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Ceramic humeral heads in shoulder arthroplasty: a systematic review

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Hypothesis: Total shoulder arthroplasty has been used for over 50 years to treat glenohumeral arthritis. In recent years, one area of innovation has been the use of ceramic-bearing surfaces. The advantages of ceramic bearing surfaces include utility in stemless implants and hemiarthroplasty, where their use in hip arthroplasty has been shown to decrease wear rates compared to metal implants and potentially reduced revision rates. With interest in utilizing ceramics for other arthroplasty indications continuing to grow, the purpose of this systematic review is to consolidate recent clinical findings involving ceramic-bearing surfaces to determine their suitability for anatomic shoulder replacement.

Methods: Medline, Embase, and Cochrane Library were searched up to April 2024 according to Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines. Metrics analyzed include patient-reported outcome measures, postoperative complications, and radiographic findings. Secondary outcomes included forward flexion, external rotation, and abduction.

Results: Eight studies comparing 716 patients were included with an average follow-up of 57.3 months (range 24-70.7). The mean age for the study population was 67.7 year old. All 8 studies included cohorts that had undergone shoulder arthroplasty with an implant with a ceramic humeral head component. All studies showed significant improvement in range of motion and patient outcome scores both postoperatively and up to 2 years after the patient's initial operation. Patient satisfaction was similarly positive, with 97% of patients reporting satisfactory results. Radiographically, 6 studies reported Lazarus grades with 71.9% (213/296) were grade 0, 23.3% (69/296) were grade 1, 3.7% (11/296) were grade 2, and 0.67% (2/296) demonstrated a grade 3 Lazarus score. One study presented a patient with a grade 5 Lazarus, making up only 0.34% (1/296) of the observed population.

Conclusion: Anatomic shoulder replacements using ceramic-bearing surfaces show safety and efficacy at numerous follow-up intervals, with complication rates approaching those of historical controls with metal implants. Future randomized controlled trials should be performed to investigate potential advantages compared to titanium and cobalt-chromium alloy humeral heads.

Level of evidence: Level IV; Systematic Review

Keywords: Ceramic-bearing surfaces; total shoulder arthroplasty; patient-reported outcome measures; radiographic findings; glenohumeral arthritis; chromium bearing surfaces

Total shoulder arthroplasty (TSA) has been used for over 50 years to treat glenohumeral arthritis. The first shoulder replacement prosthesis was developed by Dr Charles Neer as a monoblock stemmed design.[17,18] Since then, various iterations of designs have been implemented, including modular systems, stemmed implants, and nonstemmed implants. One

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Institutional review board approval was not required as this work is derived from anonymized data.

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area of innovation has been modifying humeral bearing surfaces. The advantages of these alternative bearing surfaces include utility in stemless implants and hemiarthroplasty, where their use may allow for expanded anatomic reconstruction indications, reduction in periprosthetic humeral shaft fractures, facilitating revision of humeral components, and reduced surgical time and blood loss.[4,15]

The material of these implants confers unique properties that influence their function, biological behavior, lifespan, and clinical outcome. However, there is concern regarding the long-term clinical outcomes of titanium and cobalt-chromium (CoCr) alloy humeral heads, and glenoid loosening has been implicated as a potential causative factor in necessitating future revision surgery.[20,28] Various alternative bearing surfaces, including ceramic, pyrocarbon, and polyethylene humeral heads, have recently been introduced to improve long-term outcomes and limit osteolysis and glenoid loosening.[6,8,21]

In particular, ceramics have garnered significant attention. Ceramics have been previously used in hip acetabulum replacements where the material showed decreased liner wear rates compared to metal implants and potentially reduced revision rates.[24,29] In biomechanical studies, the wear rate of glenoid polyethylene implants was significantly lower when coupled with ceramic humeral heads than when associated with metallic ones.[16] This difference in wear rate has also been theorized to increase polyethylene wear particles, which may influence glenoid radiolucent lines.[3] Ceramic wear particles have also been shown to elicit less cytotoxic response than CoCr particles; ceramic heads led to less human articular cartilage wear compared to the standard CoCr head in vitro.[1]

