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Glenoid Loosening in Total Shoulder Arthroplasty

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1. Introduction

Inflammatory or degenerative processes in glenohumeral joint lead to pain and restriction of movements of the shoulder. Prosthetic replacement of the glenohumeral joint has gained in popularity because of its efficacy in relieving pain. The pioneering successful prostheses for total shoulder arthroplasty (TSA) have been based on an unconstrained design, i.e. a metal spherical head component fixed to a metal intramedullary stem articulating with a high-density polyethylene socket. These components are stabilized in the adjacent bone using polymethylmethacrylate (PMMA) bone cement [1]. The most important cause for failure of the cemented prostheses is related to the glenoid component, with a 0.01-6% rate of loosening [2, 3, 4].

The long term survivorship data of the prosthesis developed by C. Neer for the cemented total shoulder arthroplasty (TSA) show 87% fifteen year survivorship rate for Neer I & II cemented shoulder prostheses [5]. This implant has become the gold standard, against which all the successive prosthetic designs are compared.

Further developments of TSA implants have been aimed at enhancing longevity by addressing the following most critical issues: (1) Improving the incorporation of the glenoid component using a more "biological" type of fixation in order to reduce the rate of mechanical loosening; (2) Designing a better glenoid component to achieve the lowest possible rate of wear. But still the main cause of TSA failure has remained the aseptic loosening of the glenoid component [6].

2. Aseptic loosening

Aseptic loosening of endoprostheses occurs as a result of immune rejection response to an implanted foreign material. This response is enhanced when particles of polyethylene (from the glenoid insert), metal (from the glenoid metal backplate and/or from humeral component) or from fixating PMMA are released due to a mechanically abnormal gliding of the prosthesis. These particles, below 10μ in size, usually in 0.5-1.0μ range [7], induce local and systemic recruitment of macrophages and osteoclasts [8], with subsequential generation of reactive pseudomembrane and local lysis of the prosthesis-bone interface [9] (Figure 1). The lysis of the fixation interface of the prosthesis causes its eventual loosening. Since in the TSA prosthesis the glenoid component is exposed to the higher stresses and usually constructed, at least partly, from polyethylene, it's loaded surface is prone to wear and its surrounding is exposed to the wear particles' seeding. For this reason the immune rejection response is concentrated mainly around the glenoid component.
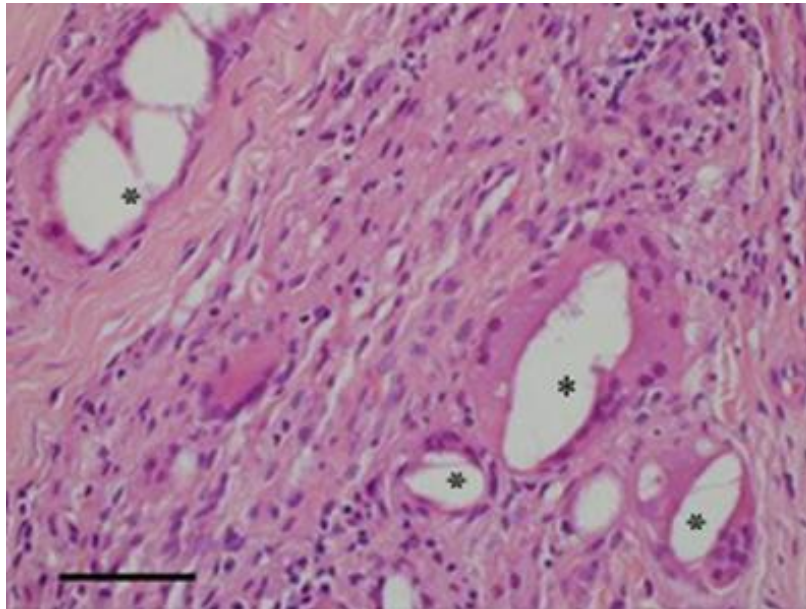

Figure 1. Micrograph (scale 200μ, HE staining) of pseodocapsule retrieved from the surface of a failed prosthesis. Characteristic foreign body reaction [10] is evident around areas of debris (*).

3. Mechanical considerations

The main cause of the wear of the glenoid component is its high loading by the eccentric forces. The excessive eccentric forces are generated when the transverse axis of the implanted glenoid is situated in a position which is incompatible with normal anatomical version of glenoid, e. g. between 2^0 of anteversion and 13^0 of retroversion [11]. This might happen when the prosthesis is implanted in an arthritic joint with advanced erosion of the posterior

glenoid. Therefore care should be taken to reshape the glenoid towards an anteverted sur‐ face, in the physiological range, prior to implantation of the glenoid component [12].

