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SHOULDER ARTHROPLASTY (G ATHWAL, SECTION EDITOR)

Total shoulder arthroplasty: are the humeral components getting shorter?

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Abstract Each generation of total shoulder arthroplasy has improved on the previous. The newest humeral component innovation is shortening the humeral component or eliminating the stem entirely to rely on stemless fixation in the humeral metaphysis. This offers theoretical advantages of preserved bone stock, less stress shielding, eliminating the diaphyseal stress riser, ease of stem removal at revision, and humeral head placement independent from the humeral shaft axis. There are a number of short term cohorts that have shown low complication rates and outcomes similar to previous generations of stemmed humeral components. Longer term and better designed studies are needed in order for short stems and stemless components to become the standard of care.

Keywords Shoulder arthroplasty · Short stem humerus · Stemless humerus

Introduction

Shoulder arthroplasty has gone through many design revisions since Neer first presented his 6-year results of 48 shoulders in 1974 [1]. This first-generation stem had only five size options with increasing diameters of stems but otherwise similar geometry [1]. A second generation of implants was designed in the early 1990s with increased modularity allowing better reconstruction of native humeral head and metaphyseal anatomy [2]. These second-generation implants were usually uncemented meaning that the humeral metaphysis dictated the alignment [2, 3]. The modular components did not reproduce humeral head anatomy perfectly and unfortunately were often overstuffed [2]. A third generation of implants was then developed to allow for recreation of the anatomic humeral neck and humeral head [2, 4]. These implants featured offset humeral heads and, often, cemented stems to allow for recreation of the neck-shaft angle [5]. Most recently a fourth generation of humeral components has been developed featuring short stem and stemless designs [6]. These are not resurfacing implants but rather are humeral head replacements that anchor exclusively in the humeral metaphysis [6].

Over the last decades, there has been much debate about how to optimally fix a humeral component in the humerus. Initially, cement fixation of the humeral component was mandatory [1]. Recent results have begun to show that this is no longer necessary in second- and third-generation implants [3, 7–12]. In fact, conventional thinking holds that isolated humeral stem loosening is a rare complication in the absence of infection. This has led surgeons and industry to question how long the humeral component of a total shoulder needs to be. Surgeons are constantly balancing the need for stable fixation of the humeral component with the need for the ability to revise the humeral component when need be for complications which could be infection, fracture, dislocation or aseptic loosening [13].

Rationale for shorter humeral stems

There are at least five reasons why shorter humeral stems may prove advantageous: preserved bone stock, less stress

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shielding, no diaphyseal stress riser, ease of stem removal at revision, and humeral head placement independent from orthopedic axis (Table 1).

The first reason why shorter humeral stems may be beneficial is that bone stock is preserved. This is important in the case of a periprosthetic fracture or a potential future revision. Obtaining proximal fixation around a humeral stem is difficult when managing a periprosthetic humerus fracture. Leaving more proximal bone untouched increases the options for fixation. If a humeral stem loosens, the potential joint space extends around the entire stem. Importantly, much of the cortical bone destruction can occur at the tip of the stem meaning that each subsequent revision needs to extend further distal [14].

The second reason that shorter humeral stems may be beneficial is to avoid stress shielding of the proximal humerus. Arthroplasty principles dictate that metaphyseal fixation is optimal in order to ensure that as much bone as possible is loaded [9]. Raiss et al. described a very low revision rate with all humeral components but did describe radiographic evidence of stress shielding in as many as 82.5% of traditional humeral components [7]. The diaphyseal portion of a humeral stem serves to transfer some of the load away from the proximal humerus and can generate osteopenia [15].

Third, metaphyseal stems will avoid a diaphyseal stress riser. Lee et al. have shown that reaming the diaphysis causes a stress riser even before the component is inserted since the canal is often reamed asymmetrically [16]. Periprosthetic humerus fractures are due to the stress riser in diaphyseal humerus bone [17]. Moving the stress riser to proximal metaphyseal bone may decrease the rate of fracture or at minimum preserves distal diaphyseal bone stock for potential fixation or revision surgery.

