



**HAL**  
open science

## The minimum follow-up required for radial head arthroplasty

Pierre Laumonerie, Nicolas Reina, Panagiotis Kerezoudis, Stéphanie Delclaux,  
Meagan E. Tibbo, Nicolas Bonneville, Pierre Mansat

► **To cite this version:**

Pierre Laumonerie, Nicolas Reina, Panagiotis Kerezoudis, Stéphanie Delclaux, Meagan E. Tibbo, et al.. The minimum follow-up required for radial head arthroplasty. *The Bone & Joint Journal (BJJ)*, 2017, 99-B (12), pp.1561-1570. 10.1302/0301-620X.99B12.BJJ-2017-0543.R2 . hal-02134587

**HAL Id: hal-02134587**

**<https://hal.science/hal-02134587v1>**

Submitted on 20 May 2019

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.





## Open Archive Toulouse Archive Ouverte (OATAO)

OATAO is an open access repository that collects the work of some Toulouse researchers and makes it freely available over the web where possible.

This is an author's version published in: <https://oatao.univ-toulouse.fr/23064>

**Official URL :** <https://doi.org/10.1302/0301-620X.99B12.BJJ-2017-0543.R2>

### To cite this version :

Laumonerie, Pierre and Reina, Nicolas and Kerezoudis, Panagiotis and Delclaux, Stéphanie and Tibbo, Meagan E. and Bonneville, Nicolas  and Mansat, Pierre  *The minimum follow-up required for radial head arthroplasty.* (2017) *The Bone & Joint Journal*, 99-B (12). 1561-1570. ISSN 2049-4394

Any correspondence concerning this service should be sent to the repository administrator:

[tech-oatao@listes-diff.inp-toulouse.fr](mailto:tech-oatao@listes-diff.inp-toulouse.fr)

# The minimum follow-up required for radial head arthroplasty

## A META-ANALYSIS

P. Laumonerie,  
N. Reina,  
P. Kerezoudis,  
S. Declaux,  
M. E. Tibbo,  
N. Bonneville,  
P. Mansat

*From Hôpital Pierre-Paul Riquet,  
Toulouse, France*

### Aims

The primary aim of this study was to define the standard minimum follow-up required to produce a reliable estimate of the rate of re-operation after radial head arthroplasty (RHA). The secondary objective was to define the leading reasons for re-operation.

### Materials and Methods

Four electronic databases, between January 2000 and March 2017 were searched. Articles reporting reasons for re-operation (Group I) and results (Group II) after RHA were included. In Group I, a meta-analysis was performed to obtain the standard minimum follow-up, the mean time to re-operation and the reason for failure. In Group II, the minimum follow-up for each study was compared with the standard minimum follow-up.

### Results

A total of 40 studies were analysed: three were Group I and included 80 implants and 37 were Group II and included 1192 implants. In Group I, the mean time to re-operation was 1.37 years (0 to 11.25), the standard minimum follow-up was 3.25 years; painful loosening was the main indication for re-operation. In Group II, 33 Group II articles (89.2%) reported a minimum follow-up of < 3.25 years.

### Conclusion

The literature does not provide a reliable estimate of the rate of re-operation after RHA. The reproducibility of results would be improved by using a minimum follow-up of three years combined with a consensus of the definition of the reasons for failure after RHA.

■ P. Laumonerie, MD,  
Orthopaedic Surgeon  
■ N. Reina, MD, PhD,  
Orthopaedic Surgeon  
■ S. Declaux, MD,  
Orthopaedic Surgeon  
■ N. Bonneville, MD, PhD,  
Orthopaedic Surgeon  
■ P. Mansat, MD, PhD,  
Orthopaedic Surgeon  
Institut Locomoteur, Hôpital  
Pierre-Paul Riquet, Place du Dr  
Baylac, TSA 40 031, Toulouse  
31059, France.

■ P. Kerezoudis, MD,  
Neurosurgeon  
■ M. E. Tibbo, MD, Orthopaedic  
Surgeon  
Mayo Clinic, 1216 2nd Street  
SW, Rochester, Minnesota  
55905, USA.

Correspondence should be sent  
to P. Laumonerie; email:  
laumonerie.pierre@hotmail.fr

One-third of fractures involving the elbow joint affect the radial head<sup>1,2</sup> and the treatment of Mason III fractures remains controversial.<sup>3-10</sup> Open reduction and internal fixation is the standard treatment for comminuted fractures of the proximal radius,<sup>3-7</sup> whilst arthroplasty or simple resection of the radial head are alternatives.<sup>3,4,6,8-15</sup> Resection of the radial head yields satisfactory long-term results.<sup>12-17</sup> The alteration of the kinematics of the elbow and forearm and self-perpetuating cycle of degenerative changes can result from other factors (increasing pressure on the ulna for example) than progressive valgus instability, radial ascent and secondary ulnocarpal injury.<sup>16-20</sup> In the presence of associated ligamentous injury, radial head arthroplasty (RHA) can give better results.<sup>9,18-24</sup> Reconstruction of the lateral column through RHA permits the maintenance of the normal axis of the elbow and reduces the risk of degenerative arthritis in both the elbow and wrist joints.<sup>10,25</sup> RHA is therefore an alternative choice for the treatment of acute and

chronic proximal radial fractures.<sup>4-6,11,26</sup> Heijink et al<sup>27</sup> in a systematic review, reported that the medium- and long-term functional results after RHA were good to excellent in 85% of patients using the Mayo Elbow performance score. Recently, variable complication rates have been reported, including rates of re-operation ranging from 0% to 29% after RHA.<sup>27-30</sup> However, the indications for further surgery have rarely been described.<sup>27</sup> Van Riet et al<sup>30</sup> stated that painful loosening was the main reason for failure of RHA. The low numbers in the studies, the lack of a standardised classification of the reason for failure and the plurality of methodologies used have prevented reproducible studies of RHA.