In recent years, these alternative bearing surfaces have become a focus of clinical studies evaluating their efficacy and long-term results. However, most recent reviews have investigated metal composite heads,[13,27] and no integrated review of the clinical outcomes for ceramic implants currently exists. With interest in these modalities continuing to grow, consolidating recent findings will allow surgeons to make informed decisions regarding indications and contraindications for particular implants. This systematic review will discuss the outcomes and complications of ceramic implants in shoulder arthroplasty. This discussion aims to consolidate recent clinical findings involving ceramic-bearing surfaces to determine their suitability for anatomic shoulder replacement.

Materials and methods

This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[19] Before beginning the literature search, a search protocol was created and published online at the PROSPERO International Prospective Register of Systematic Reviews (CRD42023470490). A search strategy was used to query 3 electronic databases: Medline, Embase, and Cochrane Library, from January 2013 until December 2023. The search strategy aimed to identify all studies investigating the clinical outcomes of ceramic-bearing surfaces in shoulder arthroplasty. The reference lists of selected articles were also screened to identify other relevant studies. The search string was as follows: "Total shoulder replacement" OR "aTSA" OR "anatomic total shoulder arthroplasty" OR "anatomic shoulder replacement" AND ("stemless" OR "ceramic" OR "Affinis" OR "shortstem" OR "short-stemmed").

Studies were to have a publication date within ten years from the search date. Inclusion criteria were as follows: (1) primary studies of shoulder arthroplasty in humans (level of evidence I-IV), (2) published in a peer-reviewed journal, (3) full text available, and (4) published in English. Exclusion criteria were (1) use of non-ceramic bearing surfaces, (2) less than 6-month average follow-up, (3) lack of reported clinical or radiographic outcomes, and (4) reverse total shoulder replacements. If multiple articles reported on the same cohort of patients were included in study identification, the article including the highest number of participants was used.

Eligibility and study selection

Titles, abstracts, and full text of retrieved studies were screened by 2 reviewers (C. H., S. I.) following the establishment of search criteria. Disagreements at the title and abstract stages were automatically included. The full-text evaluation was independently performed by 2 reviewers who selected relevant studies based on predetermined selection criteria. Full-text stage discrepancies were resolved by reaching a consensus between reviewers. If an agreement regarding inclusion could not be reached, the discrepancy was resolved by a third senior reviewer (E. B.). In addition, relevant reference lists of included studies were analyzed to add articles that had not yet been reviewed. Inclusion criteria were as follows: patients who have undergone an aTSA with a ceramic bearing surface, including any reported patient outcome measure or radiographical outcome, and written in English. Only studies that specifically recorded results for ceramic-bearing surface aTSAs were included. A Preferred Reporting Items for Systematic reviews and Meta-Analyses flowchart of the search strategy is illustrated in Figure 1. Eight studies were included after screening and full-text evaluation (Fig. 1).

Two investigators (C. H., S. I.) independently evaluated the methodologic quality of the included studies based on the Oxford Centre for Evidence-Based Medicine Levels of Evidence (I-IV). For nonrandomized controlled studies, the Methodological Index for Nonrandomized Studies (MINORS) score was used to assess quality. A higher score correlates with higher study quality and a lower risk of bias.

Three primary outcomes were analyzed: patient-reported outcome measures, postoperative complications, and radiographic findings. The patient-reported outcome measures included the American Shoulder and Elbow Surgeons (ASES), Shoulder Pain and Disability Index (SPADI), Disabilities of the Arm, Shoulder, and Hand (DASH), Visual Analog Score (VAS), Satisfaction scores, and Constant scores. All postoperative and surgical complications were included, along with the incidence and timeline of revision operations. Secondary outcomes included forward flexion, external rotation, and abduction.