Fourth, revision of the humeral component is technically easier when the component is accessible from the proximal part of the humerus. The trend away from cement for fixation of the humeral component has been partly for this reason and likewise the use of shorter components will make revision simpler [8, 18].

Table 1 Rationale for shorter humeral components

Preserved bone stock	• Bone stock for fixation of periprosthetic humerus fracture • Bone stock at time of a future revision
No stress shielding	• Most proximal humeral bone is loaded
No diaphyseal stress riser	• Stress riser is in trabecular metaphyseal bone • No diaphyseal reaming
Ease of stem removal	• Proximal access to implant bone interface
Humeral head placement independent from orthopedic axis	• Allows alignment in deformity surgery

Finally, stemmed humeral components require a near anatomic relationship between the humeral head and the humeral shaft axis [19]. Unfortunately, in cases of congenital or post-traumatic deformity this is not always the case. Traditional stems require that the humeral axis be aligned with the tuberosities and anatomic neck since the humeral head is attached to the stem in a near anatomic fashion. Stemless designs provide surgeons the opportunity to reconstruct the proximal humerus without relying on the humeral diaphysis for alignment or fixation since they do not have a shaft portion to the component [20].

There are times when a long stem is needed. The most common indications include significant proximal bone loss or very large humeral canals [21]. In these patients, cement may also be needed in order to get satisfactory fixation of the humeral component but these patients are the exception rather than the rule. Patients typically did well when long stems were used for these indications [21].

Stemless options

There are at least five companies that now make stemless humeral components [22•]. While not all these products are currently available in all countries, there are a number of ongoing clinical trials. If the results of these trials show good functional outcomes and low complication rates, stemless humeral components will become an option for patients and surgeons.

Biomet

Biomet currently makes two stemless humeral components. The newest is known as the Nano (Biomet, Warsaw, IN) and this implant is currently being investigated in the USA but no outcome data are yet available [23]. The TESS (Biomet, Warsaw, IN) has been produced for the last decade and has been investigated by a number of groups around the world.

Huguet et al. reported on 72 implants with at least 36-months follow-up [24]. This group used cementless glenoid components in all cases. The mean Constant score in this cohort was 75.

Kadum et al. followed a heterogeneous group cohort of 56 patients but unfortunately only had 14-month follow-up on average and as short at 9-month follow-up in some cases [25]. This cohort included 22 patients with an anatomic non-stemmed component. The other patients included 17 with non-stemmed reverse TESS components and 10 cemented stemmed reverse or anatomic components. This heterogeneous group had a post operative quickDASH of 34. Unfortunately, the results of the anatomic and reverse groups are not reported separately.

Razamjou et al. reported on a cohort of 17 patients treated with anatomic TESS total shoulder replacements with an average follow-up of 2 years [26•]. Each patient had a cemented keeled polyethylene glenoid component. They then compared their outcomes with cohorts of traditional humeral components. They report a Constant score of 92 and a quickDASH of 23. At 2-years follow-up the clinical outcome was not different than the cohorts who received more traditional humeral components.

Berth et al. reported on a group of 41 patients with at least 2 years of follow-up [27]. All these patients had cemented keeled glenoids but unfortunately the results were not as good with a mean Constant score of 55 and a DASH of 47.

Only one group has looked exclusively at the TESS reverse implant. Ballas et al. followed 56 patients for at least 38 months but on average 58 months [28]. The mean Constant score was 62 at the most recent follow-up.

Arthrex

Arthrex currently makes a stemless humeral component which is called Eclipse (Arthrex, Naples, FL). This implant has been produced in Europe and there are two outcome studies. There is an ongoing clinical trial studying outcomes as well.

Schoch et al. followed a cohort of 115 patients for 12 months [29]. The mean Constant score at most recent follow-up was 66. Similarly, Brunner et al. followed 233 patients for 23 months on average and reported a mean Constant score of 79 [30].