The primary objective of this study was to define the minimum follow-up required to analyse the complications of RHA. The hypothesis was that the minimum follow-up in the published series was inadequate. The secondary objective was to establish clear definitions for

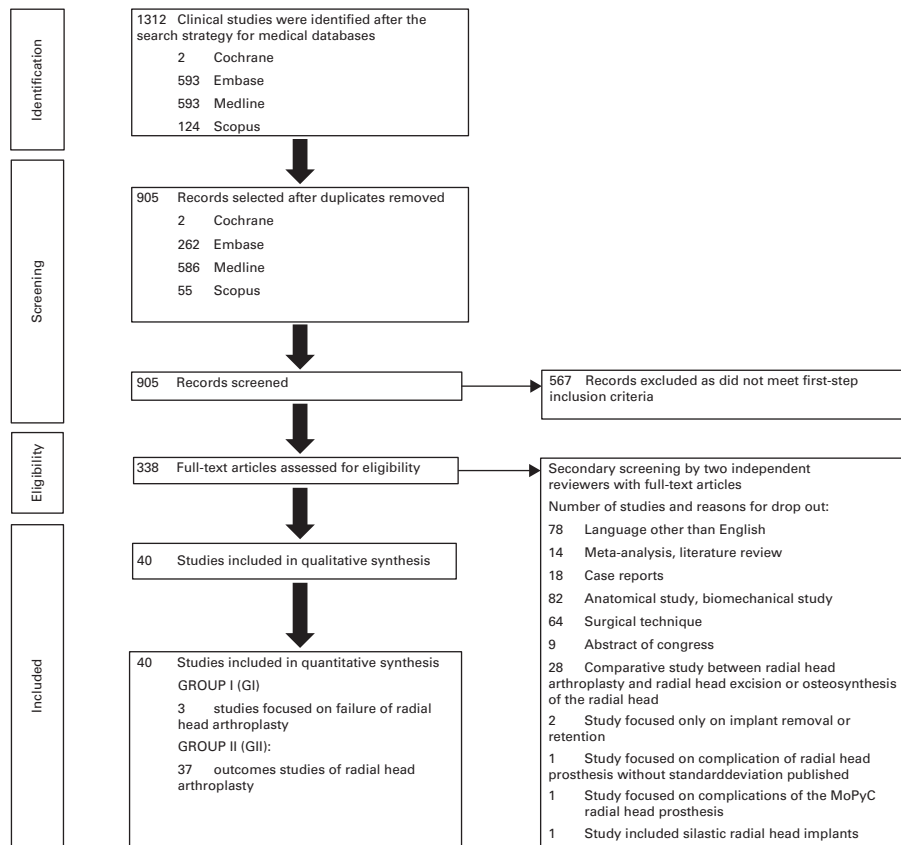


Fig. 1

Summary of search strategy (Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart) for relevant studies on minimum follow-up of radial head arthroplasty and the indications for re-operation.

the reasons for failure of RHA with the hypothesis that painful loosening was the main reason for re-operation.

## Materials and Methods

A literature search was performed using Ovid Medline, Ovid Embase, Scopus and Cochrane Library and the Medical Subject Headings vocabulary. The search was limited to English language literature. The following terms were combined with 'AND' and 'OR': 'radial head'; 'arthroplasty'; 'prosthesis'; 'radial head prosthesis'; and 'radial head arthroplasty'. The references in each study were reviewed to identify additional articles corresponding to the research criteria. Inclusion criteria involved studies that addressed failure of RHA and described the reasons for removal of the implant and those reporting the clinical and radiographical outcomes of RHA, published between January 2000 and March 2017.

Exclusion criteria were; biomechanical and anatomical studies, meta-analyses and systematic reviews, case reports, abstracts and studies comparing RHA and other forms of treatment. Studies which did not report the mean time between the initial surgery and re-intervention were excluded as were those that focused on implant-specific complications or those that included silastic radial head

implants (Silastic Swanson Radial Head Implant; Dow Corning Corporation, Midland, Michigan). Data were extracted from manuscripts, tables and figures. Two investigators (PL, NR) independently reviewed the text of all eligible articles, disagreement being resolved with discussion and consensus. When information was incomplete, the corresponding authors of the articles were contacted.

Articles were divided into those related only to the reasons for removal of the implant (complete exchange, exchange of the acetabular component alone or conversion to a radio-capitellar prosthesis) and re-operation with retention of the implant (Group I). Gathering comprehensive data from each study for all patients in this group allowed for meta-analysis of the cohorts as a single group. These data were: age, gender, removal, re-operation with (or without) removal of the implant, failure, follow-up to re-operation and reasons for failure. Group II articles included those reporting the clinical and radiographic outcomes of RHA. A description of the results from Groups I and II comprised the total number of RHAs, re-operations with removal or retention of the implant. The design of the implant (bipolar or monopolar) and the timing of the re-operation (acute or delayed) were also reported for both groups. The double standard deviation of the mean time to

**Table I.** Patient characteristics of articles reporting re-operations for failed radial head arthroplasty (Group I)

|  | Duckworth et al <sup>37</sup> | Kachooei et al <sup>38</sup> | Laumonerie et al <sup>39</sup> | Overall         |
|--|-------------------------------|------------------------------|--------------------------------|-----------------|
| Country of principal institution                                     | United Kingdom                | United States                | France                         | N/A             |
| Date of inclusion  | 1994 to 2010                  | 2000 to 2014                 | 2002 to 2015                   | 1994 to 2015    |
| Year of publication  | 2014                          | 2016                         | 2016                           | N/A             |
| Study design   | Retrospective, single-centre  | Retrospective, single-centre | Retrospective, single-centre   | N/A             |
| Patients (n)   | 29                            | 22                           | 29                             | 80              |
| Male (n)   | 12                            | 11                           | 22                             | 45              |
| Female (n)   | 17                            | 11                           | 7                              | 35              |
| Mean age (yrs, range)  | 44.4 (16 to 93)               | 49.6 (23 to 64)              | 50.4 (20 to 73)                | 48.1 (16 to 93) |
| Acute application (n)  | 29                            | 22                           | 18                             | 69              |
| Delayed application (n)  | 0                             | 0                            | 11                             | 11              |
| <b>Associated lesions (n)</b>  |                               |                              |                                |                 |
| Terrible triad   | 2                             | 10                           | 13                             | 25              |
| Essex-Lopresti   | 1                             | 0                            | 1                              | 2               |
| Monteggia or olecranon fractures                                     | 9                             | 11                           | 10                             | 30              |
| Ligamentous injury (medial or lateral collateral ligament)           | 5                             | 13                           | 11                             | 29              |
| None   | 11                            | 4                            | 10                             | 25              |
| <b>Radial head implant (n)</b>                                       | 29                            | 22                           | 29                             | 80              |
| Monopolar design   | 29                            | 22                           | 0                              | 51              |
| Bipolar design   | 0                             | 0                            | 29                             | 29              |
| Tight-fitting implant anchorage, overall                             | 29                            | 5                            | 29                             | 63              |
| Tight-fitting implant anchorage, cemented                            | 29                            | 0                            | 29                             | 58              |
| Tight-fitting implant anchorage, press-fit                           | 0                             | 5                            | 0                              | 5               |
| Loose-fitting implant anchorage                                      | 0                             | 17                           | 0                              | 17              |
| <b>Causes of re-operation with removal of the implant (n)</b>        | <b>26</b>                     | <b>18</b>                    | <b>18</b>                      | <b>62</b>       |
| Painful loosening  | 5                             | 3                            | 13                             | 21              |
| Persistent stiffness   | 12                            | 6                            | 0                              | 18              |
| Humero-radial conflict   | 0                             | 5                            | 4                              | 9               |
| Isolated diffuse pain  | 6                             | 0                            | 0                              | 6               |
| Deep infection   | 1                             | 2                            | 0                              | 3               |
| Clinical instability   | 0                             | 1                            | 1                              | 2               |
| Synovitis  | 2                             | 0                            | 0                              | 2               |
| Painful heterotopic ossification (normal ROM)                        | 0                             | 1                            | 0                              | 1               |
| <b>Indication for re-operation with retention of the implant (n)</b> | <b>5</b>                      | <b>4</b>                     | <b>11</b>                      | <b>20</b>       |
| Clinical instability   | 0                             | 1                            | 6                              | 7               |
| Persistent stiffness   | 0                             | 2                            | 1                              | 3               |
| Subluxation of the radial head                                       | 3                             | 0                            | 0                              | 3               |
| Ulnar nerve palsy  | 2                             | 0                            | 3                              | 5               |
| Painful loosening  | 0                             | 1                            | 0                              | 1               |
| Humero-radial conflict   | 0                             | 0                            | 1                              | 1               |

