Clinical and Radiographic Outcomes of Three Different Glenoid Designs with Anatomic Total Shoulder Arthroplasty at Short-Term, Mid-Term, and Long-Term Follow-up

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Introduction: Anatomic Total Shoulder Arthroplasty (aTSA) is an effective treatment solution for glenohumeral osteoarthritis; however, there is some debate regarding which glenoid implant design is associated with the best results. The purpose of this study is to compare the clinical and radiographic aTSA outcomes at short-term, mid-term, and long-term follow-up for three different glenoid designs: 1) hybrid cage, 2) cemented peg, and 3) cemented keel glenoid.

Methods: 1,802 aTSA patients (981 cage, 527 peg, and 294 keel) with 2-year minimum follow-up (mean 61 months) were analyzed in this study. Patients were evaluated pre-operatively and at multiple post-operative timepoints for shoulder function, pain, active range of motion, and clinical outcome scores. Adverse events and revisions were also recorded. Finally, patients were radiographically evaluated at each post-operatively timepoint for the presence and magnitude of radiolucent glenoid and humeral lines.

Results: Prior to surgery, patients with keel glenoids had a significantly higher percentage of female patients than peg (64% vs. 53%, p=0.0046) and cage (64% vs. 52%, p=0.0004) glenoids. Patients with cage glenoids were significantly younger at the time of surgery than peg (66 years vs. 67 years, p=0.0008) and keel (66 years vs. 67 years, p=0.0271) glenoids, had a significantly greater percentage of patients with osteoarthritis than peg (96% vs. 93%, p=0.0060) and keel (96% vs. 88%, p<0.0001) glenoids, and had a significantly greater percentage of patients having previous shoulder surgery than peg (19% vs. 13%, p=0.0028) and keel (19% vs. 10%, p=0.0001) glenoids. Patients with cage glenoids generally had significantly higher clinical scores and active motion prior to surgery as compared to both peg and keel glenoids. Patients with peg glenoids had significantly more comorbidities than keel glenoid and cage glenoid patients, including having a significantly greater amount of inflammatory arthritis (peg vs. keel, 18% vs. 8%, p=0.0050; peg vs. cage, 18% vs. 11%, p=0.0040) and heart disease (peg vs. keel, 18% vs. 10%, p=0.0083; peg vs. cage, 18% vs. 14%, p=0.0265, respectively). Patients with peg glenoids also had significantly greater preoperative retroversion than keel (10.8 vs. 5.6, p=0.0001) and cage (10.8 vs. 6.6, p<0.0001) glenoid patients.

To compare clinical outcomes more directly by glenoid type and understand if outcome scores are maintained over the follow-up duration, we analyzed and compared outcomes by glenoid type at different post-operative intervals of 2-3 years, 3-5 years, 5-8 years, 8-10 years, and 10+ years. The UCLA (Figure 1A), ASES (Figure 1B), Constant (Figure 1C), and SAS (Figure 1D) scores are graphically presented at each short-term, mid-term, and long-term follow-up timepoint. At latest follow-up, clinical outcomes, pain, function, and active range of motion at latest follow-up are compared between the three glenoid types. Cage glenoid patients had significantly higher outcome scores for each of the UCLA, ASES, Constant, and SAS scores compared to both peg and keel glenoid patients (all p<0.0001). 53% of cage glenoid patients achieved a 100-point ASES score, which was significantly greater (p<0.0001) than the 30% of keel glenoid patients who achieved a ceiling ASES score and significantly greater (p<0.0001) than the 32% of peg glenoid patients who achieved a ceiling ASES score. Additionally, cage glenoid patients had significantly higher global shoulder function (cage vs. peg, 8.6 vs. 7.8, p<0.0001; cage vs. keel, 8.6 vs. 7.8, p<0.0001), significantly less pain (cage vs. peg, 1.1 vs. 1.9, p<0.0001; cage vs. keel, 1.1 vs. 1.6, p=0.0002), and significantly higher active range of motion for all measures (expect internal rotation for just keel patients), compared to both peg and keel glenoid patients. Keel glenoid patients had significantly higher outcomes scores than peg patients for the UCLA (p=0.0004), Constant (p=0.0031), and SAS scores (p=0.0008), and had significantly more active forward elevation than peg glenoid patients (p<0.0001).

