Review Article

Stemless Humeral Implants in Total Shoulder Arthroplasty

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Abstract

Through an iteration of various advancements, both short stem and stemless options for humeral fixation have been proposed and have shown clinical promise. The proposed benefits of a stemless humeral implant include greater bone preservation, less stress shielding, less risk of a diaphyseal stress riser, decreased surgical time, and less intraoperative blood loss. Potential downsides include the dependence on proximal bone quality for fixation, increased cost, the dependence on the strength of subscapularis fixation, and pending FDA approval for multiple implants. The purpose of this article is to review the evidence behind stemless implants including the biomechanical advantages and disadvantages, surgical technique, and clinical outcomes.

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Dr. Fehringer or an immediate family member has received IP royalties and serves as a paid consultant to Wright Medical Technology and has stock or stock options held in Genesis and Shoulder Innovations. Dr. Ponce or an immediate family member has received IP royalties from Wright Medical Technology; is a member of a speakers' bureau or has made paid presentations on behalf of and serves as a paid consultant to Tornier; and has stock or stock options held in Help Lightning. Neither of the following authors nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Brabston and Dr. Owen.

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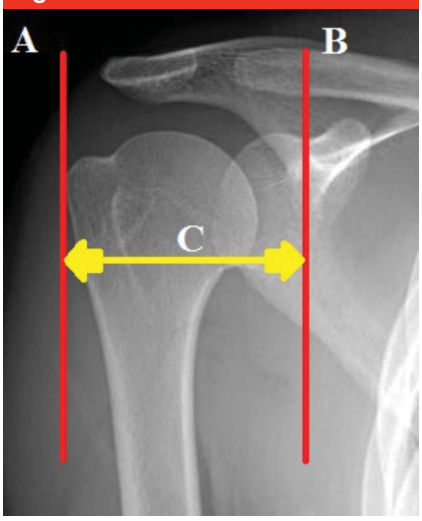
The evolution of modern shoulder arthroplasty must be recognized within the context of its historical development. Modern shoulder arthroplasty began in 1955 with Dr. Charles Neer[1]'s stemmed monoblock hemiarthroplasty for proximal humeral fractures. The implant initially had a single head size with fixed geometry, but it progressed to having two head sizes and an improved head radius of curvature to match the native anatomy. The introduction of the glenoid component in the late 1970s marked the true beginning of the modern total shoulder arthroplasty (TSA).[2] Second-generation implants were developed and were more modular with separate head and stem components to allow for improved recreation of anatomy, but they remained limited to fixed proximal geometry combined with diaphyseal fixation. Third-generation implants from the 1990s and 2000s added even more modularity to match a patient's anatomy by including various degrees of version, offset, and inclination along with shorter stems to allow for greater proximal humeral fixation. The use of a stemmed humeral component remained indispensable for nearly 50 years until 2004, when a stemless or "canal sparing" shoulder arthroplasty was introduced in Europe.[3] This stemless implant, which differs from a humeral head resurfacing, represents the latest advancement and a "fourth-generation" style of shoulder arthroplasty implant. After a decade since stemless shoulder arthroplasties were first implanted, the FDA approved their use in the United States in 2015.

Biomechanics of Stemless Humeral Implants

Despite numerous implant options, the primary goal of TSA is stable recreation of appropriate joint mechanics while minimally altering the surrounding metabolic bone environment. The aim of stemless arthroplasty is to reproduce the anatomic center of rotation (COR) while providing a potentially advantageous biologic response to the absence of a stem.

Figure 1



The distance from the greater tuberosity (**A**) to the base of the lateral coracoid (**B**) is the lateral humeral offset (**C**).

Recreation of the Anatomic Center of Rotation

Restoring the COR in TSA is critically important to functional outcomes and has had a strong bearing on implant design.[4,5] If the COR is altered, the moment arm of the deltoid and rotator cuff creates abnormal forces that increases concerns for dysfunction and premature implant failure. Several parameters have been cited that seek to measure recreation of the glenohumeral joint. The lateral humeral offset (LHO) is a reproducible radiographic measurement that helps quantify how implant positioning and sizes influence the distance between a constant point, the coracoid, and the point that is directly influenced by implant positioning, the greater tuberosity[6-8] (Figure 1). This measurement can act as a surrogate for assessment of the glenohumeral relationship and is typically measured in comparison to the contralateral shoulder. Overlengthening the LHO by as little as 4 to 5 mm can decrease range of motion and cause abnormal translation and increased subacromial contact.[9,10]

Several studies have examined the restoration of proximal humeral anatomy using third-generation stemmed implants. Wirth et al[11] identified a significant difference between preoperative and postoperative head height and surface arc in patients undergoing stemmed TSA. Another study found offset discrepancies to be dependent on the eccentricity of the humeral head as it rotates around the fixed point of a stemmed implant.[12] The authors concluded that to recreate the anatomic relationship of the proximal humerus, a more adjustable prosthesis was needed. These studies suggest that offset is largely dependent upon stem placement, which is dependent upon the variable anatomy of the proximal humerus.