N/A, not applicable; ROM, range of movement

re-operation in Group I (2SDGI) was used as the reference minimum follow-up for the analysis of complications. Comparison of the 2SDGI with the minimum follow-up in each article in Group II was performed to test the primary hypothesis. The reasons for re-operation and the mean time to re-operation with removal or retention of the implant in Group I were analysed to validate the secondary hypothesis.

**Statistical analysis.** We used independent *t*-tests or Wilcoxon-Rank Sum tests and chi-squared or Fisher's Exact tests to compare continuous and categorical variables respectively, in correlation with the type of implant (bipolar or monopolar). We calculated the weighted proportions for the following pre-and post-operative variables: inclusion of acute injuries, percentage inclusion of delayed injuries, rates of removal, rates of revision and re-operation. In order to account for anticipated heterogeneity in the studies, we used a random effects DerSimonian-Laird

model.<sup>31,32</sup> Heterogeneity was evaluated using Cochran *I*<sup>2</sup> test. Confidence intervals (CI) were fixed at 95%. Publication bias regarding the rate of re-operation following RHA was assessed after constructing a funnel plot of the Logit of the rate of re-operation against its standard error. Asymmetry at the bottom of the plot, i.e. higher concentration of studies on one side of the mean rate of re-operation than on the other, is suggestive of publication bias.<sup>33</sup> Statistical significance was set at *p* < 0.05. For the purposes of the statistical analysis as well as the design of the figures, two commercially available softwares were used: JMP (JMP Version 11, SAS Institute Inc., Cary, North Carolina) and Comprehensive Meta-analysis (Biostat, Englewood, New Jersey).

## Results

A total of 1312 studies were initially identified. After exclusion of duplicates and irrelevant articles, 339 eligible

**Table II.** Patient characteristics of articles reporting follow-up of radial head arthroplasty (Group II)

| Authors                        | Year of publication | Type of study | Acute cases, n (%) | Delayed cases, n (%) | Re-operations, n (%) |
|--------------------------------|---------------------|---------------|--------------------|----------------------|----------------------|
| Tarallo et al <sup>43</sup>    | 2017                | Monopolar     | 31 (100)           | 0 (0)                | 0 (0)                |
| Gauci et al <sup>44</sup>      | 2016                | Bipolar       | 26 (60.46)         | 17 (39.53)           | 8 (18.60)            |
| Moghaddam et al <sup>45</sup>  | 2016                | Monopolar     | 75 (100)           | 0 (0)                | 5 (6.67)             |
| Marsh et al <sup>42</sup>      | 2016                | Monopolar     | 55 (100)           | 0 (0)                | 0 (0)                |
| Levy et al <sup>46</sup>       | 2016                | Monopolar     | 15 (100)           | 0 (0)                | 4 (26.67)            |
| Kodde et al <sup>47</sup>      | 2016                | Bipolar       | 5 (18.52)          | 22 (81.48)           | 8 (29.63)            |
| Heijink et al <sup>48</sup>    | 2016                | Bipolar       | 8 (33.33)          | 16 (66.67)           | 2 (8.33)             |
| Abdulla et al <sup>49</sup>    | 2015                | Bipolar       | 21 (100)           | 0 (0)                | 0 (0)                |
| Laun et al <sup>50</sup>       | 2015                | Bipolar       | 12 (100)           | 0 (0)                | 0 (0)                |
| Mou et al <sup>51</sup>        | 2015                | Monopolar     | 12 (100)           | 0 (0)                | 0 (0)                |
| Allavena et al <sup>52</sup>   | 2014                | Bipolar       | 16 (72.72)         | 6 (27.27)            | 10 (45.00)           |
| Berschback et al <sup>53</sup> | 2013                | Bi-monopolar  | 27 (100)           | 0 (0)                | 2 (7.40)             |
| El Sallakh <sup>54</sup>       | 2013                | Monopolar     | 12 (100)           | 0 (0)                | 0 (0)                |
| Sarris et al <sup>55</sup>     | 2013                | Bipolar       | 30 (93.75)         | 2 (6.25)             | 2 (6.25)             |
| Ricón et al <sup>56</sup>      | 2012                | Bipolar       | 28 (100)           | 0 (0)                | 5 (17.85)            |
| Zunkiewicz et al <sup>57</sup> | 2012                | Bipolar       | 23 (76.67)         | 7 (23.30)            | 2 (6.67)             |
| Katthagen et al <sup>58</sup>  | 2012                | Monopolar     | 16 (51.51)         | 15 (48.39)           | 6 (19.35)            |
| Rotini et al <sup>59</sup>     | 2012                | Bipolar       | 11 (35.48)         | 20 (64.51)           | 2 (6.45)             |
| Ha et al <sup>60</sup>         | 2012                | Bi-monopolar  | 243 (94.18)        | 15 (5.81)            | 62 (24.02)           |
| Muhm et al <sup>61</sup>       | 2011                | Monopolar     | 25 (100)           | 0 (0)                | 0 (0)                |
| Maghen et al <sup>62</sup>     | 2011                | Monopolar     | 21 (91.30)         | 2 (8.87)             | 6 (26.09)            |
| Lamas et al <sup>63</sup>      | 2010                | Bipolar       | 47 (100)           | 0 (0)                | 3 (6.38)             |
| Celli et al <sup>64</sup>      | 2010                | Bipolar       | 16 (100)           | 0 (0)                | 0 (0)                |
| Burkhart et al <sup>41</sup>   | 2010                | Bipolar       | 9 (52.94)          | 8 (47.06)            | 1 (5.88)             |
| Fehringer et al <sup>65</sup>  | 2009                | Monopolar     | 17 (100)           | 0 (0)                | 0 (0)                |
| Shore et al <sup>66</sup>      | 2008                | Monopolar     | 0 (0)              | 32 (100)             | 0 (0)                |
| Lim and Chan <sup>67</sup>     | 2008                | Bipolar       | 6 (100)            | 0 (0)                | 0 (0)                |
| Doornberg et al <sup>68</sup>  | 2007                | Monopolar     | 27 (100)           | 0 (0)                | 7 (25.92)            |
| Popovic et al <sup>40</sup>    | 2007                | Bipolar       | 51 (100)           | 0 (0)                | 1 (1.96)             |
| Wretenberg et al <sup>69</sup> | 2006                | Monopolar     | 22 (100)           | 0 (0)                | 5 (22.73)            |
| Dotzis et al <sup>70</sup>     | 2006                | Bipolar       | 12 (85.71)         | 2 (14.29)            | 1 (7.14)             |
| Chapman et al <sup>71</sup>    | 2006                | Monopolar     | 8 (50.00)          | 8 (50.00)            | 0 (0)                |
| Grewal et al <sup>72</sup>     | 2006                | Monopolar     | 26 (100)           | 0 (0)                | 1 (3.84)             |
| Brinkman et al <sup>73</sup>   | 2005                | Bipolar       | 0 (0)              | 11 (100)             | 2 (18.18)            |
| Harrington et al <sup>74</sup> | 2001                | Monopolar     | 20 (100)           | 0 (0)                | 4 (20.00)            |
| Moro et al <sup>10</sup>       | 2001                | Monopolar     | 25 (100)           | 0 (0)                | 0 (0)                |
| Popovic et al <sup>75</sup>    | 2000                | Bipolar       | 11 (100)           | 0 (0)                | 0 (0)                |

