Glenoid or not glenoid component in primary osteoarthritis

Kany Jean

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ORIGINAL ARTICLE

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Abstract The optimal choice for the treatment of end-stage primary glenohumeral osteoarthritis remains controversial, with alternatives including total shoulder replacement (TSR) and humeral head replacement (HHR). The objective of this review is to analyze the effect of TSR compared with HHR on rates of pain relief, range of motion, patient satisfaction and revision surgery in patients with primary glenohumeral osteoarthritis. Compared with HHR, TSR provided significantly greater pain relief, gain in forward elevation, and gain in external rotation and patient satisfaction. Furthermore, TSR required significantly less revision surgery glenoid component loosening than patients undergoing HHR (progression of osteoarthritis changes with subchondral sclerosis, joint space narrowing and glenoid subsidence). A convex-back pegged glenoid component with a modern instrumented cement pressurization technique achieves risk of loosening. For 10 years, a high interest regarding new designs of uncemented metal back glenoid components has developed with promising results, because they allow glenoid bone graft in case of glenoid erosion or dysplasia and a one-stage glenoid bone reconstruction in case of revision surgery.

Keywords Glenoid component · Metal-backed · Full-cemented

Introduction

Failure of the glenoid component is the most common complication of total shoulder arthroplasty and accounts for a majority of the unsatisfactory results after this procedure. It is often manifested clinically by pain, loss of function and the presence of a clunking noise and sensation and is one of the primary reasons for revision [1–4]. Authors still debate to better understand causes of these failures: what about technical mistakes, patient anatomical conditions or glenoid design components? So far, the full-polyethylene (full-PE) glenoid component (certainly the most commonly fitted component at the present time) can be cemented (pegged or keeled), or not (ingrowth). A certain concern regarding metal back (MB) glenoid components has developed, due to problems mentioned in the literature [5], such as dismantling, rapid wear of polyethylene and foreign body reaction leading to loosening. However, glenoid loosening is often well tolerated [6] with a revision rate of only 2–5 % [7].

The purpose of this review is to analyze the clinical and biomechanical data currently available to determine the potential benefits as well as limitations of glenoid.

So, we will successively study

- Causes of glenoid component failures
- Results and survival rate of humeral head replacement (HHR)
- Results and survival rate of total shoulder replacement (TSR) with specific analysis of the glenoid component
    - TSR with full-PE implant (cemented or ingrowth)
    - TSR with MB component
- Possible strategies for minimizing the risk of glenoid component failure

K. Jean (✉)
Shoulder Department, Clinique de l'Union,
31240 Saint Jean, France
e-mail: jean.kany@clinique-union.fr

The causes of glenoid component failures

Failures can occur with the glenoid component itself, with the component seating, with the initial component fixation, with the bone and with the prosthesis loading.

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Failure of the glenoid component itself

Failures in this category are characterized by physical change in the glenoid prosthesis occurring after it is inserted. Distortion (thinning of the PE) can occur by the pattern of loaded motion of the humeral head by a combination of wear and cold flow [8]. This distortion appears as much as in conforming implants than in un-conforming ones (mismatch). Pitting and abrasion arise from the interposition of particles of bone, cement or PE. Fracture (pegs, keel, screw for MB) or delaminating of the PE can happen in case of insufficient bone support (fatigue fracture) or in case of instability with recurrent dislocation of the prosthesis. The PE/metal-backed interface is subject to wear or dismantling. Because it is difficult to chemically bond PE and metal, the metal must achieve a mechanical purchase on the PE. Dissociation results when eccentric loads exceed the strength of the fixation of the two components of the prosthesis to each other or when loading of the glenoid component deforms the polyethylene so that it is no longer captured by the metal portion of the component. However, even an MB device introduces a risk of PE–metal dissociation, this being an engineering problem likely to be solved.

Failure of component seating

The inadequate support of the body of the glenoid component by the underlying bone predisposes the component to deformation, fatigue and micro-motion with a heightened risk of loosening. Most of the time, they are technical mistakes made by the surgeon, which can, therefore, be easily solved with a very precise surgical technique.