The proposed biomechanical benefit of a stemless implant is founded on the idea that replacement of the resected humeral head with an implant of the exact height, diameter, and eccentricity more adequately recreates the anatomic COR.[13] Without a stem, the COR and joint forces are more reliant on the head anatomy. Kadum et al[8] recently examined the ability of a stemless humeral implant to restore anatomic LHO. The authors found that when comparing the LHO between the stemless arthroplasty and the contralateral nondiseased shoulder, the LHO differed from the contralateral shoulder by only 1.3 mm (±4.6 mm). In this particular study, stemless implants were not compared with stemmed implants, making the potential biomechanical benefits unsubstantiated.

Biological Response of Proximal Humeral Bone to Implants

Biomechanical principles of proximal bone response, specifically in the form of bone resorption, remodeling, and ingrowth potential, are other potential considerations for stemless humeral arthroplasty. The bone responds to stress, and stress shielding is a normal biological response of the bone to an implant of a differing modulus of elasticity. When any implant is inserted, there is a change in the distribution of load to the surrounding bone, which can lead to bone resorption or a failure of ingrowth resulting in potential loosening.[14] This normal adaptation of the bone can lead to the bone becoming thinner (external remodeling) or less dense (internal remodeling).[15,16] Stress shielding around the humeral stem has been found to be as high as 82% in traditional stemmed implants.[15,17-19] Additionally, this may have importance regarding the need for revision surgery as loss of bone around a stemmed prosthesis may lead to additional bone loss through the process of stem extraction.

The impact of humeral stem length on stress shielding has been examined.[20] Razfar et al[20] examined the changes in both trabecular and cortical bone stresses using finite element analysis (FEA). They tested three different stem lengths in various degrees of abduction and compared the stress distributions of various regions of the bone. In longer stems, the proximal cortical stresses were significantly reduced as the proximal cortical bone was essentially "off-loaded." The authors of this paper further noted that proximal stresses in the stemless implant were closer to normal stresses with loading of the metaphyseal bone compared with those implants that relied on diaphyseal fixation. Using a single AP radiograph, Habermeyer et al[21] demonstrated that there was a 41% decrease in bone density as a response to the stemless implant. These results do seem to pose an interesting caveat to our understanding of how the proximal humeral bone quality responds to the stemless implant.

Significant variations in the metabolic capabilities of the proximal humerus have been identified in stemless arthroplasty.[22] Advanced CT imaging of stemless implants identified highest levels of metabolic activity in the most proximal segment of bone directly under the implant within 3 months of implantation.[22] Interestingly, no significantly decreased bone response could be found in osteopenic or osteoporotic patients.

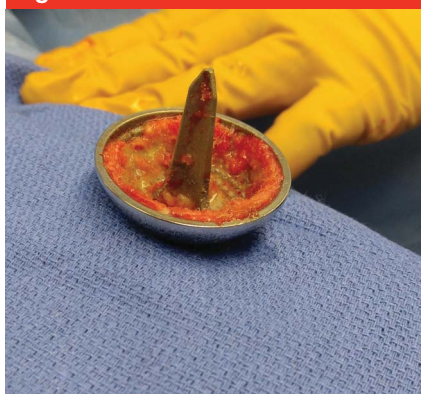
Another distinguishing feature between the biomechanics of stemless implants and those of longer stem implants is the concern for a diaphyseal stress riser and the risk of periprosthetic fracture with longer stem implants. Intraoperative periprosthetic humeral fractures with stemmed humeral implants have a reported prevalence of 1.5%, whereas the rates of postoperative periprosthetic fractures range from 1.6% to 2.4%.[23,24] Periprosthetic fractures often involve the tip of the implant secondary to diaphyseal implant stresses.[25] These fractures may result in nonunion. Theoretically, a stemless implant avoids milling the diaphysis and filling the canal with a rigid implant, thereby lessening the risk of a diaphyseal stress riser at the distal tip of the implant. The stemless implant is not without the risk of fracture, however. Huguet et al[3] identified a higher-than-expected intra-operative fracture risk in up to 7% of cases that underwent stemless implant. This was believed to be due to the implantation technique for four of five intraoperative proximal humeral fractures that required immediate revision out of concern for implant stability.