articles were identified. After detailed evaluation of the articles, 40 observational studies were included in the analysis and divided into two groups. Group I comprised three observational studies assessing failures of RHA requiring re-operation with removal or retention of the implant. Four single-centre retrospective studies dedicated exclusively to complications after RHA were excluded. Two of these did not include patients who underwent re-operation with retention of the implant.<sup>30,34</sup> One did not publish the standard deviation of their data<sup>35</sup> and one only discussed the complications associated with the MoPyC pyrocarbon radial head implant (Bioprofile-Tornier, Cedex, France).<sup>36</sup> Group II comprised of 37 observational studies reporting the clinical and radiographic outcomes of RHA (Fig. 1).

Group I included 80 patients (45 men and 35 women, mean age 48 years (18 to 73)) requiring re-operation; 63 implants were removed and 17 were retained. Two patients from Duckworth et al's<sup>37</sup> series required re-operation because of an ulnar nerve palsy and pain which were

treated by revision of the implant and ulnar neurolysis (Table I).<sup>37-39</sup>

Group II included 1174 patients (635 men and 539 women) with a mean age of 48.72 years (26 to 61). Out of 1192 implants, 696 were monopolar and 496 were bipolar. A total of 1009 RHAs were performed for acute injuries (90% (0% to 100%)) and 183 for chronic lesions or post-traumatic sequelae (10% (0% to 100%)) (Table II).<sup>10,40-75</sup> The mean rate of re-operation was 9.7% (0% to 45%) (Fig. 2); the mean rates of removal and retention of the implant were 3.8% (0% to 22.7%) and 6.13% (0% to 27.3%), respectively. The rates of acute injury ranged from 0% to 100% (pooled proportion (PP) 0.90, 95% CI 0.78 to 0.93,  $I^2 = 54.80\%$ ). The rates of chronic injury ranged from 0% to 100% (PP 0.10, 95% CI 0.07 to 0.21,  $I^2 = 54.8\%$ ). The rates of re-operation ranged from 0% to 45% (PP 0.10, 95% CI 0.09 to 0.16,  $I^2 = 9.46\%$ ). The rates of removal of the implant ranged from 0% to 27.3% (PP 0.04, 95% CI 0.05 to 0.10;  $I^2 = 54.5\%$ ) and the rates of retention of the

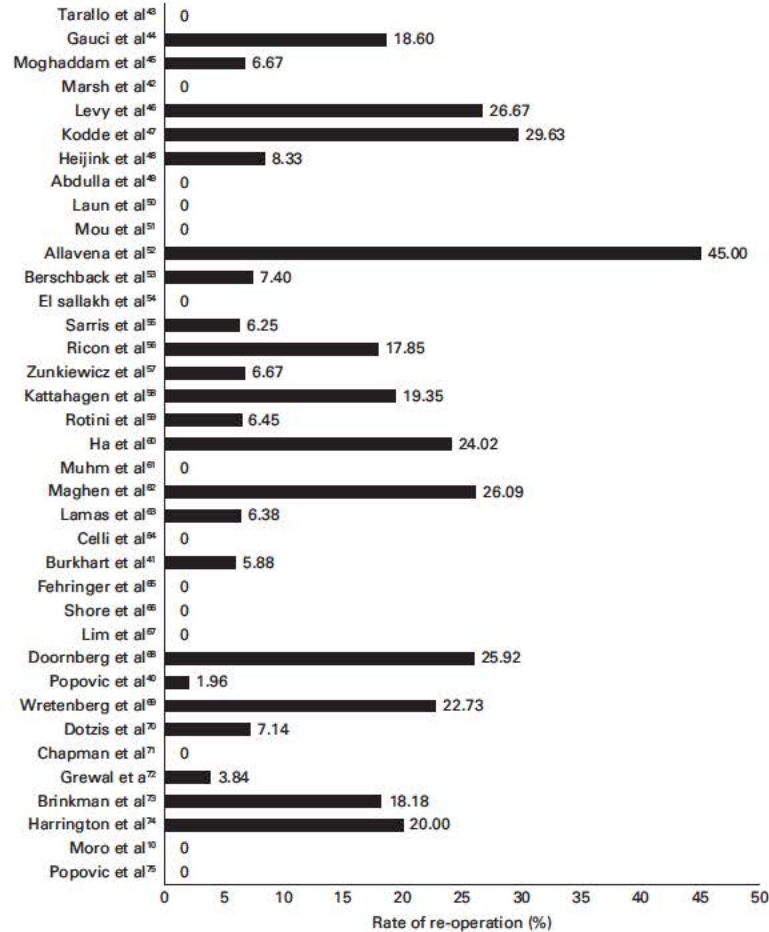


Fig. 2

Rate of re-operation in 37 articles (Group II) describing the outcomes of radial head arthroplasty published between January 2000 and March 2017.

implant ranged from 0% to 22.7% (PP 0.06, 95% CI 0.06 to 0.11,  $I^2 = 51.1\%$ ) respectively. Based on the  $I^2$  value there was moderate heterogeneity between the included studies.