A flat bone surface provides less component stability than a concave one [9, 10], and concentric reaming around a normalized glenoid centerline stabilizes the glenoid component. The objective is to minimize wobble (movement of the component) and warp (bending of the component) when they are challenged by off-center loads [11].

Glenoid component malposition (not fully seated on the prepared bone) is common, especially in case of glenoid dysplasia such as glenoid type B2 or C [12].

Most of the time, a full-cemented glenoid component (either with pegs or with a keel) is chosen. Although the grouting effect of cement increases the quality of contact between the component and bone by filling in small voids, the interposing cement between the back of the component and the bone can pose a risk because a thin layer of cement is brittle and highly susceptible to fatigue or fracture [13]. Addition of antibiotics in the cement increases this risk [14].

Fracture of the glenoid (anterior wall) is a common mistake, especially with keeled implants. Care must be taken to prevent this serious complication with the help of a very good exposure, a mini-invasive instrumentation component design and the use of curare. Specific MB component designs (with winglet) can help the surgeon repair and graft the glenoid (Arrow, FH Orthopedics, Fig. 1).

Last but not least, reaming may heat the glenoid bone, leading to a zone of necrosis and loss of surface support [15].

Failure of the initial component fixation

In case of insufficient primary fixation of the glenoid component, the motion may lead to a cycle of bone resorption around the implant, with a high risk of loosening.

Interposition of fluid or clot between the cement and the glenoid bone suboptimal the security of the fixation, as does avoiding cement to penetrate into the cancellous bone [16]. Lack of secure fixation reduces the ability of the component to resist to the rocking-chair effect [17]. On the other hand, age, osteoporosis, rheumatoid diseases and, more seriously, excessive reaming can compromise glenoid bone stock.

Failure of bone

Bone resorption may result from micro-motion (stress shielding), from infection (low-virulence organisms like *Propionibacter acnes* or *Staphyloccocus epidermidis*) or from bone necrosis due to the heat produced by the reaming [15].

Ultra-high molecular weight PE may induce an immunologic response to proteins with a high prevalence of antibodies to these PE-bound proteins [18].

And finally, minutes particles from PE can lead to progressive resorption of bone [19], with or without fibroblasts respond. But prevalence is less than for hip or knee.

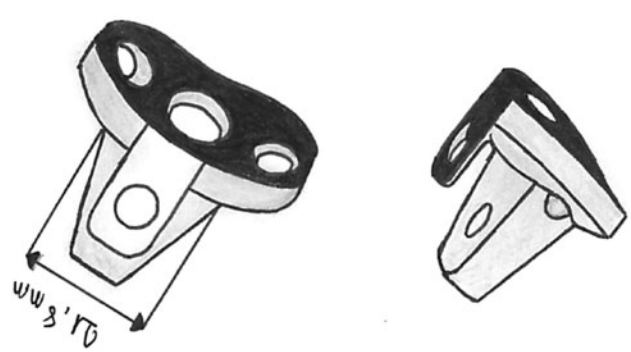

Fig. 1 Convex-based socket with hydroxyapatite resurfacing common for anatomical and reverse prosthesis (*Arrow* FH Orthopedics). The addition of an anterior plate in the design allows a sagittal screwing

Prosthetic loading

Eccentric loading challenges the integrity of PE, cement and bone.

Some translation occurs with shoulder motion. With conforming joint surfaces (no mismatch), the humeral head cannot translate on the glenoid component without rim loading [20, 21].

The «rocking-chair effect» described by Matsen [17] explains the glenoid component loosening in case of malposition causes by eccentric loading and lifting up of the opposite unloaded rim (in the coronal or the sagittal plan).

Therefore, abnormal glenoid component version, inferior or superior placement, increases rate of loosening.

