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Does the polarity of radial head arthroplasty affect functional outcomes? A systematic review and meta-analysis

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Background: Radial head arthroplasty allows a high degree of customizability, and implant polarity has emerged as an important variable. The purpose of this meta-analysis was to evaluate differences in functional and clinical outcomes between patients receiving monopolar and bipolar radial head prosthetic implants.
Methods: A systematic review and meta-analysis were employed, and 65 articles were identified in three databases. Twelve articles contained non-English or insufficient text and were consequently excluded, and 20 others did not contain sufficient data or follow-up. The remaining 33 articles were qualitatively and quantitatively reviewed.
Results: In total, 33 populations were identified, with 809 unduplicated patients: 565 with monopolar and 244 with bipolar implants. In these respective patients, the mean follow-up was 40.2 and 56.9 months. Average Mayo Elbow Performance Score were 86.7 and 87.4 (P=0.80), respectively; average Disability of the Arm, Shoulder, and Hand scores were 17.9 and 14.7 (P=0.47), and average final flexion/extension arcs were 119.4° and 118.7° (P=0.48). Revision rates were 4.07% and 6.56%, while complication rates were 19.65% and 20.08% in the respective monopolar and bipolar patients. These increased relative risks associated with bipolar implants were not significant.
Conclusions: Radial head implant polarity does not appear to affect functional outcomes. While bipolar prosthetic design may increase the risks of revision and complications, the increases were not significant.
Level of evidence: IV.

Keywords: Arthroplasty; Bipolar; Monopolar; Radial head arthroplasty; Radial head

INTRODUCTION

Recent trends and studies have suggested that radial head arthroplasty is a preferred option in treatment of comminuted radial head fractures not amenable to open reduction and internal fixation, and that it is superior to radial head resection [1]. When deciding arthroplasty options, surgeons may select monopolar or bipolar radial head arthroplasty. The polarity of this implant has emerged as an area of controversy [1-3], and there is currently little clarity as to which type may be superior. A monopolar radial head prosthesis is fixed between the head and the neck, while bipolar implants contain an articulating head/neck segment that permits greater biomechanical freedom. Both monopolar and bipolar implants have demonstrated the ability to restore valgus stability to the elbow in several biomechanical and clinical studies [2-5].

Bipolar radial head prostheses were first introduced by Judet in 1988, serving as an alternative to the original monopolar design [2-3,6]. Bipolar implants allow increased motion of the prosthetic radial head, theoretically enabling a more congruent association of the radiocapitellar joint. In addition, the increased articu-

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lation of the head has been proposed to decrease stress at the implant-bone interface [4,7]. However, several complications have been noted with bipolar designs, including aseptic loosening and, importantly, radiocapitellar instability [6,8-10]. A bipolar articulation may also lead to polyethylene or other mechanical wear between the head and neck of the prosthesis. Specifically, conflicting data have been found in bipolar implant use in patients with elbow dislocation [1].

The purpose of this meta-analysis is to evaluate differences in functional and clinical outcomes between patients receiving monopolar or bipolar radial head prosthetic implants. We hypothesized that patients who undergo radial head arthroplasty with a monopolar prosthesis would have significantly fewer complications, loosening, and instability events related to the articulating prosthesis irrespective of indication.

METHODS

A systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Three authors conducted the search independently using PubMed, Embase, and Medline databases. The electronic search citation algorithm used was: (radial head) AND (arthroplasty) NOT (shoulder) NOT (knee) NOT (hip). Inclusion demanded full-text studies, written in English, with level I-IV evidence. All references were cross- referenced to ensure they had already been reviewed. The search resulted in 65 articles with no duplicates (43 PubMed, 22 Embase). Twelve studies were excluded as they were not in English or full text, and an additional 20 populations were excluded due to lack of appropriate data; some studies had duplicate data sets, others lacked the standard 24 months of mean follow-up, and others did not explicitly identify specific implant design (monopolar or bipolar). This left 33 studies to be included in this review.

All populations underwent radial head arthroplasty for a variety of indications. There were no requirements for rehabilitation for studies to be included. Populations were separated into monopolar and bipolar groups for further analysis. The variables collected from each study were year of publication, country, level of evidence, study design, inclusion period, number of patients, number of patients lost to follow-up, mean follow-up, mean age, numbers of men and women included, indication for surgery, type of fixation, material type used, modularity, number of revisions, revision rate, complications, and complication rate, as well as well-validated outcome measurements. These validated outcome measurements were the Mayo Elbow Performance Score (MEPS), the Disability of the Arm, Shoulder, and Hand (DASH) score, and the mean Flexion/Extension arc.