The mean time to re-operation for the patients in Group I was 1.37 years (0 to 11.2). The reference minimum follow-up (2SDGI) in these studies was 3.25 years. The mean time to removal was significantly greater than the mean time to re-operation with retention of the implant: 1.7 years (0 to 11.2) versus 0.3 years (0.02 to 1.08), respectively (95% CI 0.84 to 1.79,  $p = 0.001$ ).

A total of 33 Group II articles (89.2%) included patients with < 3.25 years of minimum follow-up (Fig. 3). The mean minimum follow-up was 1.74 years (0.08 to 6.5). The minimum follow-up for each Group II article is shown in Figure 3. The mean follow-up for Group II articles was 3.9 years (1.0 to 12.1).

The three main reasons for re-operation in Group I articles were painful loosening (22), persistent stiffness (21) and humero-radial conflict (ten). The primary reasons for removal and revision were painful loosening (21) and instability (seven) (Table I; Fig. 4). Diagnostic criteria for the

four most common complications are shown in Table III and form the basis of a new classification.

**Publication bias.** The funnel plot is shown in Figure 5. There was significant asymmetry at the bottom right side of the plot, meaning a lack of smaller studies with higher rates of re-operation, suggesting potential publication bias.

## Discussion

Following our review of the literature from the 01 January 2000, we found that the outcomes of RHA have generally been reported with a minimum follow-up of < 3.25 months (89.2% of patients in 33 of 37 studies). In order to obtain reproducible results it is important to have a minimum follow-up period and to establish clear definitions of the reasons for failure of RHA.<sup>76</sup> According to the Meta-analysis of the Observational Studies in Epidemiology group, six key points define the methodological qualities of observational studies: 1) clear definition of outcomes; 2) clear definition of the assessment of outcome; 3) an independent assessment of the parameters of outcome; 4) sufficient follow-up; 5) no selective loss during follow-up; and

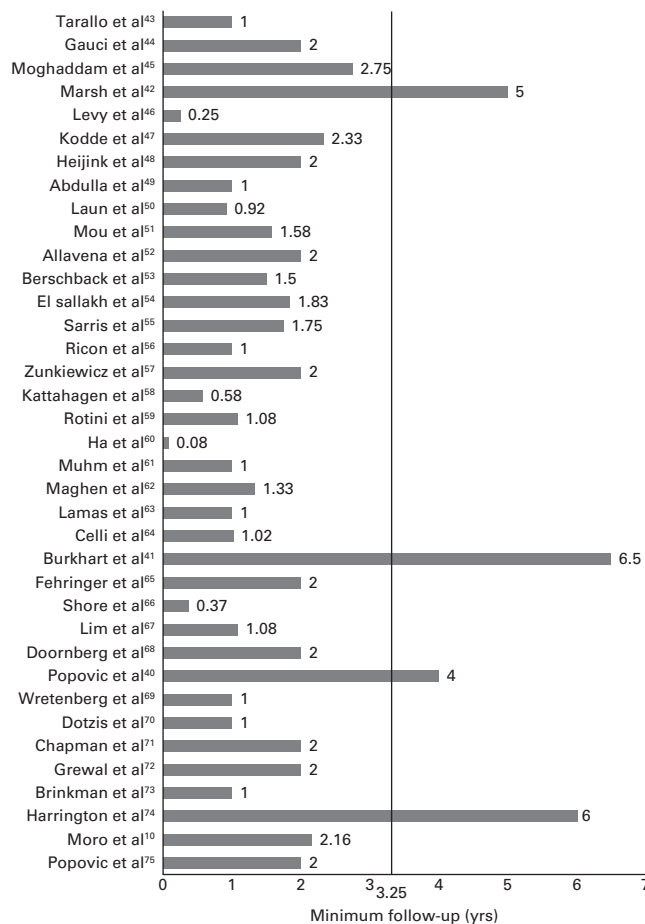


Fig. 3

Minimum follow-up in 37 articles (Group II) describing the outcomes of radial head arthroplasty published between January 2000 and November 2016.

6) the identification of important confounders and prognostic factors.<sup>76</sup>

The current literature underestimates the rate of failure of RHA and smaller studies with higher rates of re-operation are less likely to be published. The heterogeneity of mean and minimum follow-up times in the studies could compromise the reproducibility of the outcomes. We therefore propose a minimum follow-up of 39 months following RHA. Of the four studies with a minimum follow-up of > 39 months,<sup>40-42,74</sup> one reported the reasons for failure of RHA (two minor and one major capitellar wear) beyond the minimum follow-up time.<sup>39</sup> Neuhaus et al<sup>34</sup> in a case series of 14 patients reported that 50% of those that required removal of the implant occurred during the first post-operative year with a mean time of 1.92 years (0.04 to 12). The mean time to re-operation with retention of the implant in our review was 0.28 years (0.02 to 1.08), which was consistent with the literature.<sup>26,27</sup> The time to re-operation with retention of the implant was significantly lower than the time to removal of the implant. The distribution of the reasons for failure was also skewed when patients with too short of a follow-up were included.

Based on the 80 patients in Group I who underwent re-operation, we have devised a new classification system which includes four main modes of failure of an RHA: painful loosening; stiffness; humero-radial conflict and instability. The other reasons for failure were isolated or diffuse pain in the elbow, deep infection, subluxation, synovitis and painful heterotopic ossification with a normal range of movement. We suggest that this new classification will be reproducible.