Last but not least, rotator cuff deficiency or a neurologic lesion may lead to instability and therefore to a failure. Subscapularis deficiency will allow an anterior instability; supraspinatus deficiency will allow an upward migration of the humeral head as well as a suprascapular nerve lesion. Such a situation will induce the "rocking-horse" effect.

Discussion

Survival rate of hemiarthroplasties

Many surgeons choose not to implant a glenoid component because they think that it does not improve patient outcome and because of concerns about component loosening or to preserve the bone stock. To HHR, the benefits consist in decreased operative time, decreased blood loss, and less technical difficulty (no glenoid exposure and resurfacing), yet there is concern regarding the progression of glenoid arthritic changes (subchondral sclerosis and joint space narrowing) and the need for future revision surgery or conversion to TSR [22]. TSR is associated with increased operative time and blood loss, is more technically challenging and faces the risks of potential glenoid loosening and polyethylene's wear [7, 22]. Glenoid resurfacing is contraindicated if inadequate bone stock or irreparable rotator cuff tears (or both) are present, and relatively indicated for a vascular necrosis of the humeral head with normal glenoid articular cartilage. Besides, the advantages of glenoid resurfacing are not so well defined [23–25].

Radnay [26] searched computerized databases for clinical studies between 1966 and 2004 studies that concerned TSR and HHR for the treatment of primary glenohumeral osteoarthritis. He identified 23 with a total of 1952 patients and mean follow-up of 43.5 months. This analysis demonstrates that patients with shoulders undergoing glenoid resurfacing have significantly improved absolute postoperative pain scores compared with those undergoing hemiarthroplasty (85.8 vs. 77.6). Moreover, the rate of revision surgery after TSR is significantly lower, especially when all-polyethylene glenoid components are evaluated. These results suggest that the need for glenoid revision after TSR is less common than the need for glenoid resurfacing after an unsuccessful HHR. However, the results must be carefully considered because the mean follow-up is 43.4 months.

Survival rate of full-PE (cemented) glenoid implant

First full-PE cemented glenoid component was performed by Neer in 1970 [27]. The results are now well known [4, 28]. Early radiolucencies were initially described by Neer in 1982 [29], and despite modern prosthetic designs and surgical techniques, they are still common [3, 30–32]. Although the clinical results are stable with a survival rate of 88 % at 15 years, 83 % at 20 years [23, 32], the frequency of glenoid radiolucencies is high [31]. The reported incidence ranges from 30 to 90 %. This variability has been attributed to differences in radiographic techniques [33], grading and reporting methods [11, 34] and has contributed to the uncertainty regarding the relationship to loosening, and probably underestimated. The relationship of glenoid loosening to early radiolucencies is still unclear [29, 32, 35–37].

Early radiolucencies at the cement–bone interface have been traditionally related to cementing technique [29] and, more recently, to thermal necrosis as well [16]. Modern instrumented cement pressurization technique achieves a low incidence of early radiolucent lines at both the bone–cement (fixation) interface and the subchondral bone–component (seating) interface [38].

Early radiolucencies at the subchondral bone–component interface are related to incomplete glenoid component seating [31], which has been shown to increase rocking forces at the component age [35]. Recent biomechanical, animal and retrospective studies have involved glenoid design in the development of glenoid lucency.

Although many surgeons will implant a keeled glenoid whether exposition is difficult or in case of deficient bone stock [39], these studies indicate that cemented pegged glenoid components appear to have better fixation, better bony ingrowth and a lower rate of radiolucencies over time when compared with keeled components [31, 39, 40]. These results have been confirmed by Gartsmann [41], whereas Throckmorton [42] could not find any statistical differences in clinical or radiographic outcomes between pegged and keeled components at intermediate-term follow-up (4 years).

Despite the fact that some authors are still debating to confirm whether or not an evolving radiolucency really represents loosening [28], glenoid problems are at the origin of 25 % of all total shoulder arthroplasty failures

[43]. However, glenoid loosening (Fig. 2) is often well tolerated [6] with a revision rate of only 2–5 % [7].