Data extraction

Two authors (C. H., S. I.) extracted data from the included studies. Data was extracted from the included studies by 2 of the authors (C. H., S. I.). These data were cross-checked, and

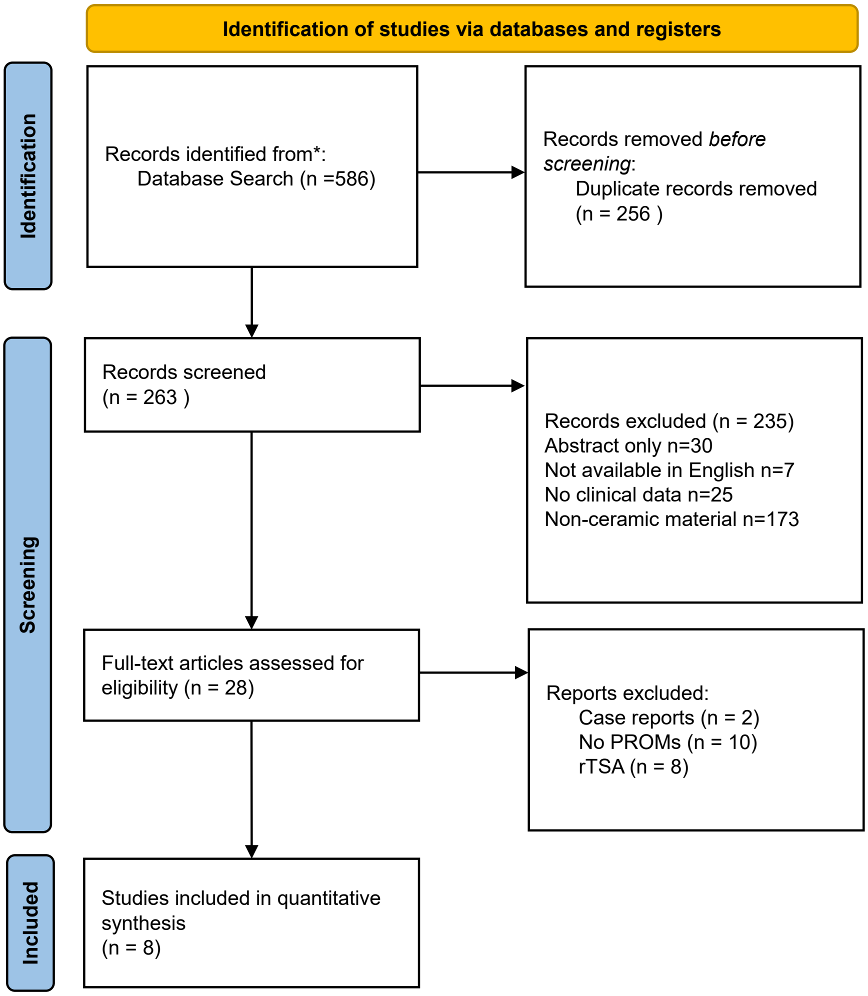

Figure 1 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram demonstrating the selection process of the 9 included studies that investigated. *PROMs*, patient-reported outcome measures.

incongruencies were discussed and reviewed by the 2 reviewers discussed. The following data were extracted: (1) study information: author, publication year, country, study design, level of evidence; (2) follow-up period; (3) study population: number of participants, sex, handedness, operative location, and age; (4) results of primary and secondary outcome measures: clinical outcomes, radiographic outcomes, and mechanical outcomes; (5) complications reported. Authors were contacted if data were missing. Data that was only available in graphs were read off the charts.

Results

Study characteristics

Of the 8 included studies, 5 were prospective, and 3 were retrospective. The studies were all published between the years 2013 and 2023. The total number of patients included across all studies equaled 716 patients. All 8 studies included cohorts that had undergone shoulder arthroplasty with an implant with a ceramic humeral head component. One study designated the patients into 2 groups and utilized ceramic and cobalt titanium metal humeral head implants for the 2 cohorts.[3] Six of the studies reported average patient follow-up time.[3,7,9,10,14,22] Two studies recorded separate average follow-up times for clinical and radiographic outcomes.[3,10] The average follow-up was 57.3 months (range 24-70.7). The mean age for the study population was 67.7 year old (Table I).