We were able to confirm that painful loosening is the main indication for re-operation after RHA<sup>29,30,77</sup> which is in agreement with the findings of van Riet et al,<sup>30</sup> although Neuhaus et al<sup>34</sup> were unable to find a significant link between radiographic loosening and persistent pain. We found that the definition of painful loosening described by O'Driscoll and Herald<sup>77</sup> was clear and reproducible. According to biomechanical studies,<sup>78,79</sup> there is an increased risk of painful loosening when using narrow or short stems. The method of anchorage (tight or loose fit, etc.) is also a risk factor. The increased rate of loosening in short-stemmed designs in Group I constituted a confounding bias for the analysis of painful loosening.<sup>39</sup> Laumonerie et al<sup>39</sup>



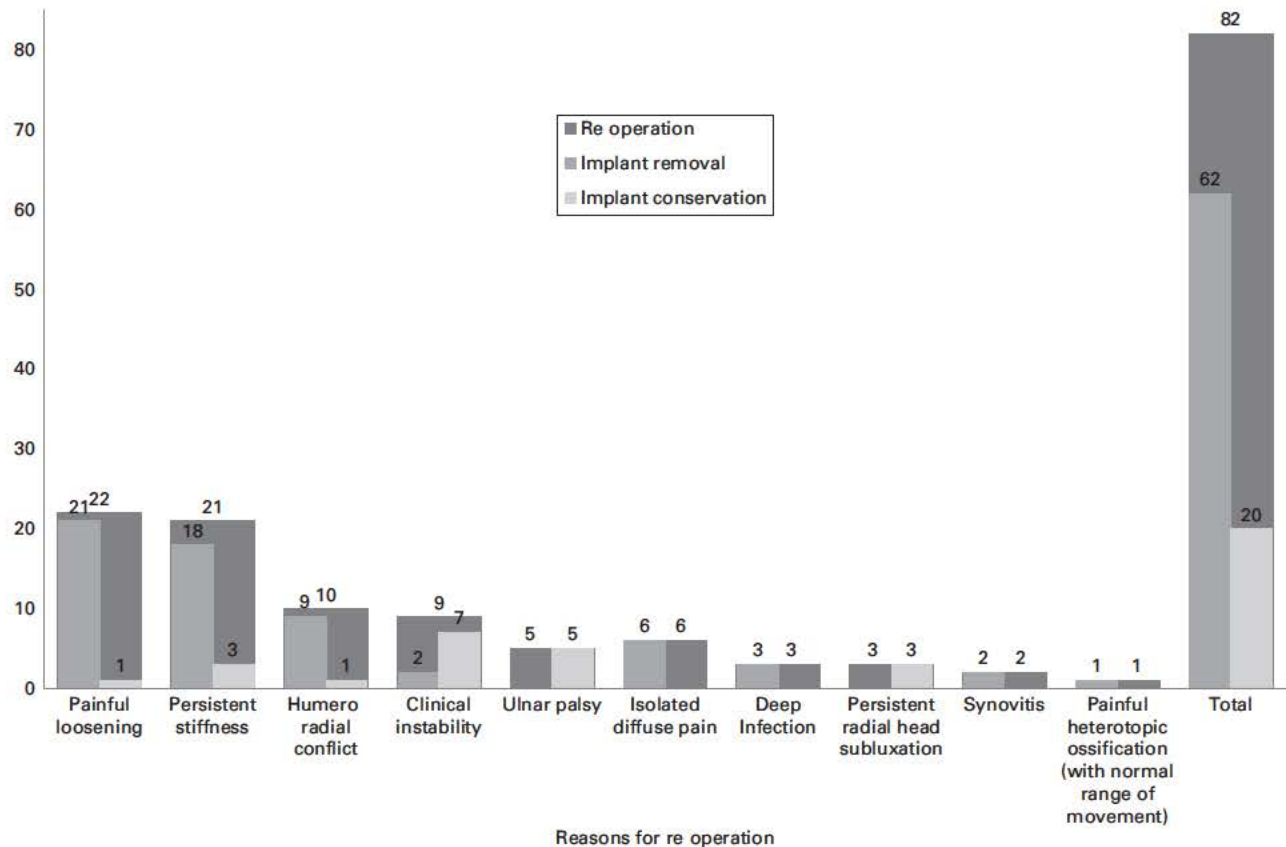


Fig. 4

Indications for re-operation with removal or retention of the implant (Group I).

Table III. Revised nomenclature for failure of radial head implants

| Cause                              | Rate of re-operation (%) | Definition   |
|------------------------------------|--------------------------|--|
| I Painful loosening                | 27.5                     | New type of pain characterised by insidious pain in the proximal radial aspect of the forearm, exacerbated by loading the radiocapitellar joint and relieved by rest; radiographic signs of loosening are not needed |
| II Persistent stiffness            | 26.25                    | Active and passive range of movement limited after radial head arthroplasty  |
| III Humero-radial conflict         | 12.5                     | Persistent pain in the proximal radial aspect of the forearm associated with capitellar osteopenia, capitellar erosion or prosthesis overstuffing  |
| IV Persistent clinical instability | 11.25                    | Clinical instability confirmed by the posterolateral rotatory apprehension test  |

speculated that difficulties in obtaining satisfactory stability when using short stemmed bipolar implants (rHead RECON prosthesis; Stryker-Small Bone Innovation, Morrisville, Pennsylvania) may predispose the surgeon to favour stability over the positioning of the implant.

In our review, instability was the main reason for re-operation with retention of the implant. Biomechanical studies have shown a significantly higher rate of instability in bipolar implants, which has been confirmed in clinical studies although without statistical evidence.<sup>80-82</sup> Moon et al<sup>82</sup> argued that the superior radiocapitellar stability of monopolar devices can be explained by the increased concave compression of the implants.