The major cause of glenoid loosening is considered to be eccentric (i.e., off-center) loading, called the "rocking-horse" phenomenon [3, 5, 24, 34, 44, 45]. Off-center loading is caused by migration of the humeral head, particularly superiorly, usually as a result of rotator cuff muscle tears [32, 34]. Inferior migration [43] and posterior and anterior wear [2, 20, 40] have also been associated with loosening. In some cases, this has resulted in a noticeable tilt of the glenoid component [3, 34, 43]. Glenoid design can play a central part in loosening, as indicated by the much higher loosening rates experienced by fully constrained designs [2]. Anglin [9] showed by a mechanical testing that roughened fixation far outperformed a smooth fixation surface, a curved backing showed almost half the distraction of a flat backing and a non-constrained prosthesis distracted less than a more constrained prosthesis.

Excessive glenoid component retroversion can result in increased glenoid component loosening. Proper placement of the glenoid component is made more difficult with increasing bone loss (glenoid type B2 and C from Walch classification 12). In cases where a correction of retroversion to being perpendicular to the plane of the scapula is not possible without severe compromise in the bone volume, the options include placing the glenoid component in more retroversion. This may result in perforation of the anterior glenoid wall with a portion of the fixation features

Fig. 2 Loosening of a full-polyethylene glenoid component

of the component. An additional alternative would be to combine reaming the anterior part of the glenoid and buildup of the bone deficient posterior part of the glenoid with bone graft or an augmentation of the glenoid component. Nevertheless, this remains a technically challenging and time-consuming procedure, and risk of loosening of the cemented full-PE glenoid implant is high by graft loosening or resorption.

The survival rate of MB implants

Since 1970 [27], full-cemented PE glenoid component has remained the « gold standard » . Nevertheless, so far the main problem of anatomical shoulder arthroplasty is still glenoid loosening, and also the main cause of failure. We still face a problem even with new generations of modular prosthesis.

The original idea of MB glenoid component dated from 1978 (Neer Mark II). With time, other MB glenoid components were manufactured and implanted: the Cofield MB, the English Mac Nab, the Roper-Day prosthesis, the Kirschner II-C, the Burkead MB and the Aequalis. Every publication [5] rejected the overall MB concept because the latter leads to more frequent complications than the full-cemented one (glenoid radiolucencies, glenoid loosening, bony resorption, PE–metal dissociations, rate of revisions).

The two main encountered challenges to design a non-cemented MB implant are as follows:

- Too much thickness lateralizes the prosthesis with a risk of stiffness and rotator cuff tear. In order to decrease the lateralization, it is necessary to ream more with a risk of weakness of the bony support.
- The polyethylene–metal interface is subject to wear or dismantling

Those outdated MB glenoid components are debatable: cemented MB (Neer Mark II), no mismatch and heavy thickness (Cofield MB), bad primary fixation (Kirschner II-C, Burkead MB) flat-backed with expanding screws (Aequalis). Authors did not hesitate to question the MB concept in general rather than the MB glenoid component design itself. Only one recent study [45] defends the idea of the MB concept.

The success of the MB glenoid component in the reverse shoulder replacement (RSR) and the development of the "versatility concept" (revision from TSR to RSR in case of acquired rotator cuff deficiency) lead us to develop a high interest in a new MB concept. A convex-based socket with hydroxyapatite resurfacing common for anatomical and reverse prosthesis has been developed and implanted since 2003 (Arrow, FH Orthopedics). The addition of an anterior plate in the design allows a sagittal screwing, very efficient when a socket reconstruction for glenoid loosening or glenoid bone loss is needed (Fig. 3). In case of revision surgery with significant glenoid bone loss, a long peg crossing the native cortical glenoid bone and acting as a keel allows a one-stage bone graft surgery (Fig. 4). From 2003 to 2011, we implanted 143 MB and 236 full-cemented pegged PE for TSR in osteoarthritis. Minimum follow-up was 24 months for 158 cases (37 metal-backed glenoid components and 121 full-cemented glenoid components). Mean age was 69 years, with 64 % females. We only had 6 metal-backed revisions for loosening, that means only 4.19 %. At the same time, we had 11 full-cemented PE revisions, which means 4.6 %.