There were 181 reported complications which resulted in 106 revisions. Cage glenoids had significantly fewer complications (7.4%) and revisions (3.5%) than peg (13.1% complications, p=0.0003; 9.7% revisions, p<0.0001) and keel (13.3% complications, p=0.0019; 7.1% revisions, p=0.0065) glenoids. No difference in complication rate or revision rate was observed between cemented peg and keel glenoids. Aseptic glenoid loosening was the most common complication and was reported in 53 patients: 11 cage glenoid patients (1.1%), 17 keel glenoid patients (5.8%), and 25 peg glenoid patients (4.7%). Irrespective of glenoid design, aseptic glenoid loosening/glenoid failure occurred most commonly in B3 glenoids (14.3%) and least commonly in A1 (2.5%), C (0%), and D (0%) glenoids; however, patients with C (0.5%) and D (1.0%) glenoids were rarely seen and patients with A1 (48.7%) glenoids were most common. While cage glenoids had a significantly lower complication rate, revision rate, and aseptic glenoid loosening rate than peg and keel glenoids, cage glenoids were observed to experience a unique failure mode of articular surface disassociation from the titanium pegs due to failure of the locking mechanism, which occurred in 13 of 981 patients for a rate of 1.3%. This disassociation failure occurred in 8 female and 5 male patients at an average time of 52 months (range: 12-102 months). Cage glenoid patients had a significantly lower glenoid RLL rate than peg (9.9% vs. 51%, p<0.0001) and keel (9.9% vs. 37%, p<0.0001) glenoids. Figure 2 illustrates the impact of follow-up duration on the formation of RLL for each glenoid type. The presence of glenoid RLL resulted in significantly worse outcomes as compared to patients without glenoid RLL, for each glenoid design.

Discussion: The results of this 1,802 aTSA patient study demonstrate significant improvements in pain and function for all 3 glenoid designs analyzed, from short-term to long-term follow-up. Some differences in outcomes between glenoid types were observed. Cage glenoid patients experienced significantly higher outcome scores, active range of motion, and less pain, and significantly lower rates of radiolucent glenoid lines, aseptic glenoid loosening, and revisions as compared to patients with cemented peg and keel glenoids. These findings provide greater evidence to suggest that hybrid glenoids are associated with superior clinical outcomes compared to cemented peg glenoids. Regarding revision surgery, cage glenoid patients were significantly less likely to require a revision than both peg and keel glenoid patients. Specifically, 7.4% of cage glenoid patients had a complication and 3.5% were revised or had a reoperation; however, it is important to note that the indication for reoperation differed between the glenoid cohorts. Patients with cage glenoids had a unique failure mode of poly-disassociation. This modular junction failure occurs due to malalignment/malpositioning when preparing the central and peripheral peg glenoid holes. Any angular divergence and/or positional deviation between drilled glenoid holes and the implant pegs, during impaction of the press-fit central peg, can cause the peripheral pegs to bend/splay as the implant is seated, which can ultimately lead to modular locking mechanism failure and articular surface dissociation. While rare, this failure mechanism highlights the importance of adequate glenoid exposure and proper surgical technique. Despite low rates of glenoid RLL with this hybrid device, it is unclear if this will decrease the incidence of aseptic glenoid loosening in the long-term, but our results, even when considering the poly-disassociation failure mode, support the ongoing use of this hybrid device.

Significance: In conclusion, aTSA is demonstrated to be a reliable treatment solution for glenohumeral arthritis using all 3 glenoid designs analyzed in this study, from short-term to long-term follow-up. When compared to gold-standard cemented peg or keeled glenoid designs, the hybrid cage design was associated with significantly better outcome scores, range of motion, and pain reduction, as well as significantly lower rates of glenoid radiolucent lines, aseptic glenoid loosening, complications, and the need for revision. These results support the ongoing clinical use of hybrid glenoids, but even longer-term clinical follow-up is required given the rare but unique disassociation failure mode of these modular devices.