In the longitudinal axis the excessive eccentric forces are generated when the superior stabi‐ lization of the humeral head is insufficient, therefore in patients with massive tears of the rotator cuff muscles an implantation of the glenoid component is contraindicated.

The full conformity between the TSA prosthesis components may also lead to an enhanced stress on the globoid rim due to the loss of the humeral head translation, which is possible in the normal shoulder joint, and as a consequence there is a higher risk for prosthetic loos‐ ening. [13,14]. The exact degree of optimal mismatch of the glenoid and the humeral head radii is not known. Furthermore the suboptimal mismatch of the glenoid and humeral com‐ ponent curvature can lead to a considerable rate of polyethylene wear due to an uneven force distribution between the components and a point loading and a point wear of the polyethylene [14].

4. Material considerations

There are several unique issues in TSA that should be addressed in the prosthesis design. First is a limited space and a limited bone stock for the glenoid component implantation. Two main difficulties arise due to this limitation:

1. The fixation area of the glenoid component is limited, either for cemented or cementless fixation. In order to increase fixation interface the glenoid components bear keels (cen‐ tral or in offset position), pegs (straight or tapered) and/or curved backsurface of the in‐ sert. It is not clear what type of fixation design is optimal for the cemented fixation [11]. There is some clinical evidence that a central tapered peg on a metal back-plate, covered by hydroxyapatite for enhanced ossiointegration, and initially fixed by two screws, might reduce loosening rate of glenoid component in cementless press fit fixation [15] (Figure 2).

2. The polyethylene gliding surface is essential in most designs of the glenoid component. The polyethylene surface should be at least 3 mm thick, preferably 4-6 mm thick, in or‐ der to diminish its wear following interaction with metal head of the humeral compo‐ nent [16]. This requirement prevents the versatile use of the cementless designs of a glenoid component, because they require the use of a metal back-plate under the poly‐ ethylene insert, with essential limitation of the later thickness in order to prevent the joint overstuffing. For this reason there is a high preference for use of all polyethylene made glenoid components for cemented implantation. This type of design allows the use of more thick polyethylene component, with lower wear rate. But the cemented fix‐ ation of this type of glenoid component might produce thermal mediated, adjacent to the implant, bone necrosis while PMMA polymerization and therefore eventually an enhanced loosening. Currently there is no clear information which of the fixation meth‐ ods of the glenoid component is clinically advantageous.

Figure 2. An example of glenoid component for cementless implantation: a polyethylene insert mounted on a metal back-plate with tapered peg covered by hydroxyapatite. The initial press fit fixation is enhanced by two screws. This design showed improved survivorship rates.

5. Clinical signs of the glenoid component loosening

The clinical signs of the TSA prosthesis failure include an increased level of pain during fol-low-up, that appeared to be related to the implant, with restriction of external rotation to under 20° and abduction to under 60° and/or newly developed radiolucency at the glenoid component interface with the underlying bone, more than 2mm in width [17]. The recogni-tion of coexistence of both physical and radiographic signs is essential, since the isolated finding of periprosthetic radiolucency, without pain or significant restriction of movements of the shoulder, might not be of a high clinical importance (Figure 3). This consideration

should be undertaken carefully in order to avoid unnecessary revision surgery. In all the cases of suspected TSA prosthesis loosening a standard workup for possible periprosthetic infection should be done in order to avoid a devastating misdiagnosis [18] (the discussion of this topic is out of the scope of the present chapter).

Figure 3. A shoulder radiograph (anterior-posterior view) of 60 years old male patient, three years after cemented TSA. Lucency is evident in the direct proximity to the glenoid component, but the patient is pain free and has good range of movements of the operated shoulder, without any laboratory evidence of infection and is satisfied from the function of the operated shoulder.

6. Survivorship data of TSA prostheses with special emphasis on glenoid loosening

In order to get a meaningful evaluation of the implanted prostheses longevity a powerful statistical tool of survivorship analysis is used [19]. Because the relative complicity in this method implementation, especially in defining the criteria for the "failure" of the implanted prostheses, only few reports on survivorship data of TSA exist, mainly with the parameter of a revision surgery as the indication of the failed prosthesis.