Contrary to previous publications, rate of complications and revisions is less with our Arrow MB than with the Arrow full-cemented one. In addition, the Arrow MB allows glenoid bone graft, even in case of significant bone loss, and then a one-stage procedure for revisions. Last but not least, versatility decreases operative time, blood loss and technical difficulty for rotator cuff deficiency after TSR.

Possible strategies for minimizing the risk of glenoid component failure

A rigorous selection of indications remains the key to success. Patients with poor-quality glenoid bone, glenoid bone deficiency or major glenoid deformity are at increased risks for glenoid component failures. Patients whose shoulders

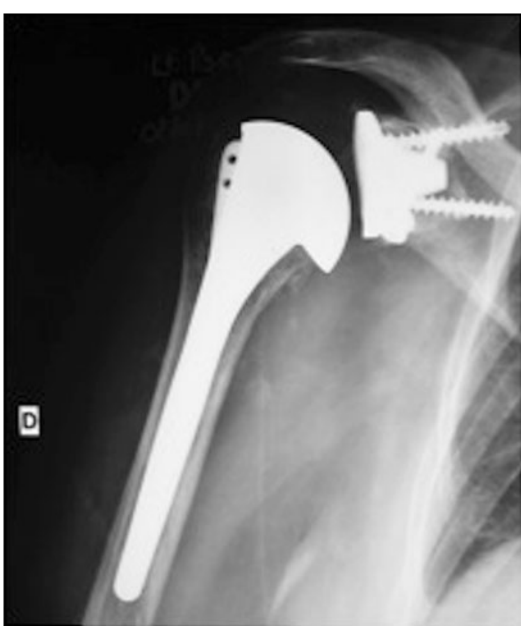

Fig. 3 The addition of an anterior plate allows a sagittal screwing for glenoid bone loss or glenoid loosening

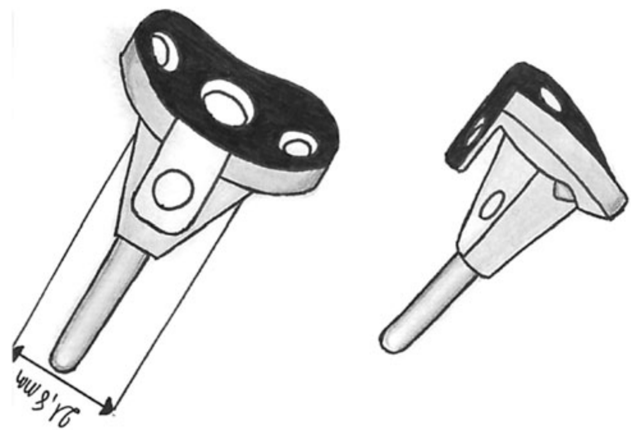

Fig. 4 Metal-backed glenoid component with addition of a long peg (*Arrow* FH Orthopedics) in case of glenoid bone loss

are prone to eccentric loading, such as those with lower-extremity weakness and those with glenohumeral instability or rotator cuff deficiency, have higher rates of glenoid component failures.

Convex-backed, full-cemented and pegged PE component seems to become the “gold standard” [5, 10, 28, 37, 41, 46–49]. No clear evidence supports the outperformance of a cross-linked PE. The humeral head radius of curvature has to be smaller than the glenoid component one, respecting a 3 mm minimal mismatch and allowing some translation in the motion like in normal anatomy and physiological conditions [13, 21, 47, 48, 50].

It is desirable to restore normal glenoid version by reaming along a normalized glenoid centerline, avoiding eccentric loads onto the glenoid component in both the anterior–posterior and the superior–inferior directions. In case of glenoid dysplasia with posterior bone erosion, a new generation MB glenoid component optimizes the primary fixation (press-fit) and therefore allows a cancellous bone graft. Care must be taken when reaming in order to minimize the risk of thermal damage to the bone.