Continuous variables—MEPS, DASH score, and flexion/extension arc—were reported as standardized mean differences when available. Dichotomous variables—revision and complication rates—were reported using risk ratios. With the high degree of heterogeneity among the data sets used, a random effects model was used. We assigned statistical significance to P-value <0.05.

RESULTS

A total of 809 patients (monopolar = 565, bipolar = 244) was identified in the 33 populations. Mean follow-up was 45.8 months (monopolar = 40.2, bipolar = 56.9). Most populations (54.5%) reported "fractures" as the indication for radial head arthroplasty. Most studied populations were retrospective (87.8%) (Tables 1 and 2) [8,10-39].

Outcomes were described using the following validated metrics: DASH score, MEPS, and flexion-extension arcs (Table 3). MEPS was reported by 84.8% of the 33 populations (monopolar = 86.3%, bipolar = 81.8%). The total combined average of the MEPS was 86.9, and no statistically significant difference was found between the groups (monopolar = 86.7, bipolar = 87.4; 95% CI, –5.0 to 3.5; P = 0.80). The DASH score was reported by fewer populations, in only 45.4% (monopolar = 45.5%, bipolar = 45.4%). There was no overall mean statistical difference reported between the two groups (overall = 16.8, monopolar = 17.9, bipolar = 14.7; 95% CI, –3.8 to 10.2; P = 0.47). All but three populations reported mean flexion-extension arc (overall = 87.9%, monopolar = 86.4%, bipolar = 90.9%). No statistical difference in ROM arc was reported among the groups (overall = 119.1, monopolar = 119.4°, bipolar = 118.7°; 95% CI, –8.5 to 9.8; P = 0.48).

In addition to these functional metrics, revision rates and complications were also calculated (Table 3). An overall revision rate of 4.82% was found, with a monopolar rate of 4.07% and bipolar rate of 6.56%. While a 61% increased risk for revision was associated with bipolar implants, this increase was not significant (relative rate [RR]: monopolar = 0.76, bipolar = 1.31; 95% CI, 0.86 to 9.8; P = 0.13). The complication rate of the combined populations was 19.78% (monopolar = 19.65%, bipolar = 20.08%), with a 2% not significantly increased risk with bipolar implants (RR monopolar = 0.98, bipolar = 1.02; 95% CI, 0.76 to 1.38; P = 0.89). The most frequently reported complications of monopolar implants were ulnar nerve palsies, followed by stiffness and wound infection. For bipolar implants, the most commonly reported complications were ulnar nerve palsies, followed by heterotopic ossification and stiffness.

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Table 1. Outcomes of monopolar cohort