Range of motion

Range of motion (ROM) was evaluated in 5 of the 8 included studies, including 325 patients.[3,7,14,22,25] Among the studies, various postoperative ROM measurements were recorded, such as forward flexion, external rotation, and abduction. Greiner et al reported postoperative improvement in forward flexion (129.7°) and abduction (116.1°). Bell et al found average postoperative forward flexion values to be 148.9° amongst its ceramic humeral head cohort. McMillan et al did not measure preoperative ROM values but provided average postoperative values for

Table I Summary of the characteristics for the included studies

Authors	Journal	Study type	Year published	No. of patients enrolled, n	Humeral head implant	Humeral stem	Glenoid implant	M:F ratio, n	Mean follow-up time, mo	Average age, yr
Greiner et al[7]	Arch of Ortho and Trauma Surgery	P	2013	97	Ceramic (Affinis)	Cemented or press fit	PE, two-pegged, cemented	25:72	58.8	66.6
Bell et al[3]	JSES	P	2019	23	Ceramic (Affinis); Cobalt Chromium (Affinis)	Press fit tapered long stem; press fit short stem	PE, two-pegged cemented	13:10	24 (C); 66 (RA)	67.9
Jordan et al[9]	Shoulder and Elbow	P	2019	207	Ceramic (Affinis)	Stemless, press fit	PE, two-pegged cemented	77:130	70.7	64.8
Karssiens et al[10]	Bone and Joint Open	P	2021	141	Ceramic (Affinis)	Stemless, press fit	PE, two-pegged cemented	57:84	44.4 (C); 33.8 (RA)	68.0
McMillan et al[13]	JSES	R	2021	62	Ceramic (Affinis)	Stemless, press fit	PE, two-pegged cemented	17:45	46.8	69.0
Simon et al[24]	BMC MSK Disorders	P	2022	92	Ceramic (Affinis)	Stemless, press fit	PE, two-pegged cemented	42:50	51.4	68.1
Edwards et al[5]	Shoulder and Elbow	R	2023	43	Ceramic (Affinis)	Stemless, press fit	PE, two-pegged cemented	27:16	64.2	67.0
Raval et al[21]	Shoulder and Elbow	R	2023	51	Ceramic (Affinis)	Stemless, press fit	PE, two-pegged cemented	21:30	66	70.2

Arch of Ortho and Trauma Surgery, Archives of Orthopaedic and Trauma Surgery; *JSES*, Journal of Shoulder and Elbow Surgery; *BMC MSK Disorders*, BioMed Central Musculoskeletal Disorders; *P*, prospective; *R*, retrospective; *M*, male; *F*, female; *NR*, not reported; *C*, clinical; *RA*, radiologic; *PE*, polyethylene.

Relevant details of each study, including demographics, study type, year published, total number of subjects enrolled, implant utilized, and mean follow-up time.

forward flexion (157°) and external rotation (39°). Postoperatively, Simon et al showed improvement in forward flexion and external rotation with average values of 151.1° and 61.58°, respectively. Additionally, Raval et al noted improvement in average postoperative values for forward flexion (140°), external rotation (40°), and abduction (90°) (Table II). Overall, the ROM improved for every category: average forward flexion improved from 79.8° to 140.9°. Average abduction was calculated to be 51.1° preoperatively and 107.1° postoperatively.