Seating has to be optimized by careful preparation of the glenoid bone looking for a precise fit between the back of the glenoid component and the bone surface, minimizing the amount of cement to reduce heat damage to the bone. In addition, placing the glenoid component directly on a carefully prepared congruently reamed joint surface avoids the need to insert cement between the back of the glenoid component and the glenoid bone surface, eliminating the risk of fatigue fracture of this thin brittle layer of cement. Seating a full-cemented glenoid component needs a modern instrumented cement pressurization technique in order to remove fluid and clot from the fixation holes and therefore to minimize the development of an immediate postoperative lucent line that indicates suboptimal fixation.

Conclusion

For the treatment of primary glenohumeral osteoarthritis, TSR significantly outperforms HHR with regard to pain relief, range of motion and patient satisfaction. Furthermore, despite the increased technical difficulty and potential problems associated with the placement of a glenoid component, TSR maintains low rates of glenoid loosening and significantly lower rates of revision surgery, especially when current all-polyethylene glenoid components are used. These results suggest that the need for glenoid revision after TSR is less common than the need for glenoid resurfacing after an unsuccessful HHR. TSR appears to be the adequate surgical treatment for patients with end-stage primary glenohumeral osteoarthritis. No references nowadays seem likely to stop the study of the MB glenoid concept. MB glenoid components allow and help the surgeon for glenoid reconstruction and bone graft in case of glenoid erosion (glenoid type B2 and C) and glenoid bone loss (one-stage revision surgery). What is more, according to the authors' experience, the absence of loosening, stress shielding and, for the time being, of signs of early polyethylene wear has for 10 years encouraged carrying out the experiment.

Conflict of interest The author is "Arrow shoulder prosthesis" designer.