Figure 1. Comparison of UCLA (Figure 1A, top left), ASES (Figure 1B, top right), Constant (Figure 1C, bottom left), and SAS (Figure 1D, bottom right) scores at various short-term, mid-term, and long-term follow-up timepoints for cage, peg, and keel glenoids.

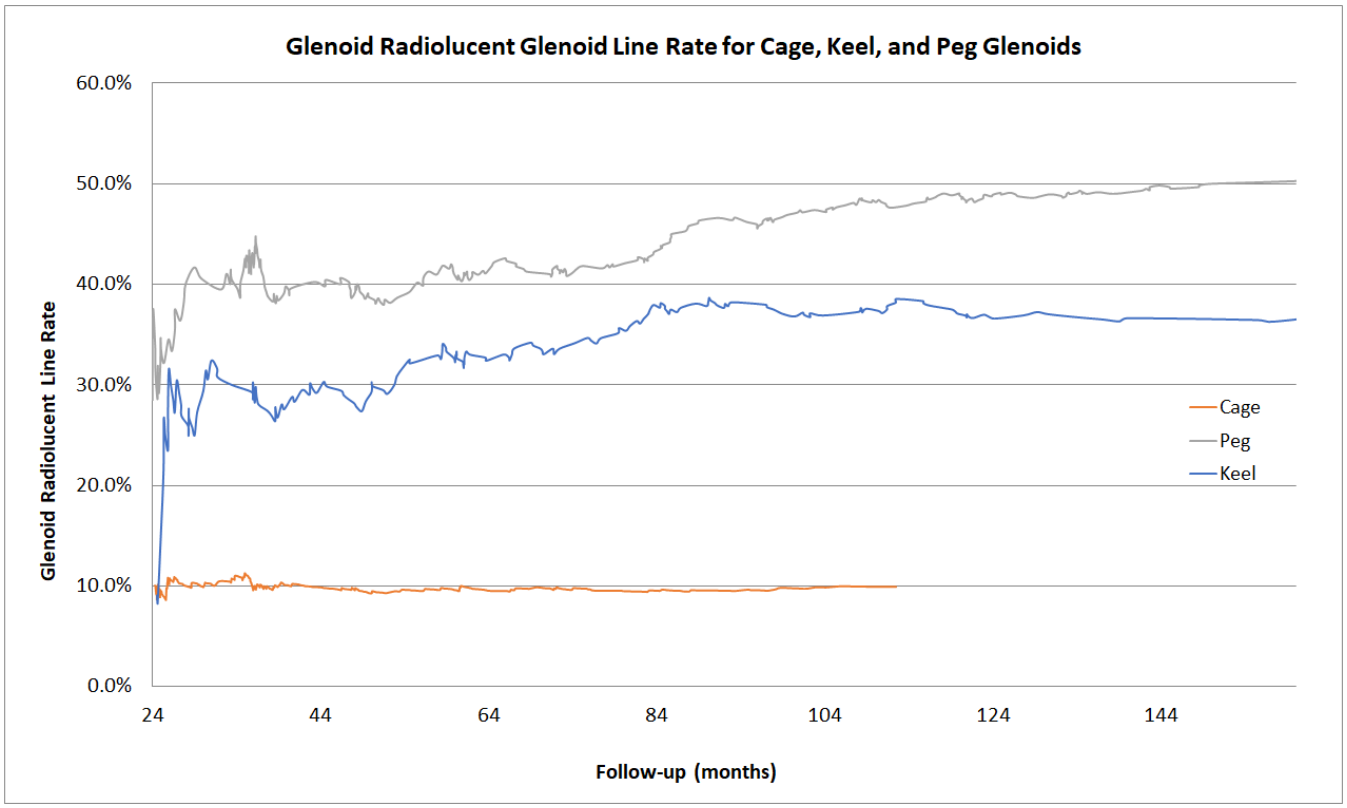

Figure 2. Comparison of Radiolucent Glenoid Line Rates by Glenoid Type over the Post-operative Follow-up Duration