Although stemless shoulder arthroplasty may have biomechanical benefits, complete reliance upon the metaphyseal bone for implant stability could not be achieved because of other biomechanical concerns. Avoiding implant motion is important as it can prevent osteointegration and lead to an increased bony resorption by altering stress kinematics in the proximal humerus. A recent FEA study found that 99% of the impacted stemless implants experienced micro motion which further increased when loaded in abduction.[26] The same group, using a cadaver model, identified that cancellous bone quality and the size of the load placed on the implants can increase implant micro motion.[27] These findings either support a stemless implant in patients with insufficient proximal bone quality to either or suggest that these patients tolerate postoperative physical therapy. This has not been directly correlated in clinical outcomes.[21]

Altered Bone Response in Resurfacing Arthroplasty

Resurfacing arthroplasty has been proposed as a precursor to the more recent stemless replacement strategies. It is different from stemless arthroplasty. Although clinical outcomes with resurfacing arthroplasty have been favorable, there have been challenges in reproducing the anatomy with a resurfacing implant, which led to overstuffing and abnormal joint kinematics.[28-30] In addition to this, resurfacing arthroplasty has had some technical challenges with proper glenoid exposure. The proximal bone response with stemless arthroplasty also appears to be different than that with resurfacing arthroplasty. In a recent study that examined proximal bone response to resurfacing arthroplasty using both FEA and in vivo analysis, the authors found an increased compressive strain at the stem and at the outer rim of the implant along with a high level of bone resorption under the central implant shell.[31] Implant retrieval analysis confirms these results with greater bone formation in locations of greater compressive strain and reduced bone stock under the unloaded central portion (Figure 2). Ajami et al[32] examined the histological response of the bone surrounding the humeral head resurfacing and found that there was a reduced and "inhomogeneous" bone stock under the implant with signs of stress shielding at the stem and implant rim. This finding led the authors to conclude that there was a satisfactory osseous integration with the caveat that the reduced and poor-quality bone had implications that could affect long term survivorship.

Figure 2



Humeral head resurfacing. Explant of humeral head resurfacing shows peripheral ongrowth of bone with central amorphous bone changes around the central portion of the implant.

Surgical Technique

Proper surgical technique for the implantation of a stemless TSA begins with appropriate management and patient selection for TSA. Patients with degenerative changes in the glenohumeral joint must initially undergo nonsurgical treatment, which may consist of physical therapy, glenohumeral injections, use of anti-inflammatory medication, and medical optimization to reduce surgical complications. Selection of patients is based on the following inclusion criteria: adequate glenoid bone stock, functioning rotator cuff, revision of a humeral stem, and willingness to

comply with postoperative therapy and activity restrictions.

The authors agree that certain more specific criteria should be applied in patient selection for a stemless TSA. Inclusion criteria for those patients would be those patients without proximal humeral metaphyseal defects, middle aged patients with advanced osteoarthritis, patients with osteonecrosis of the humeral head and those patients who are expected to undergo revision arthroplasty due to the normal failure characteristics of an anatomic total shoulder within the expected lifetime of the implant.

The surgery begins with a standard deltopectoral or anterolateral approach. After identifying the axillary nerve and protecting it throughout the case, the biceps tendon can be identified and released for tenodesis. Management of the subscapularis may be decided by the treating physician's preference. We do recommend creating a 2 mm-thin lesser tuberosity osteotomy out of the concern of disrupting the important cortical shell of the proximal humerus, which may compromise stable implantation of the humeral component. After the release, the subscapularis is tagged and protected. Osteophytes are removed to identify the anatomic neck. The superior cuff is protected, and humeral osteotomy is performed. A cutting guide may be used according to preference. This is important in a post-traumatic arthritis setting where proximal or metaphyseal deformity can lead to improper angulation of the cutting guide. The calcar and outer ring of the cortical bone is preserved to allow for the most rigid construct possible for proximal implantation. Carefully placing retractors on the proximal humerus is important to not distort or alter the proximal surface. A proper osteotomy is indicated by the humeral head being more oval than circular and a "best-fit" size should be assumed so that adequate coverage is performed. At this point, the surgeon should examine the proximal bone quality, as the stemless arthroplasty relies heavily on impaction implantation. If the surgeon feels that stable fixation cannot be achieved within the proximal metaphyseal bone, then a stemmed implant may be considered. Depending on the choice of implant, the necessary humeral instrumentation can be placed. Most of the implantation systems allow for impaction broaching of the proximal humerus; however, some systems use a screw-in cage for fixation. The largest possible center metaphyseal implant size that fully sits within the osteotomy cut surface is recommended, and trial heads can then be placed on the trial humeral metaphyseal implant. The smallest diameter head that covers the anterior, superior, and posterior surface of the osteotomy is selected as the remaining 1 to 2 mm inferior rim can be rongeured to a concentric fit. This step can prevent overstuffing and allow for proper match of humeral head glenoid implant radius curvatures. Typically, 3 to 4 drill holes are placed within the bicipital groove to allow passage of #2 or #5 permanent sutures exiting through the osteotomy site. These sutures can be wrapped around some of the implant designs to give better fixation for the final subscapularis repair. In all but one system, the final metaphyseal implant is placed but incompletely impacted before final impaction with the selected humeral head size to assure adequate Morse taper engagement. Following assessment of range of motion and soft tissue balancing, the subscapularis and lateral rotator interval are repaired (Figure 3, A–I).