References

1. Matsen FA 3rd, Bicknell RT, Lippitt SB (2007) Shoulder arthroplasty: the socket perspective. J Shoulder Elbow Surg 16(5 Suppl):S241–S247
2. Wirth MA, Rockwood CA Jr (1996) Complications of total shoulder-replacement arthroplasty. J Bone Joint Surg Am 78:603–616
3. Barrett WP, Franklin JL, Jackins SE, Wyss CR, Matsen FA 3rd (1987) Total shoulder arthroplasty. J Bone Joint Surg Am 69:865–872
4. Bohsali KI, Wirth MA, Rockwood CA Jr (2006) Complications of total shoulder arthroplasty. J Bone Joint Surg Am 88:2279–2292
5. Boileau P, Avidor C, Krishnan SG, Walch G, Kempf JF, Molé D (2002) Cemented polyethylene versus uncemented metal-backed glenoid components in total shoulder arthroplasty: a prospective, double-blind, randomized study. J Shoulder Elbow Surg 11:351–359
6. Neer CS (1990) Glenohumeral arthroplasty. In: Neer R (ed) Shoulder reconstruction. Saunders, Philadelphia, pp 220–260
7. Rodosky MW, Bigliani LU (2002) Indications for glenoid resurfacing in shoulder arthroplasty. J Shoulder Elbow Surg 5:231–248
8. Braman JP, Falicov A, Boorman R, Matsen FA (2006) 3rd Alterations in surface geometry in retrieved polyethylene glenoid component. J Orthop Res 24:1249–1260
9. Anglin C, Wyss UP, Pichora DR (2000) Mechanical testing of shoulder prostheses and recommendations for glenoid design. J Shoulder Elbow Surg 9:323–331
10. Szabo I, Buscayret F, Edwards TB, Nemoz C, Boileau P, Walch G (2005) Radiographic comparison of flat-back and convex-back glenoid components in total shoulder arthroplasty. J Shoulder Elbow Surg 14:63
11. Collins D, Tencer A, Sidles J, Matsen F III (1992) Edge displacement and deformation of glenoid components in response to eccentric loading. The effect of preparation of the glenoid bone. J Bone Joint Surg Am 74:501–507
12. Walch G, Badet R, Boulahia A, Khoury A (1999) Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 14:756–760
13. Terrier A, Büchler P, Farron A (2006) Influence of glenohumeral conformity on glenoid stresses after total shoulder arthroplasty. J Shoulder Elbow Surg 15:515–520
14. Postak PD, Greenwald AS (2006) The influence of antibiotics on the fatigue life of the acrylic bone cément. J Bone Joint Surg Am 88(Suppl 4):148–155
15. Anglin C, Wyss UP, Nyffeler RW, Gerber C (2001) Loosening performance of cemented glenoid prosthesis design pairs. Clin Biomech 16:144–150
16. Churchill RS, Boorman RS, Fehringer EV, Matsen FA III (2004) Glenoid cementing may generate sufficient heat to endanger the surrounding bone. Clin Orthop Relat Res 419:76–79
17. Matsen FA, Franklin JL, Barret WP, Jackins SE (1988) Glenoid loosening in total shoulder arthroplasty: association with rotator cuff deficiency. J Arthroplasty 3:39
18. Wooley PH, Fitzgerald RH, Song Z, Davis P, Whalen JD, Trumble S, Nasser S (1999) Proteins bound to polyethylene components in patients who have aseptic loosening after total joint arthroplasty. A preliminary report. J Bone Joint Surg Am 81:616–623
19. Maloney WJ, Smith RL, Schmalzried TP, Chiba J, Huene D, Rubash H (1995) Isolation and characterization of wear particles generated in patients who have had failure of a hip arthroplasty without cement. J Bone Joint Am 77:1301–1310
20. Harryman DT, Sidles JA, Harris SL, Lippitt SB, Matsen FA III (1995) The effect of articular conformity and size of the humeral head component on laxity and motion after glenohumeral arthroplasty. J Bone Joint Surg Am 77A:555–563
21. Walch G, Edwards TB, Boulahia A, Boileau P, Mole D, Adeleine P (2002) The influence of glenohumeral prosthetic mismatch on glenoid radiolucent lines: results of a multicenter study. J Bone Joint Surg Am 84:2186–2191
22. Hattrup SJ (2001) Current controversies in shoulder arthroplasty. Curr Opin Orthop 12:301–306
23. Sperling JW, Cofield RH, Rowland CM (1998) Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. J Bone Joint Surg Am 80:464–473
24. Rodosky MW, Weinstein DM, Pollock RG, Flatow EL, Bigliani LU, Neer CS (1995) On the rarity of glenoid component failure. J Should Elbow Surg 4(1):S13
25. Gartsman GM, Roddey TS, Hammerman SM (2000) Shoulder arthroplasty with or without resurfacing of the glenoid in patients who have osteoarthritis. J Bone Joint Surg Am 82:26–34
26. Radnay CS, Setter KJ, Chambers L, Levine WN, Bigliani LU, Ahmad CS (2007) Total shoulder replacement compared with humeral head replacement for the treatment of primary glenohumeral osteoarthritis: a systematic review. J Shoulder Elbow Surg 16:396–402
27. Neer CS (1974) Replacement arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 56:1–13
28. Cheung EV, Sperling JW, Cofield RH (2008) Revision shoulder arthroplasty for glenoid component loosening. J Shoulder Elbow Surg 17:371–375
29. Neer CS II, Watson KC, Stanton FJ (1982) Recent experiences in total shoulder arthroplasty. J Bone Joint Surg 64A:319–337