Study	Country	Level of evidence (I–V)	Study design	Inclusion period	Number of patients	Number of patients lost to follow-up	Mean follow-up (mo)	Mean age (yr)	Male	Female	Indication	Type of fixation	Material type	Modularity	MEPS	DASH score	Flexion/extension arc (°)	Revision	Revision rate (%)	Complication	Complication rate (%)
Moro et al. (2001) [11]	Canada	IV	Retrospective	NR	27	3	39	54	11	13	Fractures only	Fixed: press-fit (Richards Radial Head by Smith and Nephew)	Metal	Monoblock	80.0	17.0	148	0	0	6	0.2
Chapman et al. (2006) [12]	USA	IV	Retrospective	1996–2000	16	2	37	50	9	7	Heterogeneous population	Fixed: press fit (Solar by Stryker)	Metal (vitallium)	Modular	86.9	27.5	115	0	0	2	0.1
Lim et al. (2008) [13]	Singapore	IV	Retrospective	2001–2005	6	1	29.7	53	2	4	Fractures only	Fixed: cemented (Vitallium/Howmedica)	Metal	Monoblock	78.4	13.6	100	0	0	3	NR
Heijink et al. (2010) [14]	USA	IV	Retrospective	1998–2002	8	0	36	38	4	4	Chronic es-sex-lopresti lesions	Fixed: cemented (6), press-fit (2); Implants: avanta, custom avanta, judet	Metal	Monoblock	71.0	NR	129	5	0.6	5	0.6
Katthagen et al. (2013) [15]	Germany	IV	Retrospective	2007–2011	29	2	25	60	8	23	Heterogeneous population	Fixed: press fit (Radial Head by Corin)	Metal	Monoblock	87.2	NR	108.9	5	0.2	11	0.4
Sarris et al. (2012) [16]	Greece	IV	Retrospective	NR	32	0	27	54	20	12	Fractures only	Fixed: expandable stem (MoPyC by Tornier)	Metal (w/pyrocarbon)	Modular	NR	NR	130	0	0	3	0.1
El Sallakh et al. (2013) [17]	Egypt	IV	Retrospective	2007–2009	12	2	42	39	5	7	Fractures only	Fixed: press fit (MARHP, Acumed)	Metal	Modular	92.0	12.0	115	0	0	0	0
Ricón et al. (2012) [18]	Spain	IV	Retrospective	2002–2008	28	0	32	54	11	17	Fractures only	Fixed: expandable stem (MoPyC, Tornier)	Pyrocarbon	Modular	92.0	NR	105	2	0.1	19	0.7
Berschback et al. (2013) [19]	USA	IV	Retrospective	2004–2010	13	0	33	46	8	5	Essex-lopresti injuries	Fixed: press-fit and cemented (Anatomic RHS by Acumed)	Metal	Modular	92.0	13.3	127	NR	NR	NR	NR
Mou et al. (2015) [20]	China	IV	Retrospective	2008–2011	12	0	60.8	41	6	6	Fractures only	Fixed: press fit (Uncemented; Acumed AARHS)	Metal	Modular	NR	11.9	130	0	0	0	0
Levy et al. (2016) [21]	USA	IV	Retrospective	2007–2014	15	4	26	62	9	6	Fractures only	Fixed: press fit	Metal	Modular	85.0	NR	124	2	0.1	4	0.3
Gauci et al. (2016) [22]	France	IV	Retrospective	2006–2013	52	13	46	52	30	35	Heterogeneous population	Fixed: press fit (modular pyrocarbon radial head prosthesis; MoPyC, BioProfile) by Tournier	Metal	Monoblock	96.0	NR	145	0	0	11	0.2
Ashwood et al. (2004) [23]	Australia	IV	Retrospective	1996–2001	16	0	33.6	45	8	8	Fractures only	Unfixed: smooth intentional loose fit (Evolve by Wright Med)	Metal	Modular	87.0	NR	NR	0	0	6	NR

(Continued to the next page)

Table 1. Continued

Study	Country	Level of evidence (I–V)	Study design	Inclusion period	Number of patients	Number of patients lost to follow-up	Mean follow-up (mo)	Mean age (yr)	Male	Female	Indication	Type of fixation	Material type	Modularity	MEPS	DASH score	Flexion/extension arc (°)	Revision	Revision rate (%)	Compli-cation	Complica-tion rate (%)
Wretenberg et al. (2006) [24]	Sweden	NR	Retrospective	1994–2001	22	4	44.4	52	11	7	Fractures only	Unfixed: smooth intentional loose fit (Radius Head Component by Link)	Metal	Modular	NR	NR	115	0	0	NR	NR
Doornberg et al. (2007) [25]	USA	IV	Retrospective	NR	27	10	40	52	13	14	Fractures only	Unfixed: smooth intentional loose fit (Evolve by Wright)	Metal	Modular	85.0	17.0	111	2	0.1	7	NR
Chien et al. (2010) [26]	Taiwan	IV	NR	2002–2008	13	0	38.3	37	9	4	Heterogeneous population	Unfixed: smooth intentional loose fit (Evolve by Wright Med)	Metal	Modular	86.9	NR	120.3	0	0	2	0.2
Muhm et al. (2011) [27]	Germany	NR	Retrospective	2001–2009	25	0	61.2	59	12	13	Heterogeneous population	Unfixed: smooth intentional loose fit (Evolve)	Metal	Modular	85.2	24.9	111.6	NR	NR	5	0.2
Chen et al. (2011) [28]	China	NR	Prospective	2004–2007	22	0	33.6	-	34	11	Heterogeneous population	Unfixed: uncemented loose fit (Wright Medical Technology)	Titanium	Modular	92.1	NR	NR	NR	NR	3	0.1
Watters et al. (2014) [29]	USA	NR	Retrospective	1996–2008	30	4	24	48	16	14	Terrible Triad injuries	Unfixed: smooth intentional loose fit (Evolve)	Metal	Modular	90.0	15.7	106	3	0.1	2	0.1
Moghaddam et al. (2016) [30]	Germany	IV	Retrospective	2001–2009	85	10	41.5	55.9	35	40	Fractures only	Unfixed: smooth intentional loose fit (Evolve)	Metal	Modular	83.3	26.1	119.2	3	0	18	0.2
Yan et al. (2015) [31]	China	NR	Prospective	2005–2008	20	0	36	37	11	9	Fractures only	Unfixed: smooth intentional loose fit, uncemented (Radius Head Component by Link)	Metal	Monoblock	85.8	NR	101.4	1	0.1	4	0.2
Marsh et al. (2016) [32]	Canada	III	Retrospective	2000–2008	55	17	98	61	21	34	Heterogeneous population	Unfixed: smooth intentional loose fit (Evolve by Wright Med)	Metal	Modular	91.0	NR	126	0	0	NR	NR
Monopolar results (sum)					565	72	40.2	50.0	293	293					86.67	17.90	119.37	23	4.07	111	19.65