Postoperative Rehabilitation

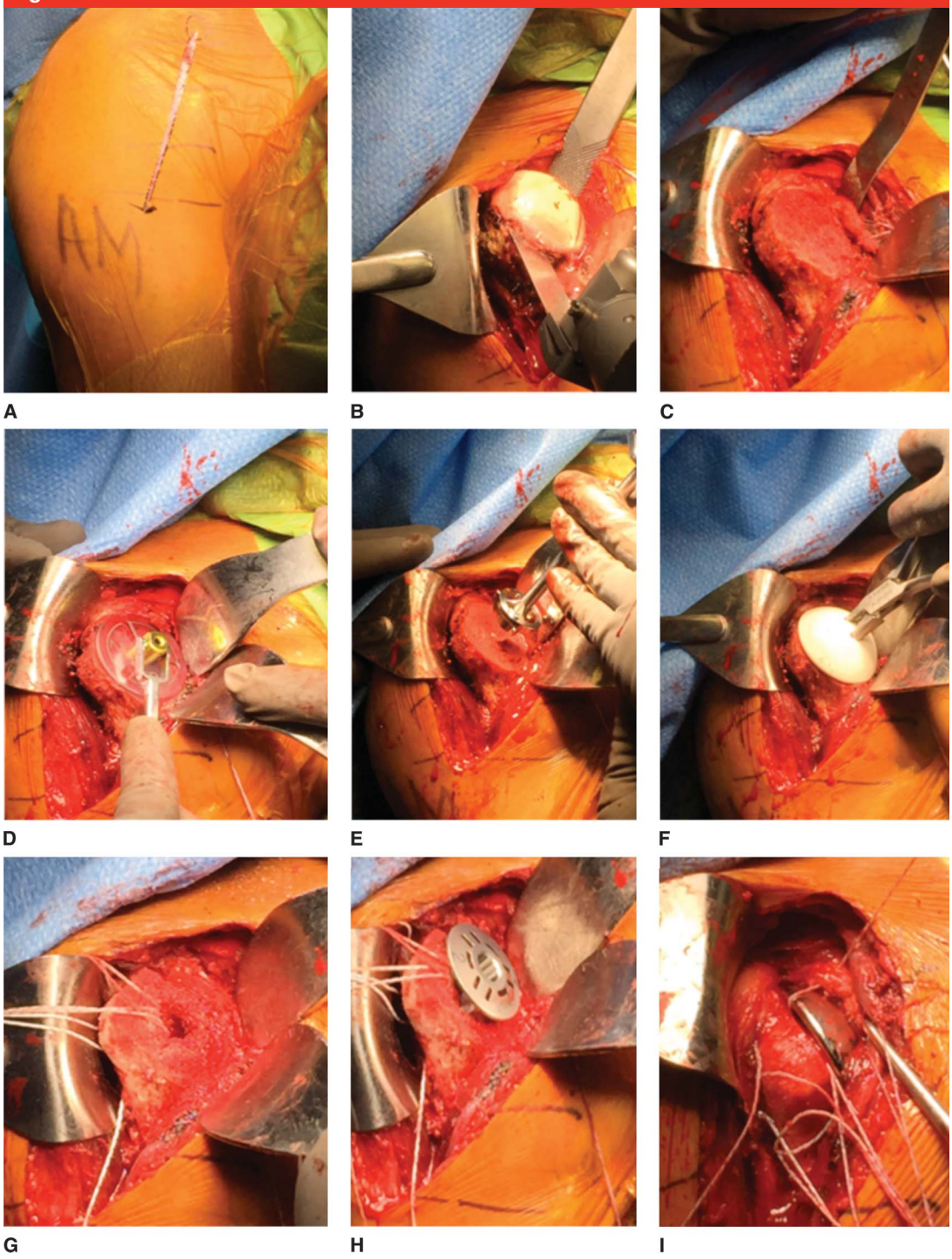
The recommended post-operative rehabilitation protocol is the same as that for a classic anatomic TSA. This includes a slow transition from immobilization, to passive motion, to active motion as well as strengthening of the muscles of the shoulder. There should also be limitation to external rotation during the early rehabilitation period to prevent injury to and rupture of the subscapularis.