Patient outcome scores

Several surveys were utilized across the included studies to measure relevant patient outcomes. These surveys included ASES, SPADI, DASH, VAS, Satisfaction scores, and Constant scores. Two studies (135 patients) measured preoperative ASES scores with an average of 40.9.[5,25] Three studies (158 patients) measured postoperative ASES values with an average score of 94.3.[3,5,25] Among studies that measured preoperative and postoperative values the average improvement was 53.5. Similarly, the SPADI score was calculated preoperatively in 2 studies (135 patients) and postoperatively in 3 (158 patients).[3,5,25] The average preoperative and postoperative SPADI scores across the 3 studies were 63.0 and 4.1, respectively. For studies that measured preoperative and postoperative values, the average decrease was 58.9 (Table II). Constant scores were reported preoperatively in 3 of the 8 studies (396 patients), with an average value of 27.1.[7,9,25] Postoperative Constant scores were described in 4 of the 8 studies (439 patients) and demonstrated an average value of 70.4.[5,7,9,25] The net improvement from studies measuring both preoperative and postoperative values was calculated to be 43.3 points. Preoperative DASH scores were only reported in one paper, averaging 46.5.[25] Postoperatively, Bell et al, Simon et al, and Edwards et al stated DASH scores with an average of 8.06 across the 3 studies. VAS scores in all 3 studies that measured the value demonstrated improvement postoperatively. Meanwhile, the average satisfaction score for the 2 studies that reported the value was 97 postoperatively (Table II).[3,25]

Radiographic findings

All 8 studies reported postoperative radiographic findings with an assortment of observations. Four of the 8 studies stated radiolucency during postoperative radiographic evaluation.[3,7,9,10] In comparison to the CoCr humeral head group, Bell et al described significantly fewer glenoid radiolucent lines amongst the ceramic humeral head group ($P < .001$). Meanwhile, McMillan et al reported no significant radiographic findings during its final patient follow-up (Table II).

Six of the 8 studies reported Lazarus grades after a designated follow-up time[3,5,7,14,22,25] (Table III). Within the selected study population, 71.9% (213/296) were grade 0, 23.3% (69/296) were grade 1, 3.7% (11/296) were grade 2, and 0.67% (2/296) demonstrated a grade 3 Lazarus score. One study presented a patient with a grade 5 Lazarus, making up only 0.34% (1/296) of the observed population (Table III).[7]

Complications

Of the 716 patients across all included studies, 27 underwent revision surgery (3.8%). Two studies reported no revision surgeries at all.[3,22] The causes of revision surgery among study participants were varied, with rotator cuff failure being the most prevalent pathology, accounting for 33.3% (9/27) of revision surgeries. Concurrently, infection was the second leading cause of revision surgery, making up 18.5% (5/27) of the surgical interventions. Other causes of revision surgery within the study population included: glenoid component loosening (n = 4), ongoing pain (n = 2), disturbed wound healing (n = 1), subscapular tenotomy failure (n = 1), post-traumatic subcapital/metaphyseal fracture (n = 1), aseptic stem loosening (n = 1), heterotopic ossification (n = 1), and proximal humeral migration (n = 1) (Table IV).

Meanwhile, some patients experienced complications that did not require revision surgery, with acromioclavicular joint pain (n = 7) being the predominant pathology. Other complications included intraoperative fracture of the lateral humeral cortex (n = 2), postoperative radial nerve palsy (n = 1), diffuse pain (n = 3), and infection which was cleared clinically with a débridement, antibiotics, and implant retention procedure (n = 1) (Table IV).

Discussion

As methods to improve outcomes for anatomic TSA (aTSA)continue to evolve, ceramic humeral heads have significant utility in achieving quality outcomes in the short- and long-term. Several factors have been implicated in total shoulder replacement failure, including glenoid loosening and secondary rotator cuff insufficiency.[2,8,19] Ceramic implants offer an option for stemless implants with better in-vivo wear characteristics than their traditional metal counterparts.[26] This study aimed to provide a comprehensive clinical overview of modern ceramic implants to give context to the promising results in laboratory settings.

Regarding clinical results, our study shows positive results at various follow-up intervals. The majority of studies provided at least one measure of clinical improvement, and all showed significant improvement postoperatively and up to 2 years after the patient's initial operation.[3] Patient

Table II Summary of subjective and objective patient outcomes from included studies including range of motion measurements and patient-reported outcome measurements