30. Bell SN, Gschwend N (1986) Clinical experience with total arthroplasty and hemiarthroplasty of the shoulder using the Neer prosthesis. Int Orthop 10:217–222
31. Lazarus MD, Jensen KL, Southworth C, Matsen FA III (2002) The radiographic evaluation of keeled and pegged glenoid component insertion. J Bone Joint Surg Am 84-A:1174–1182
32. Torchia ME, Cofield RH, Settergen CR (1997) Total shoulder arthroplasty with the Neer prosthesis: long-term results. J Shoulder Elbow Surg 6:495–505
33. Havig MT, Kumar A, Carpenter W, Seiler JG III (1997) Assessment of radiolucent lines about the glenoid. An in vitro radiographic study. J Bone Joint Surg Am 79:428–432
34. Franklin JL, Barrett WP, Jackins SE, Matsen FA III (1998) Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. J Arthroplasty 3:39–46
35. Cofield RH (1984) Total shoulder arthroplasty with the Neer prosthesis. J Bone Joint Surg Am 66:899–906
36. Godenèche A, Boileau P, Favard L et al (2002) Prosthetic replacement in the treatment of osteoarthritis of the shoulder: early results of 268 cases. J Shoulder Elbow Sur 11:11–18
37. Wallace AL, Phillips RL, MacDougal GA, Walsh WR, Sonnabend DH (1999) Resurfacing of the glenoid in total shoulder arthroplasty. A comparison, at a mean of five years, of prostheses inserted with and without cement. J Bone Joint Surg Am 81:510–518
38. Barwood S, Setter KJ, Blaine TA, Bigliani LU (2008) The incidence of early radiolucencies about a pegged glenoid component using cement pressurization. J Shoulder Elbow Surg 17:703–708
39. Lacroix D, Murphy LA, Prendergast PJ (2000) Three-dimensional finite element analysis of glenoid replacement prostheses: a comparison of keeled and pegged anchorage systems. J Biomech Eng 122:430–436
40. Wirth MA, Korvick DL, Basamania CJ et al (2001) Radiologic, mechanical, and histologic evaluation of 2 glenoid prosthesis designs in a canine model. J Shoulder Elbow Surg 10:140–148
41. Gartsman GM, Elkousy HA, Warnock KM, Edwards TB, O'Connor DP (2005) Radiographic comparison of pegged and keeled glenoid components. J Shoulder Elbow Surg 14:252–257
42. Throckmorton TW, Zarkadas PC, Sperling JW, Cofield RH (2010) Pegged versus keeled glenoid components in total shoulder arthroplasty. J Shoulder Elbow Surg 19:726–733
43. Sneppen O, Fruensgaard S, Johannsen HV, Olsen BS, Sojbjerg JO, Andersen NH (1996) Total shoulder replacement in rheumatoid arthritis: proximal migration and loosening. J Should Elbow Surg 5:47–52
44. Boileau P, Molé D, Walch G (1999) Technique of glenoid resurfacing in shoulder arthroplasty. In: Walch G, Boileau P (eds) Shoulder arthroplasty. Springer, Berlin, pp 147–161
45. Mathur K, Fourie B, Clement N, Stirrat AN (2005) The métal Backed glenoid component in total shoulder arthroplasty-minimum 5 years follow-up. J Bone Joint Surg Br 87(Suppl 2):160–161
46. Wallace AL, Walsh WR, Sonnabend DH (1999) Dissociation of the glenoid component in cementless total shoulder arthroplasty. J Shoulder Elbow Surg 8:81–84
47. Anglin C, Wyss UP, Nyffeler RW, Gerber C (2001) Loosening performance of cemented glenoid prosthesis design pairs. Clin Biomech 16:144–150
48. Anglin C, Wyss UP, Pichora DR (2000) Mechanical testing of shoulder prostheses and recommendations for glenoid design. J Shoulder Elbow Surg 9:323–331
49. Lazarus MD, Jensen KL, Southworth C, Matsen FA 3rd (2002) The radiographic evaluation of keeled and pegged glenoid component insertion. J Bone Joint Surg Am 84:1174–1182
50. Couteau B, Mansat P, Estival'ezes E, Darmana R, Mansat M, Egan J (2001) Finite element analysis of the mechanical behavior of a scapula implanted with a glenoid prosthesis. Clin Biomech 16:566–575