Stemless Designs and Clinical Outcomes

Approximately seven different stemless designs are available from six implant companies.[33] The Wright Medical/Tornier Simpliciti and Zimmer Biomet Sidus are currently the only FDA-approved stemless shoulder implants. Further independent investigational device exemption trials are under way with U.S. FDA oversight. Although there are various specific designs to proximal fixation for the stemless designs, they have all been designed with the goal of achieving appropriate time zero fixation to allow for either ongrowth or ingrowth fixation. Most the designs include impaction with a wide metaphyseal fixation with female designs, but several have individual design differences that will be discussed below. A summary of clinical outcomes is found in Table 1, highlighting humeral complications. The two main categories of stemless implants are impaction and screw-in, with the majority being impaction type.

The Wright Medical/Tornier Simpliciti is an impaction-type implant and was the first stemless humeral implant approved by FDA for use within the US after receiving clearance in March 2015 (Figure 4, A). The device has been commercially available in Europe since 2011 and is a two-piece design with multiple head diameters and thicknesses. The fixation device is a solid collared design with an ingrowth porous surface that is impacted into the proximal humerus. The collar has a female Morse taper for the proposed benefit of improved glenoid visualization.

Figure 3



Surgical approach for stemless arthroplasty using an impaction central metaphyseal implant. An incision is made based on a deltopectoral approach (**A**). After using the approach, the subscapularis is tagged and a tenotomy or peel is performed to gain access to the glenohumeral joint. Osteophytes are removed, and an anatomic head cut is made without use of a guide (**B**) revealing the ovoid osteotomy site (**C**). A guide is used to size the proximal surface and a guide pin is placed. **D**, The impaction punch is used for press-fit of the central metaphyseal implant (**E**). The head is sized for a perfect fit of the proximal humerus. **F**, Drill holes are made in the bicipital groove into the osteotomy, and nonabsorbable suture is placed. **G**, The central metaphyseal implant is impacted into a place several millimeters off the bone. **H**, The final head is impacted onto the central metaphyseal implant allowing engagement of the Morse taper and appropriate fit of the implant onto the osteotomy surface. **I**, The nonabsorbable suture is placed through the subscapularis and tied.

Table 1

Summary of Stemless Humeral Implants With Study Size, Average Age, Average Follow-up, Outcome Scores, Revision Rate, Complication Rate, and Individual Complications

Study	Study Size	Follow-up	Overall Complication Rate	Humeral Complication Rate	Specific Complications
Brunner et al, 2012[46]	233 patients	Mean 23 mo	9.8%	2.3%	Two post-op stiffness, one humeral stem loosening, two peri-prosthetic fractures, two rotator cuff deficiency, one heterotopic ossification, one impingement, two nerve lesions, three infections and one glenoid erosion
Kellinghaus and Schneider, 2013[34]	41 patients	Mean 19.4 mo	4.9%	Unavailable	One septic loosening; one aseptic loosening
Habermeyer et al, 2015[21]	78 patients	Mean: 72 mo	12.8%	Zero	Six rotator cuff tears, one greater tuberosity osteolysis, two metal-backed glenoid loosenings, one secondary glenoid wear in hemi-arthroplasty group, one late infection and one peri-prosthetic humerus fracture
Hawi, 2017[51]	43 patients	Mean 9 yr	9.3%	Zero	Six rotator cuff tears, one greater tuberosity osteolysis, one late infection and one peri-prosthetic humerus fracture
Bell and Coghlan, 2014[48]	50 patients	12 mo (n = 38); 24 mo (n = 12)	16%	0%	One revision to reverse, four AC joint pain, two musculocutaneous nerve palsy, one olecranon bursitis, two skin reactions to dressings
Churchill et al, 2016[42]	157 patients	Minimum 24 mo	3.2%	Zero	One post-op infection requiring revision, one stemmed conversion (poor bone quality), one revision (intra-op re-sizing), one subscapularis failure requiring revision, one glenoid loosening requiring revision
Huguet et al[3]	70 patients	Minimum 36 mo	9.7%	7.9%	Five intra-op cracks (all healed), one hematoma drained, one arthroscopic release for stiffness
Ballas and Beguin, 2013[41]	56 patients	Mean 58 mo	16%	3.6%	One metaphyseal fracture, one subscapularis rupture, one superficial infection, one acromion stress fracture, three glenoid dissociations, one early instability, one greater tuberosity osteolysis
Kadum et al, 2014[44]	16 patients	Mean 39 mo	37%	12.5%	Two stemless corolla displacements, four glenoid loosenings, two scapular notching

(*continued*)

Table 1 (*continued*)

Summary of Stemless Humeral Implants With Study Size, Average Age, Average Follow-up, Outcome Scores, Revision Rate, Complication Rate, and Individual Complications

Study	Study Size	Follow-up	Overall Complication Rate	Humeral Complication Rate	Specific Complications
Von Engelhardt et al, 2015[40]	67 patients	Mean 17.5 mo	17.9%	Unavailable	Three glenoid loosenings, one humeral loosening, one low-grade infections, one glenoid fracture, one instability with two subluxations, one unstable symptomatic os acromiale, one brachial plexus lesion (partially resolved), three surgical malpositionings (underwent immediate revision). Note: outcomes not delineated between stemmed and stemless implants adequately.