MEPS: Mayo Elbow Performance Score, DASH: Disability of the Arm, Shoulder, and Hand, NR: not recorded.

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Table 2. Outcomes of bipolar cohort

Study	Country	Level of evidence (I–V)	Study design	Inclusion period	Number of patients	Number of patients lost to follow-up	Mean follow-up (mo)	Mean age (yr)	Male	Female	Indication	Type of fixation	Material type	Modularity	MEPS	DASH score	Flexion/extension arc (°)	Revision	Revision rate (%)	Complication	Complication rate (%)
Brinkman et al. (2005) [8]	Holland	IV	Restrospective	1999–2003	11	0	24	43	8	3	Fractures only	Fixed: cemented (Judet CRF II by Tornier)	Metal	Modular	NR	NR	NR	2	0.2	4	0.4
Dotzis et al. (2006) [33]	France	IV	Restrospective	1992–2003	12	2	63	44.8	10	4	Fractures only	Fixed: cemented (Judet by Tornier)	Metal	Modular	NR	23.9	126	0	0.0	1	0.1
Popovic et al. (2007) [34]	Belgium	NR	Prospective	1994–2001	51	4	101	51	32	19	Fractures only	Fixed: cemented (Judet by Tornier)	Metal	Modular	83.0	NR	112	1	0	NR	NR
Burkhart et al. (2010) [35]	Germany	IV	Restrospective	1997–2000	17	2	106	44.1	14	3	Heterogeneous population	Fixed: cemented (Judet by Tornier)	Metal	Modular	90.8	9.8	103	1	0.1	NR	NR
Celli et al. (2010) [36]	Italy	IV	Restrospective	2000–2007	16	0	41.7	46.1	11	5	Fractures only	Fixed: cemented (Judet by Tornier)	Metal	Modular	89.4	11.4	117	0	0	7	0.4
Allavena et al. (2014) [37]	France	IV	Restrospective	2002–2008	22	0	50	44	15	7	Terrible Triad injuries	Fixed: cemented (Guepar by DePuy)	Metal	Modular	79.0	NR	100	6	0.3	14	0.6
Heijink et al. (2016) [14]	Netherlands	IV	Retrospective	2005–2012	25	1	50	55	7	18	Fractures only	Fixed: cemented	Metal	Modular	89.6	NR	129	1	0	7	0.3
Kodde et al. (2016) [38]	Netherlands	IV	Retrospective	2007–2011	30	3	48	48	9	21	Fractures only	Fixed: cemented (Judet by Tornier)	Metal	Modular	87.9	NR	126	3	0.1	11	0.4
Viveen et al. (2017) [39]	Netherlands	IV	Prospective	2006–2013	16	0	75	49	2	14	Fractures only	Fixed: cemented (Judet by Tornier)	Metal	Modular	83.1	NR	127	0	0	5	0.5
Zunkiewicz et al. (2012) [10]	USA	IV	Restrospective	2004–2006	30	4	34	NR	13	21	Heterogeneous population	Unfixed: smooth intentional loose fit (Katalyst)	Metal	Modular	92.0	13.8	126	2	0.1	NR	NR
Berschback et al. (2013) [19]	USA	IV	Retrospective	2004–2010	14	7	33	46	6	8	Essex-Lopresti injuries	Unfixed: smooth intentional loose fit (Katalyst by Integra)	Metal	Modular	92.0	14.6	121	NR	NR	NR	NR
Bipolar group (sums)					244	23	56.9	47.1	127	123					87.4	14.7	118.7	16	6.56	49	20.08

MEPS: Mayo Elbow Performance Score, DASH: Disability of the Arm, Shoulder, and Hand, NR: not recorded.