Mathys

Mathys makes a stemless humeral component known as the Affinis Short (Mathys, Bettlach, Switzerland). Uniquely, this implant uses a ceramic on polyethylene bearing surface [31]. Two outcome studies are available.

Joudet et al. presented an abstract at the Australian Orthopedic Association Meeting reporting 1 year follow-up of 53 patients with this implant [31]. The mean Constant score at 1 year was 55.2.

More recently Bell et al. reported on 38 patients with 1-year follow-up and 12 patients with 2-year follow-up [32]. All the patients had cemented glenoid components. At 1 year the, Constant score was 76 and at 2-years follow-up the Constant was 85.75.

Tornier

Tornier produces a stemless component called the Simpliciti (Tornier, Edina, MN). A clinical trial was recently completed in 2014 but the data have not yet been presented or published. The Tornier implant is presently the only FDA approved stemless system available in the USA.

Zimmer

Zimmer makes a stemless humeral component known as the Sidus (Zimmer, Warsaw, IN). A clinical trial is currently recruiting to study this implant but data are not yet available.

Short stem options

A few companies are making humeral components that are modeled after traditional components but are shorter in length.

Biomet

Biomet makes two versions of a short stem system. The first is known as the Verso (Biomet, Warsaw, IN). This implant has a short metaphyseal stem and is designed exclusively for reverse total shoulders. Biomet also makes mini and micro stem versions of the humeral components for the Comprehensive Shoulder system.

Atoun et al. reported on 31 patients with the Verso humeral component (Biomet, Warsaw, IN) who were followed for at least 24 months [33]. The mean Constant score was 56.2.

Jost et al reported on 49 anatomic comprehensive mini humeral components (Biomet, Warsaw, IN) which were followed for at least 24 months [34]. The mean Constant score was 91.

Giuseffi et al. also reported on 44 reverse total shoulders performed using the Comprehensive Mini stem (Biomet, Warsaw, IN) with at least 24-months follow-up [35]. Unfortunately, a functional outcome score was not reported but 97% had no pain or only mild pain.

Arthrex

Arthrex makes a short stem humeral component called the Univers Apex (Arthrex, Naples, FL). There are no outcome studies or ongoing clinical trials to our knowledge.

Tornier

Tornier makes a short stem humeral component called the Aquelis Ascend Flex (Tornier, Edina, MN). There are not yet any outcome studies or ongoing clinical trials to our knowledge.

Complications

Complications have been reported with each of the stemless or short stem designs. There have been less of these implants implanted than traditional humeral component designs and therefore less is known about the complications or which