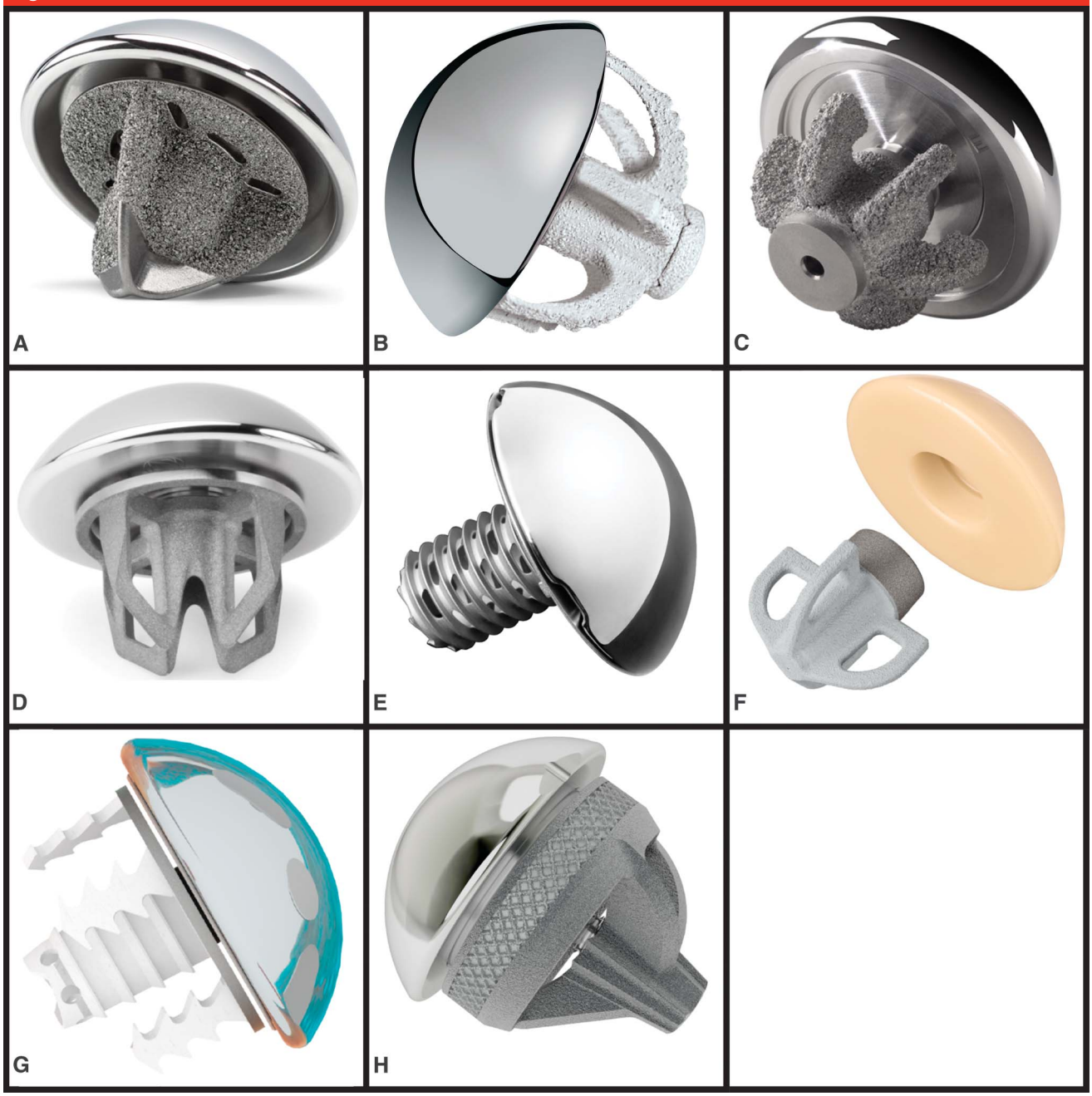
Clinically, in a 2016 prospective study with 157 patients with a minimum follow-up of 2 years, Churchill et al[42] noted an improvement in the Constant (44-81), SST (4-11), and ASES scores (38-92). There was no clinical or radiographic evidence of loosening, subsidence, migration, or osteolysis of the humeral or glenoid components. Five revision operations were performed with 1 related to insufficient humeral bone quality and 1 secondary to subscapularis repair failure.