Table 3. Cohort comparisons in regards to functional and clinical outcomes

Variable	Monopolar	Bipolar	95% CI	P-value
Follow-up (mo)	40.2 ± 16.2	56.9 ± 27.0	-	-
MEPS	86.7 ± 5.8	87.4 ± 4.6	–5.0 to 3.5	0.801
DASH score	17.9 ± 6.0	14.7 ± 5.5	–3.8 to 10.2	0.472
Flexion/extension arc (°)	119.4 ± 13.2	118.7 ± 10.5	–8.5 to 9.8	0.477
Revision rate (relative risk)	0.62	1.61	0.86 to 2.99	0.132
Complication rate (relative risk)	0.98	1.02	0.76 to 1.38	0.886

Values are presented as mean ± standard deviation unless otherwise indicated.
CI: confidence interval, MEPS: Mayo Elbow Performance Score, DASH: Disability of the Arm, Shoulder, and Hand.

DISCUSSION

Radial head arthroplasty involves several procedural variables, including the design option of using a non-articulating, "mono-" or "unipolar" implant versus a jointed, “bipolar” implant. While some studies support bipolar prostheses [2,4,10,36], citing their more congruent, dynamic capitellar articulation, others report their heightened incidence of unique complications and suboptimal performance compared to monopolar [2,3,6,40-42]. The purpose of this study was to determine if any significant advantage is offered by either implant in terms of functional outcomes, revision, and complications. Our data suggest that there is not.

Several investigations support the apparent clinical equivalency of monopolar and bipolar prosthetic design. Rotini et al. [5] noted no differential superiority when comparing results functionally, clinically, and radiographically at 2 years of follow-up. Berschback et al. [19] found no significant difference in terms of motion, strength, pain, and functional outcome. Others [7,8,10,35,36] have noted satisfactory to promising outcomes in consistent case series of bipolar RHA prostheses over 2- to 9-year follow-up. Notably, Sershon et al. [43] have recently reported 16 bipolar arthroplasty cases with excellent 10-year results in terms of functional outcomes, range of motion, stability, and implant survivability.

However, some cadaveric investigations suggest challenges with the performance of bipolar articulation at the radiocapitellar joint. For example, Moon et al. [6] suggest a bipolar implant’s propensity for dislocation by demonstrating their lower force requirement before posterior subluxation compared to both monopolar prostheses and anatomic radial heads. These results correlate with those of Chanlalit [41,42], although their specimens were compromised by significant soft tissue dissection. Given these biomechanical findings, many surgeons are concerned about radiocapitellar instability and potential dislocation as a unique complication of the bipolar design [2]. The quality of lateral collateral ligament repair and soft tissue balancing is difficult to control in clinical studies. As a result, this point is a distinct limitation when attempting to differentiate superiority of one polarity design over another.

While indications for radial head arthroplasty may play a role in implant outcomes, a study from Antoni et al. [1] that investigated polarity in the setting of fracture dislocations found no differences in outcomes between those with terrible triad injuries, Monteggia type injuries, transolecranon dislocations, and divergent dislocations. They found no differences at over two years of follow-up of 18 patients treated with bipolar implants and 40 with monopolar implants for stability, complications, revision rates, range of motion, MEPS, and radiographic parameters. Their findings are similar to those of this study, further supporting some role of indications such as concurrent dislocation. They did observe a correlation between high implant positioning and postoperative instability (P = 0.022) as well as the need for revision surgery (P = 0.021) in both groups, suggesting that surgical technique may be the most important factor when addressing injuries. Our data support this, indicating that surgeon familiarity should be the deciding factor in the absence of observed implant outcome differences.

Limitations do exist in this study. Publication bias may have been introduced by using English-only, full-text articles. Selection bias may exist as some studies may have been unintentionally omitted during article collection. Heterogeneity in data reporting, technique, indications, and follow-up inevitably skews statistical calculations. Specifically, as several implant designs limit variability in fixation technique, polarity, and component material, these variables may inherently confound one another.

CONCLUSIONS

In conclusion, our meta-analysis did not demonstrate significant differences in functional outcomes, complication rates, and revision rates between monopolar and bipolar radial head arthroplasty irrespective of indication. A multicenter prospective control trial is needed to conclude if there are true differences between these implant types.

NOTES

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Conflict of interest

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Data availability

None.

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