Table 2 Outcomes of shorter stemmed humeral components

Implant	Study	No. implants/no. patients	Follow-up	Outcome	Complications
Stemless					
Biomet TESS					
	Huguet 2010	72 implants 70 patients Age, 64.5	Minimum, 36 months	Constant, 75 SS, 17	5 intraoperative cracks (all healed), 1 hematoma drained, 1 arthroscopic release for stiffness
	Kadum 2011	56 implants 56 patients Age, 71	Mean, 14 months	quickDASH, 34 EQ5D, 0.73	2 irrigation and debridements, 1 dislocated reverse, 1 intraoperative glenoid fracture, decoupling of metaphysis and stem
	Razamjou 2013	17 implants 17 patients Age, 69	Mean, 24 months	WOOS, 85 ASES, 82 RCMS, 92 quickDASH, 23	6 central peg perforations, 1 radial nerve palsy (resolved)
	Berth 2013	41 implants 41 patients Age, 67	Mean, 31 months	Constant, 54.7 DASH, 47.4	1 crack in the glenoid, 1 brachial plexus palsy (resolved)
Biomet TESS reverse					
	Ballas 2013	56 implants 56 patients Age, 74	Mean, 58 months	Constant, 62 OSS, 17	1 intraoperative crack, 1 subscapularis rupture, 1 superficial infection, 1 acromion fracture non op 3 dissociations, 1 early humeral loosening
Biomet Nano					
	Unregistered clinical trial Recruiting				
Arthrex eclipse					
	Clinicaltrials.gov NCT01790113 Recruiting				
	Schoch 2011	115 implants 115 patients	Minimum, 12 months	Constant, 66	1 hematoma, 2 secondary cuff insufficiencies, 2 glenoid lossenings, 1 subluxation with subscapularis attenuation
	Brunner 2012	233 implants 233 patients	Mean, 23 months	Constant, 79	1 humeral stem loosening, 2 periprosthetic fractures, 3 infections, 11 other revisions
Mathys Affinis Short					
	Bell 2014	50 implants 50 patients Age 68	12 months, 38 24 months, 12	12 months ASES, 88.28 Constant, 76.12 DASH, 10.79 24 months ASES, 92.58 Constant, 85.75 DASH, 5.94,	1 revision to reverse, 4 AC joint pain, 2 musculocutaneous nerve palsy
	Joudet 2011 (Abstract)	118 patients and implants	Mean, 7 months	Constant, 54.4	1 temporary nerve palsy, 1 superficial infection, 1 stiff shoulder, 2 hematoma, 1 subscapularis rupture, 1 arm pain, 1 clicking component
Tornier Simpliciti					
	Clinicaltrials.gov NCT01390038 Completed Nov 2014				
Zimmer Sidus					
	Clinicaltrials.gov NCT01700543 Recruiting				
Short stem					
Biomet Verso					
	Atoun 2014	34 patients 34 implants Age, 73.5 (58–93)	Mean, 36 months	Constant, 56.2	2 early dislocations, 2 metaphyseal cracks, 41 glenoid crack, 1 acromion stress fracture, 5 periprosthetic fractures • 1 glenoid • 4 metaphyseal

Table 2 (continued)

Implant	Study	No. implants/no. patients	Follow-up	Outcome	Complications
Biomet Comprehensive Mini					
	Giuseffi 2014	44 patients Age, 76 (59–92)	Mean, 27 months	97% no or mild pain	2 varus stems, 1 dislocation, 13 proximal humerus resorption, 1 brachial plexus palsy, 1 superficial infection
	Jost 2011	49 implants 47 patients Age, 67 (46–83)	Mean, 29 months	Constant, 91 UCLA, 27.5	1 subscapularis rupture, 1 PE, 5 varus stems
Arthrex Univers Apex					
	No ongoing clinical trial at time of manuscript acceptance				
Tornier Aquelis Ascend Flex					
	No ongoing clinical trial at time of manuscript acceptance				

patients may be at risk. The Australian Joint Registry has tracked stemless humeral components in total shoulder arthroplasty since 2011 [36•]. In that time, only two revision operations have been performed out of 173 operations performed; one for loosening and the other for instability. The complications of each of the studies are reported in Table 2.

Future directions

It is apparent from reviewing the literature that much is left to learn regarding short stem and stemless humeral components. We know neither how nor when these implants may fail. Each cohort that has been followed so far only has outcomes around 2 or 3 years. Obviously, it is in the mid- and long-term performance of these implants that their potential benefit lies and also where the potential for failure lurks. Likewise, pursuing clinical trials with randomization of patients to either conventional or short stem implants will allow for robust conclusions about this new generation of humeral components to be made. Future investigators might consider non-inferiority protocols since it is unlikely that the new generation of implants will perform better but the theoretical advantages discussed above will hold as long as the new generation performs similarly to the current generation.

Conclusion

There are many theoretical advantages to designing shorter humeral components. These include: preserved bone stock, less stress shielding, elimination of the diaphyseal stress riser, ease of stem removal at revision, and humeral head placement independent from orthopedic axis. While some short-term outcomes are available for these implants caution regarding their use is still warranted until longer-term data are available.

Compliance with ethics guidelines

Conflict of interest Luke Harmer declares that he has no conflict of interest.

John Sperling has received royalties from Biomet outside the submitted work.

Thomas Q. Throckmorton received personal fees from Biomet during the conduct of the study. He also received personal fees from Biomet outside the submitted work.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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