The original Zimmer Biomet design, the Total Evolutive Shoulder System (TESS) is a three-component system with a six-arm impaction humeral component. The Nano is a second-generation iteration of the TESS that changed the Morse engagement device to a female component on the impaction implant side to allow for optimal glenoid visualization (Figure 4, B). The Nano system is one of two stemless devices that have convertible components to allow for a reverse total shoulder system built off of the same impacted metaphyseal implant (Figure 4, C). The Nano is currently undergoing investigational device exemption trials. The Sidus stemless implant was introduced in Europe in 2012 and received FDA approval in November 2017. It has a four-fin ongrowth surface with an open fin to allow for the bridging bone to cross the fins. In addition, the implant has an "open" design collar to allow for visualization of the osteotomy site through the collar itself. It has a male Morse taper and two component pieces.

The Zimmer Biomet stemless implant designs have the largest number of clinical outcome reports. In 2010, Huguet et al[3] reported on 70 patients who received the TESS humeral prosthesis with more than 36 months of follow-up. The radiographic review showed no osteolysis, radiolucency, stress shielding, or implant migration. The authors reported seven complications, five of which occurred intraoperatively. In these five patients, a small crack was noticed on the initial postoperative radiograph on the lateral cortex, but they healed within 2 months and without clinical instability. More recently, two reports compared the TESS stemless implant with other stemmed implants.[38,43] Razmjou et al[43] reported on 79 patients who received one of the following three implants: Neer II (22 patients), Bigliani-Flatow (40), and stemless TESS implants (17). A significant improvement was observed among the outcomes in all three groups, and no significant relationship was seen between patient satisfaction and type of prosthesis. No humeral component loosening or stress shielding was reported in the TESS group, compared with three of the Neer II (18%) and three of the BF (8%) patients. Berth and Pap[38] reported on 82 patients treated with either the Zimmer Biomet TESS or the Mathys Affinis stemmed shoulder prosthesis. There was no significant difference in the Constant scores between the groups. The mean operative time and blood loss were significantly lower in the stemless group. There were no signs of loosening of the humeral implants in either group.

Several papers have examined the results of the TESS Reverse implant.[39-41,44] Three reports compared the TESS Reverse with other shoulder arthroplasties. Kadum et al[45] published the results on their series of 56 patients who received either the TESS stemless anatomic or

Figure 4



Composite image of stemless implant options. **A**, Wright Medical Simpliciti Implant. **B**, Zimmer Biomet Nano. **C** and **D**, Zimmer Biomet TESS (Total Evolutive Shoulder System) and Sidus. The Nano (**B**) and TESS (**C**) have a porous coating whereas the Sidus (**D**) has an ongrowth surface. **E**, Arthrex Eclipse system has a screw-in cage core with holes allowing ingrowth. **F**, Mathys Affinis Short, which has a ceramic head with a grit blasted ongrowth surface. **G**, FX Solutions Easytech system has a barbed impaction post with peripheral barbs for proximal humeral purchase. **H**, Lima SMR stemless design has an impaction implant with a collared design. These images were provided courtesy of Wright Medical (**A**), Zimmer Biomet (**B**, **C**, and **D**), Arthrex (**E**), Mathys (**F**), FX (**G**), Lima (**H**).

stemmed reverse. Thirty-five patients received the stemless TESS implant. The authors noted significant improvements in the mean quickDASH, EQ-5D, and VAS scores with short-term follow-up. No radiolucencies were noted. The authors report five complications including 1 early dislocation in stemless anatomic TESS and 1 reverse TESS patient with dissociation between the stem and metaphyseal corolla. Kadum et al[44]

reported on their prospective comparative study of 37 consecutive patients receiving the TESS Reverse implant. No humeral loosening was evident, but there were two stemless implants revised at 3 and 4 days postoperatively because of corolla displacement. In 2015, von Engelhardt et al,[40] published their short-term results on 67 patients receiving TESS Reverse implants. The study included 56 stemless implants and 11 stemmed implants. The authors noted a humeral loosening which was converted to a stemmed implant, three immediate postoperative revisions of which 1 was secondary to intraoperative mispositioning of the humeral component.

In 2013, Ballas and Beguin[41] reported on their prospective single-surgeon series of 56 patients who received TESS Reverse implants. The authors expressed a concern regarding the reverse engagement mechanics with the taper. No humeral loosening was observed despite 1 case with greater tuberosity osteolysis and 1 early postoperative instability with humeral corolla loosening (revised to the stemmed component). In 2015, Teissier et al[39] reported on a prospective study of 101 patients who received 105 TESS Reverse implants. There was no evidence of humeral or glenoid component loosening.