Authors	FF (°)		ER (°)		Abduction (°)		ASES		SPADI		Constant		DASH		Satisfaction		Flexion/AE		VAS		Radiographic findings
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Greiner et al[7]	70.1	129.7	—	—	54.3	116.1	—		—	—	21.5	62.3	—	—	—	—	—	—	—	—	RLL lines found in 76.6% of cases
Bell et al[3]	74.3	148.9	—	—	—	—	—	86.3	—	8.6	—	—	—	8.8	—	98.3	74.3	148.9	5.52	0.26	Proximal humeral osteolysis (72% of cases in metal head group, 56% in ceramic head group); More frequent glenoid RLL in metal head group compared to ceramic head group ($P < .001$)
Jordan et al[9]	—	—	—	—	—	—	—	—	—	—	28.3	70.9	—	—	—	—	—	—	—	—	RLL found in 2.6% of humeral zones and 14% of glenoid zones
McMillan et al[13]	—	157	—	39	—	150	—	—	—	—	—	—	—	—	—	—	4.9	—	—	—	No patients radiologically progressive at last follow-up
Simon et al[24]	91.3	151.1	26.4	61.6	—	—	41.6	94.3	62.9	4.3	30.3	77.9	46.5	8.4	—	95.7	91.3	151.1	5.6	0.4	4 patients with evidence of osteolysis at last follow-up
Karssiens et al[10]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Proximal humeral migration in 22.2% at last follow-up; Humeral component radiolucency (1%), Glenoid RLL (15.2%)
Edwards et al[5]	—	—	—	—	—	—	39.2	94.4	63.1	3.7	—	81.0	—	7.0	—	—	—	—	5	1.0	No associations found between Walch scores and Lazarus scores
Raval et al[21]	80	140	20	40	45	90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Medial calcar osteolysis (n = 3); Glenoid osteolytic lesions (24%); Humeral proximal migration (6%)

FF, forward flexion; *ER*, external rotation; *ASES*, American Shoulder and Elbow Surgeons; *SPADI*, Shoulder Pain and Disability Index; *DASH*, Disabilities of the Arm, Shoulder, and Hand; *AE*, active elevation; *VAS*, Visual Analog Scale; *RLL*, radiolucent lines; *Pre*, preoperative; *Post*, postoperative.

Table III Lazarus grading scores for included studies

Lazarus grade	Number of subjects per study correlated with Lazarus grade, n					
	Greiner et al[7]	Bell et al[3]	McMillan et al[13]	Simon et al[24]	Edwards et al[5]	Raval et al[21]
0	66	19	41	62	25	__
1	21	4	13	11	9	11
2	2	0	7	1	0	1
3	__	0	2	__	0	0
5	1	__	__	__	__	__

The majority of patients had a Lazarus grade of zero or one.

Table IV Recorded complications for included studies

Authors	Revision surgeries, n (%)	Details
Greiner et al[7]	7 (7.2)	Revision due to: Glenoid component loosening (n = 3); Disturbed wound healing (n = 1); Postoperative infection (n = 2); Failure of subscapular tenotomy (n = 1)
Bell et al[3]	N	N
Jordan et al[9]	13 (6.3)	Revision due to: Ongoing pain (n = 2); Failed rotator cuff (n = 6); Subcapital/metaphyseal fracture after trauma (n = 1); Aseptic stem loosening (n = 1); Infection (n = 2); Glenoid component loosening (n = 1)
Karssiens et al[10]	1 (0.7)	Revision due to: rotator interval incompetence (n = 1); Other complications: Intraoperative fracture of the lateral humeral cortex (n = 2); Postoperative radial nerve palsy (n = 1)
McMillan et al[13]	4 (6.4)	Revision due to: HO development (n = 1); Developed low grade infection (n = 1); Dislocation secondary to subscapularis failure (n = 1); Superior RC failure (n = 1)
Simon et al[24]	1 (1.08)	Revision due to glenoid component loosening (n = 1); Other complications: ACJ pain (n = 7); Diffuse pain (n = 3)
Edwards et al[5]	N	N
Raval et al[21]	1 (1.9)	Revision due to proximal humeral migration (n = 1); Other complications: Postoperative infection (n = 1)

HO, heterotopic ossification; *RC*, rotator cuff; *TSA*, total shoulder arthroplasty; *ACJ*, acromioclavicular joint; *N*, none reported.
There were a total of 27 revision surgeries from the 8 included studies.

satisfaction was similarly positive, with 97% of patients reporting satisfactory results. These patient-reported outcomes are further bolstered by significant increases in ROM, especially with flexion and shoulder abduction which showed significant increases in all papers which measured preoperative and postoperative values.

