term clinical results of non-conforming designs are superior to fully conforming ones. However, the in-vitro studies by Friedman and Draughn suggest that contact stresses within non-conforming surfaces remains below the compressive yield strength of polyethylene, providing the curvature mismatch remains less than 6 mm.

SEMI-CONSTRAINED TOTAL SHOULDER ARTHROPLASTY

This type of TSA involves insertion of hooded glenoid components or subacromial spacers to restrict superior migration of the humeral component, and is reserved mainly for rotator cuff-deficient shoulders. Neer himself experimented with various

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The DANA total shoulder replacement system (Howmedica, USA) offers a choice of conventional and hooded glenoid components (From Amstutz HC, Thomas BJ, Kabo JM, Jinnah RH, Dorey FJ. The Dana total shoulder arthroplasty. J Bone Joint Surg 1988; 70-A: 1174–1181, with permission).


The superior hood of these devices will serve to transmit large sheer forces across the tenuous glenoid component bone interface. Nowadays, this type of TSA is avoided.

FULLY CONSTRAINED / FIXED FULCRUM TOTAL SHOULDER ARTHROPLASTY

The main indications for this type of TSA were shoulder arthropathies with severe rotator cuff or soft tissue deficiency, persistent prosthetic instability or tumour surgery. Many systems offered interesting novel ideas. The Stanmore® (Biomet Ltd, Bridgend, South Glamorgan, UK), Michael Reese® (Fig. 29) and Corin® systems were simple anatomical captive ball and socket devices. Other systems, such Kessel® (Biomet Ltd, UK), (Fig. 18), Liverpool, Kolbel, Bayley–Walker (Stanmore Implants World Wide Ltd, Stanmore, Middlesex, UK)® (Fig. 20) and Delta (Grammont)® (Medinov, Roanne, France)® (Fig. 13) have a reversed anatomical ball and socket configuration. The mark III Neer® (Fig. 30) system has a reversed ball and socket articulation with a further articulation between the humeral stem and a polyethylene liner within the humeral medullary canal. The Trispherical® (Fig. 31) and Floating Socket systems have a dual ball and socket articulation between the humeral and glenoid components. The latter three systems theoretically provide a greater range of motion than the other fixed fulcrum devices. Although most systems reported encouraging short-term results, complications such as aseptic loosening, glenoid fracture and component dissociation were common modes of failure and following much adverse publicity, most systems have now been withdrawn.
Despite the problems encountered with the fixed fulcrum devices, they should not be completely dismissed. Results with other types of TSA in rotator cuff deficient or persistently unstable shoulders are not encouraging (Bayley JIL 1997, personal communication). Field et al reported poor results with HA in patients with massive rotator cuff tears and previous acromioplasty as antero-superior instability of the implant were frequently observed. Laurence found remarkably low revision rates (3 out of 48 cases) for the Corin type of fixed fulcrum device after 6.8 years of mean follow-up. Bayley, in a long-term review of the Kessel® (Biomet Ltd, Bridgend, South Glamorgan, UK) total shoulder replacement, observed that, in the original cohort of 31 patients, following 4 cases of early failure there was only one further failure after 11 years of mean follow-up (Bayley JIL 1997, personal communication). The original Kessel® prosthesis is now unavailable, but an upgraded version of it (Bayley-Walker®) is currently used at our institution in selected cases (Figs 18 & 20) (Bayley JIL 1997 personal communication). Another fixed-fulcrum device promoted in recent years is the Delta (Grammont)® (Medinov, Roanne, France) prosthesis. In this system, the ball and socket articulation may be installed in both anatomical or reversed anatomical orientation (Fig. 13). This prosthesis is mainly used for cases with massive cuff tear arthropathy and the early results appear to be encouraging.

MISCELLANEOUS TYPES OF TOTAL SHOULDER ARTHROPLASTY

Interpositional arthroplasty

Burkhead et al recently reported the use of biological resurfacing of the glenoid in conjunction with the use of a conventional metal humeral component. They described the use of autogenous fascia lata or anterior shoulder capsule to cover the glenoid surface. Although the average follow-up was less than 2 years, excellent pain relief and range of motion was achieved in most patients. Milbrink and Wriggen described using interposition arthroplasty with lyophilized dura in conjunction with resection arthroplasty in rheumatoid shoulders with satisfactory early results.

Silastic interpositional arthroplasty and subacromial polyethylene spacers (Bayley JIL 1997, personal communication) have also been tried in the past but are now largely abandoned due to unacceptably high complication rates.

Osteochondral allografts

Massive osteochondral allografts are generally used in cases of bone tumour surgery or revision surgery with severe loss of host bone. The early results in this type of TSA have been good and appear superior to prosthetic replacement as better soft tissue reconstructions were achieved. However, osteochondral failure and collapse is an inevitable complication with time (Fig. 32). Many surgeons nowadays use alloprotheses or massive prosthesis to avoid this complication. Osteochondral allografts have also been used in the treatment of shoulder instability with concomitant massive humeral head defects such as in chronically locked posterior dislocation of the shoulder joint. Early results are encouraging, but degenerative disease and graft collapse remains a well-recognized long-term problem.

Resectional arthroplasty

This is nowadays considered by most surgeons as a salvage procedure and is rarely undertaken. Pain relief may be achieved in two-thirds of patients but shoulder function remains poor in most cases.

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REFERENCES