The implants of choice in patients with an associated ligamentous injury were monopolar,<sup>81-83</sup> although bipolar implants in patients in Group I studies did not depend on soft-tissue integrity.<sup>39</sup> This was an inherent limitation, as a bipolar implant is only used when there is malalignment of the proximal radius with respect to the capitellum. We found a statistically higher rate of re-operation for stiffness among monopolar implants. The causes of stiffness are multifactorial and constitute another confounding bias which was not accounted for in our study. Post-operative stiffness can be affected by the severity of the initial injury, heterotopic ossification, complex regional pain, degenerative changes and/or malpositioning of the implant.<sup>34,38,84-86</sup> However, no

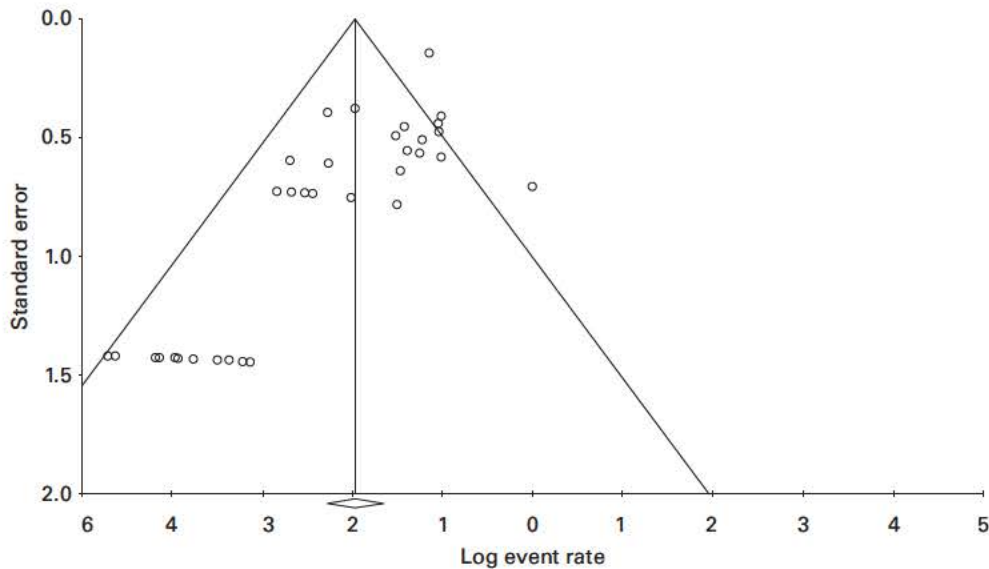


Fig. 5

Funnel plot of the included studies revealing asymmetry at the bottom. Smaller studies with higher rates of re-operation are less likely to be published. The Logit event rate for re-operation (x-axis) is presented against the standard error (y-axis). The standard error inversely corresponds to the sample size of the study.

significant differences in range of movement due to the design of the implant have been reported.<sup>27</sup>

The limitations associated with retrospective single-centre studies are a potential lack of heterogeneity in the sample, loss of data about follow-up and confounding bias. The 80 patients with failure of an RHA in Group I were from three single-centre retrospective studies which could lead to bias in the distribution of complications.<sup>37-39</sup> The selection of 2SDGI as the reference minimum follow-up was made due to the lack of any recommendations for follow-up and the need to reduce the risk of a beta type error for the primary hypothesis. This error would lead to confirming the null hypothesis when it was in fact false, while also rejecting the possibility of a significant complication due to a lack of follow-up. The classification of complications into four main reasons for failure constitutes a bias inherent in research performed using *a posteriori* consensus between two reviewers.

Our proposed standard minimum follow-up was not calculated for the functional outcomes of RHA. Giannicola et al<sup>87</sup> found that functional improvement after RHA progresses in the first post-operative year and then plateaus. Also the lack of data did not permit adjustment of the analysis according to the injuries which may be associated with fractures of the radial head. Clearly a meta-analysis focusing on the risk factors associated with failure of RHA needs to be performed to improve the understanding of the modes of failure.<sup>88-90</sup>

In conclusion, the minimum follow-up of patients who undergo an RHA in the literature is insufficient and we suggest that the rate of re-operation after RHA has been underestimated. The different methodologies used in each study do not allow for an adequate analysis of the results. We would advocate a minimum follow-up of three years to

fully evaluate the complications after RHA. We also propose a new classification of the four main reasons for failure of an RHA, of which painful loosening has been shown to be the primary cause.

#### Take home message:

- The current literature underestimates the failure rate of radial head arthroplasty.
- A minimum follow-up of three years is required to evaluate the complications after RHA.
- There is a new definition for the four main reasons for failure of RHA.

#### Author contributions:

P. Laumonerie: Conception and design, Data acquisition, Analysis and interpretation, Critical revisions, Manuscript review, Statistical analysis, Study supervision.

N. Reina: Conception and design, Data acquisition, Analysis and interpretation, Critical revisions, Manuscript review.

P. Kerezoudis: Data analysis and interpretation, Critical revisions, Manuscript review, Statistical analysis.

S. Declaux: Data analysis and interpretation, Critical revisions, Manuscript review.

M. E. Tibbo: Data analysis and interpretation, Critical revisions, Manuscript review.

N. Bonneville: Data analysis and interpretation, Critical revisions, Manuscript review.

P. Mansat: Conception and design, Data analysis and interpretation, Critical revisions, Manuscript review, Approved final version of paper, Administration, technical and material support, Study supervision.

We would like to thank A. Duckworth for sharing with us the raw data from his study.

N. Reina is a paid consultant for BBraun. N. Bonneville is a paid consultant for DePuy, A Johnson & Johnson Company, GlaxoSmithKline, Sanofi-Ventis and Tornier. P. Mansat is a paid consultant for DePuy, A Johnson & Johnson Company, Synthes, Tornier and Zimmer.

The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other non-profit organisation with which one or more of the authors are associated.