Most studies included also provided comprehensive radiographical data. The most prevalent parameter measurement was radiographic lines postoperatively, with most studies utilizing Lazarus grading. Although Greiner et al found radiolucent lines in 76.6% of their patient population, radiolucencies above 1 mm were discovered in only 8.9% of patient radiographs. Bell et al directly compared radiolucencies between metal-head long stem implants to ceramic head stemless implants. The results demonstrated significantly increased humeral osteolysis and glenoid radiolucent lines in the metal-head implants compared to the ceramic-head implants. The underlying reason for the improved stability of ceramic implants is not entirely understood, but one biomechanical study attributed the discrepancy to improved wear behavior in contrast to standard metal components, where ceramic heads showed significantly reduced polyethylene wear.[16] These findings for shoulder implants were first seen in hip replacements, where ceramic heads decreased polyethylene wear compared to their metal counterparts.[29] The decrease in wear is essential in limiting osteolysis and aseptic loosening, as metal ions have been implicated in total knee arthroplasty for contributing to immune reactions.[11] Additionally, many of the studies in this review reported using vitamin-E-enhanced polyethylene glenoid implants, which have also shown reduced wear rates compared to conventional polyethylene implants.[2] Utilization of ceramic humeral heads with vitamin-E-enhanced polyethylene glenoids may offer the possibility of improved wear characteristics and should be investigated in future studies. One concern regarding ceramic implants is the possibility of implant fracture due to decreased material ductility, which has been reported in total hip arthroplasty.[12] No such adverse outcomes were reported in the studies included in this review, but the risk for implant fracture should still be considered and monitored when using a ceramic humeral head.

When considering the suitability of ceramic heads for use in TSA, the short-term complications and long-term conversion rates must be satisfactory. Across all studies, 3.8% of the patient cohort underwent revision study within the study's time frame. This is lower than a recent large-scale database study that found a failure rate of 7.7% at 8 years.[23] The studies included in this review have shorter average follow-ups ranging from 24 to 70.7 months, likely decreasing the number of failures due to the shorter follow-up interval when compared to an 8-year follow-up interval. However, the mean follow-up of our included studies of 57.3 months correlates to a failure rate of 4.6% in the large database. Notably, the primary method of failure in the combined cohort of patients was rotator cuff failure, cited as the primary reason for conversion in 33.3% of revision surgeries. Although the same concern exists regarding different follow-up intervals, this value is congruent with 34.3% of aTSA failures being attributed to rotator cuff insufficiency in the same large database study.[23] Other complications reported are similar to those seen in standard aTSA outcomes, which further demonstrate the suitability of ceramic heads for use in aTSA. Continued monitoring of outcomes at follow-up intervals closer to 8 years may provide more satisfactory comparisons.

Limitations

The primary limitation of this study is the lack of comparative outcomes. Without comparison, these findings are less generalizable and are more prone to confounding variables such as surgeon expertise, patient selection, and variable patient population. Furthermore, the analyzed studies did not use a standardized glenoid implant or cementation technique due to surgeon preference. Various quality levels were also present in our study, with most studies being level III or IV. Lack of long-term outcomes due to the relative novelty of ceramics in shoulders. While these limitations are inherent to a systematic review, our large sample size with numerous papers limits the potential of these variables to impact findings. Furthermore, this is the first such study to investigate ceramic humeral head outcomes specifically and provides a comprehensive account of published outcomes using ceramics in anatomic shoulder replacement.

Conclusion

Anatomic shoulder replacements using ceramic-bearing surfaces show improvements in radiographic and clinical outcomes at follow-up intervals ranging from 24 to 70.7 months and should be considered a viable option for shoulder pathologies requiring arthroplasty. Continued monitoring of long-term outcomes is needed with radiographic evaluation to ensure acceptable long-term stability and clinical improvement.

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