The Arthrex Eclipse design is the only current design that does not have an impaction implant (Figure 4, D). Instead, it has a solid collar with a threaded central cage that is screwed into the bone through a collar. It is a grit-blasted ongrowth surface that has cut-outs within the threads that allow the bone to cross through the device. It has three component pieces and a male Morse taper.

In 2011, Schoch et al[37] reported on the short-term results of 115 patients receiving Arthrex Eclipse. Revisions were not reported, but the overall complication rate was 5% without evidence of humeral loosening.

Table 2

Summary of Advantages and Disadvantages of a Stemless Humeral Implant

Advantages	Disadvantages
Bone preserving[33,36,38,51]	Dependence on proximal bone stock
Decreased surgical time[36,38]	Increased cost
Lower blood loss[36,38]	Subscapularis fixation limitation
Less stress shielding distally[21]	FDA approvals
No diaphyseal stress riser[22,23]	Proximal bone response
Less lateralization[8,13]	—
Avoidance of humeral shaft for placement	—

Brunner et al[46] reported on a large prospective series with 233 patients who underwent 114 hemi-arthroplasties and 119 total shoulder arthroplasties and found that 7.2% of patients showed a decrease in bone density in the proximal portion of the coiled implant with no clinical consequences. The complications rate was 9.8% with a revision rate of 4.7%. Kelinghaus and Schneider[34] reported on medium-term results of their retrospective randomized trial of 41 patients receiving the Eclipse hemiarthroplasty. Improved clinical results were found when the measured humeral offset was less than 5 mm when compared with preoperative values.

In 2015, Habermeyer et al[21] reported the mid-term results of 78 patients receiving the Eclipse implant, with 39 of the patients receiving hemiarthroplasty and 39 patients receiving TSA. The overall complication rate was 12.8%, with an overall revision rate of 9%. None of the stemless implants were revised for loosening. In this longer-term follow-up series, a lowering of proximal humerus cancellous bone density was observed overall in 41.3% of patients with unknown clinical significance. However, these results were determined from a single AP radiograph and should be regarded with limited relevance. Future studies could focus on appropriate assessments of pre- and postsurgical bone density to better understand local bone biology following canal sparing shoulder replacement surgery.

The Mathys Medical Affinis Short stem was introduced in Europe in 2008. It is an additional impacted implant with a four-arm design coated with porous titanium to allow for ingrowth (Figure 4, E). Similar to the Sidus system, it has a two-piece, open window design with a male Morse taper. Different from the other systems, the humeral head component is ceramic.

In 2011, Joudet et al[47] presented their results on 118 patients who received the Affinis Short implant. The mean follow-up was 7 months. Sixty-one percent of the cases were total shoulder arthroplasties. Eight complications were reported, but none related to the humeral implant. In 2014, Bell and Coghlan[48] reported favorably on a prospective study involving short-term follow-up of the Mathys Affinis Short implant. The authors report a 14% complication rate with 1 revision for a postoperative supraspinatus tear.

The FX Solutions Easytech was introduced in 2015. It has a central impacted barbed post with additional smaller barbed posts at the periphery of the ringed collar with a nonporous coating to allow ongrowth (Figure 4, F). It has three components and a female Morse taper.

The Lima SMR Stemless is a recent design introduced in 2015 as part of

the shoulder modular replacement system (Figure 4, G). It is a convertible system that has four components including a locking screw, female Morse taper and an impaction trabecular metal ingrowth surface. As a convertible system, the components may be removed, and a metallic liner may be placed into the humeral implant, which articulates with an all polyethylene glenosphere.

Clinical Outcome Summary

The relatively low number of outcome reports, the mixed study methodologies, and the short-term follow-up time lengths do not permit definitive comparative conclusions between stemmed and stemless components. To date, no author has suggested that stemless or canal-sparing unconstrained shoulder arthroplasty outcomes are superior to those of stemmed implants from clinical and radiologic perspectives.[3,21,35,36,38,42,43,45,49,50] Rather, authors have noted that clinical and radiologic outcomes have been favorable with short- and intermediate-term data revealing that the outcomes are similar to those of stemmed counterparts.[3,21,35,36,38,42,43,45,49,50] Table 2 is a review of the various upsides and downsides of the stemless total shoulder implant (Table 2).

Summary

The introduction of stemless TSA marks the beginning of the consideration for TSA. The proposed benefits of a stemless humeral implant are built upon the potential of a more reproducible COR and improved biological response to the stemless implant in addition to bone preservation, helping to simplify revision arthroplasty when needed. Potential downsides include the dependence on proximal bone quality for fixation, increased cost, and the dependence on the strength of subscapularis fixation. There are also unknown parameters regarding stemless implant including concern regarding proximal bone response and mechanical engagement of the implant. In addition, there is still a need for more mid- and long-term outcomes.

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