From the few reported survivorship data a short-term glenoid failure, requiring implant removal, reaches the rate of around 6% for cemented designs and 3% for cementless designs. Overall the glenoid component failure is the cause of between 20% - 60% of all failed TSAs, cemented or cementless (Table 1). Survivorship of TSA is the highest in patients with rheumatoid arthritis and the lowest in patients implanted following trauma and fracture. The reason is probably a lower demand for shoulder activity in the former group and expectations for nearly normal function in the latter group of patients [20, 21, 22, 23].

Reference	Type of prosthesis	No. of Patients	Survivorship	End point criteria	Glenoid failure rate	Overall failure rate
Tarchia et al [21]	Neer I & II cemented	113 [31=OA, 36=RA 12=2ary OA]	10years= 93% 15years= 87%	Revision – severe pain, abd<90°, ext rot<20°	7/113	14/113
Brenner et al [23]	Neer II & Gristina cemented	51 [37=OA 14=RA]	11years= 75%	Severe pain, radiographic evidence of component loosening	3/51	6/51
Cofield [22]	Cofield cementless	180 [110=OA 28=RA 30=2ary OA 12=revisions]	Not calculated	Revision	5/180	12/180
Pfahler et al [20]	Aequalis cemented	705 [418=OA 107=RA 180=2ary OA]	Not calculated	Revision	9/705	43/705

OA = osteoarthritis, RA = rheumatoid arthritis

Table 1. Long term survivorship data on cemented and the outcome of a large series of a cementless total shoulder replacement prostheses.

7. Treatment of loose glenoid

Surgical revision of failed glenoid should address several crucial factors. One of the main factors for consideration is the preservation of an adequate bone stock following the component removal. This is essential if replantation is considered, otherwise the component resection will be the definite procedure. Interestingly several authors reported that a resection of the failed glenoid component without subsequential replantation of a new component might cause a considerably favorable clinical outcome [24].

The second crucial factor is the preservation of adequate version of the remained glenoid in order to avoid future eccentric loads on the replanted glenoid component.

These two factors can be achieved by bone grafting, autologous or by allograft, with additional controlled reaming of the remained glenoid surface. The surgeon's arsenal of glenoid components for replantation includes parts for either cemented or cementless fixation, and biological soft tissue allografts for biological resurfacing. Several reports support the use of soft tissue allograft material, e.g. Achilles tendon, meniscus etc., for glenoid resurfacing in revision surgery [25]. Finally the replantation of the glenoid component might be immediate, during the revision surgery, or late, following initial bone grafting of cavitations and/ or bone deficiencies in the treated glenoid. Since this type of surgery has no standard guidelines because of the different patterns of the bone loss of the treated glenoids, a precise surgical protocol does not exist for this purpose and a lot of the decision making depends on the surgeon's experience and methodical preferences.

In order to avoid an extensive tissue damage during the glenoid revision surgery an arthroscopic approach has been suggested and reported in a small number of published reports. This method was popularized by O'Driscoll SW et al [26]. The authors used an arthroscopic approach through the standard anterior and posterior portals, with addition of another extended portal for the glenoid component remnants' retrieval. This method is suitable only for all-polyethylene components, because they should be cut in situ to at least 3 parts (by diagonal cuts using an inserted through the portal osteotom) in order to retrieve pieces in sizes which are compatible with the retrieval portal diameter. This method allows also a subsequential bone grafting of the exposed glenoid undersurface by using metal impactors which are inserted through the created portals [27]. This is a technically demanding technique, especially due to the optical interference, e.g. "mirror effect", that is caused by the metal humeral component head and due to the difficulty to control bleeding from the exposed glenoid surface. But because of the appealing tissue preservation this method might gain more widespread use in the future.

8. Prospective on the future improvement of the glenoid component design

Two main issues should be considered when seeking the improvement of the TSA survivorship. First of all the currently used TSA methods have already reached a high, above 90%,

middle and long term survivorship rate, leaving a small, but important margin for improvement [21]. Secondary it is clear that this margin for improvement is related to the glenoid component design, since most of the failed TSAs are due to glenoid component failure. There is an example supporting this claim, when following a change of the design of the glenoid component a 10% increase in a short term survivorship of cementless TSA prosthesis has been achieved [15].

Clearly the main changes in the glenoid component design should address the rate of wear of this component and the efficiency of the component fixation. Therefore it is logical that the prospective for improvement of these issues will be related to finding the articulating surfaces generating less wear particles, even when subjected to excessive eccentric loading. Probably improving the biological osseous integration into the glenoid component will solve the complications of the current fixation either by the PMME or by the mechanical press fit fixation techniques. Some indications of the efficiency of biological fixation of the glenoid component have been already revealed in the devices coated by osteoconductive material, such as hydroxyapatite.

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