## References

1. Mason ML. Some observations on fractures of the head of the radius with a review of one hundred cases. *Br J Surg* 1954;42:123–132.
2. Kaas L, van Riet RP, Vroemen JPAM, Eygendaal D. The epidemiology of radial head fractures. *J Shoulder Elbow Surg* 2010;19:520–523.
3. Ikeda M, Sugiyama K, Kang C, Takagaki T, Oka Y. Comminuted fractures of the radial head. Comparison of resection and internal fixation. *J Bone Joint Surg [Am]* 2005;87-A:76–84.
4. Pike JM, Athwal GS, Faber KJ, King GJW. Radial head fractures—an update. *J Hand Surg Am* 2009;34:557–565.
5. Charalambous CP, Stanley JK, Mills SP, et al. Comminuted radial head fractures: aspects of current management. *J Shoulder Elbow Surg* 2011;20:996–1007.
6. Ring D. Displaced, unstable fractures of the radial head: fixation vs. replacement—what is the evidence? *Injury* 2008;39:1329–1337.
7. Chen X, Wang SC, Cao LH, et al. Comparison between radial head replacement and open reduction and internal fixation in clinical treatment of unstable, multi-fragmented radial head fractures. *Int Orthop* 2011;35:1071–1076.
8. Wallenböck E, Pötsch F. Resection of the radial head: an alternative to use of a prosthesis? *J Trauma* 1997;43:959–961.
9. Yu SY, Yan HD, Ruan HJ, Wang W, Fan CY. Comparative study of radial head resection and prosthetic replacement in surgical release of stiff elbows. *Int Orthop* 2015;39:73–79.
10. Moro JK, Werier J, MacDermid JC, Patterson SD, King GJ. Arthroplasty with a metal radial head for unreconstructible fractures of the radial head. *J Bone Joint Surg [Am]* 2001;83-A:1201–1211.
11. Zwingmann J, Welzel M, Dovi-Akue D, et al. Clinical results after different operative treatment methods of radial head and neck fractures: a systematic review and meta-analysis of clinical outcome. *Injury* 2013;44:1540–1550.
12. Antuña SA, Sánchez-Márquez JM, Barco R. Long-term results of radial head resection following isolated radial head fractures in patients younger than forty years old. *J Bone Joint Surg [Am]* 2010;92-A:558–566.
13. Iftimie PP, Calmet Garcia J, de Loyola Garcia Forcada I, Gonzalez Pedrouzo JE, Giné Gomà J. Resection arthroplasty for radial head fractures: long-term follow-up. *J Shoulder Elbow Surg* 2011;20:45–50.
14. Faldini C, Nanni M, Leonetti D, et al. Early radial head excision for displaced and comminuted radial head fractures: considerations and concerns at long-term follow-up. *J Orthop Trauma* 2012;26:236–240.
15. Yalcinkaya M, Bagatur AE, Erdogan S, Zorer G. Resection arthroplasty for Mason type III radial head fractures yield good clinical but poor radiological results in the long term. *Orthopedics* 2013;36:1358–1364.
16. Herbertsson P, Josefsson PO, Hasserius R, et al. Fractures of the radial head and neck treated with radial head excision. *J Bone Joint Surg [Am]* 2004;86-A:1925–1930.
17. Ikeda M, Oka Y. Function after early radial head resection for fracture: a retrospective evaluation of 15 patients followed for 3–18 years. *Acta Orthop Scand* 2000;71:191–194.
18. Morrey BF, Tanaka S, An KN. Valgus stability of the elbow. A definition of primary and secondary constraints. *Clin Orthop Relat Res* 1991;265:187–195.
19. Schiffern A, Bettwieser SP, Porucznik CA, Crim JR, Tashjian RZ. Proximal radial drift following radial head resection. *J Shoulder Elbow Surg* 2011;20:426–433.
20. van Riet RP, Morrey BF. Delayed valgus instability and proximal migration of the radius after radial head prosthesis failure. *J Shoulder Elbow Surg* 2010;19:7–10.
21. Boulas HJ, Morrey BF. Biomechanical evaluation of the elbow following radial head fracture. Comparison of open reduction and internal fixation vs. excision, silastic replacement, and non-operative management. *Chir Main* 1998;17:314–320.
22. Jensen SL, Olsen BS, Søjbjerg JO. Elbow joint kinematics after excision of the radial head. *J Shoulder Elbow Surg* 1999;8:238–241.
23. Jensen SL, Olsen BS, Tyrdal S, Søjbjerg JO, Sneppen O. Elbow joint laxity after experimental radial head excision and lateral collateral ligament rupture: efficacy of prosthetic replacement and ligament repair. *J Shoulder Elbow Surg* 2005;14:78–84.
24. Pomianowski S, Morrey BF, Neale PG, et al. Contribution of monoblock and bipolar radial head prostheses to valgus stability of the elbow. *J Bone Joint Surg [Am]* 2001;83-A:1829–1834.
25. Ring D, Jupiter JB, Zilberfarb J. Posterior dislocation of the elbow with fractures of the radial head and coronoid. *J Bone Joint Surg [Am]* 2002;84-A:547–551.
26. Dou Q, Yin Z, Sun L, Feng X. Prosthesis replacement in Mason III radial head fractures: A meta-analysis. *Orthop Traumatol Surg Res* 2015;101:729–734.
27. Heijink A, Kodde IF, Mulder PG, et al. Radial Head Arthroplasty: A Systematic Review. *JBJS Rev* 2016;4:4.
28. Giannicola G, Sacchetti FM, Antonietti G, et al. Radial head, radiocapitellar and total elbow arthroplasties: a review of recent literature. *Injury* 2014;45:428–436.
29. Delclaux S, Lebon J, Faraut A, et al. Complications of radial head prostheses. *Int Orthop* 2015;39:907–913.
30. van Riet RP, Sanchez-Sotelo J, Morrey BF. Failure of metal radial head replacement. *J Bone Joint Surg [Br]* 2010;92-B:661–667.
31. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986;7:177–188.
32. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. A basic introduction to fixed-effect and random-effects models for meta-analysis. *Res Synth Methods* 2010;1:97–111.
33. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997;315:629–634.
34. Neuhaus V, Christoforou DC, Kachooei AR, et al. Radial head prosthesis removal: a retrospective case series of 14 patients. *Arch Bone Jt Surg* 2015;3:88–93.
35. Viveen J, Kodde IF, Koenraadt KLM, et al. Clinical and radiographic outcome of revision surgery of radial head prostheses: midterm results in 16 patients. *J Shoulder Elbow Surg* 2017;26:394–402.
36. Hackl M, Wegmann K, Koslowsky TC, et al. Rare implant-specific complications of the MoPyC radial head prosthesis. *J Shoulder Elbow Surg* 2017;26:830–837.
37. Duckworth AD, Wickramasinghe NR, Clement ND, Court-Brown CM, McQueen MM. Radial head replacement for acute complex fractures: what are the rate and risks factors for revision or removal? *Clin Orthop Relat Res* 2014;472:2136–2143.
38. Kachooei AR, Claessen FMAP, Chase SM, et al. Factors associated with removal of a radial head prosthesis placed for acute trauma. *Injury* 2016;47:1253–1257.
39. Laumonerie P, Ancelin D, Reina N, et al. Radial head arthroplasty: reasons for surgical re-intervention, and midterm clinical and radiographic results. *Int Orthop* 2017;41:1435–1443.
40. Popovic N, Lemaire R, Georis P, Gillet P. Midterm results with a bipolar radial head prosthesis: radiographic evidence of loosening at the bone-cement interface. *J Bone Joint Surg [Am]* 2007;89-A:2469–2476.
41. Burkhart KJ, Mattyasovszky SG, Runkel M, et al. Mid- to long-term results after bipolar radial head arthroplasty. *J Shoulder Elbow Surg* 2010;19:965–972.
42. Marsh JP, Grewal R, Faber KJ, et al. Radial head fractures treated with modular metallic radial head replacement: outcomes at a mean follow-up of eight years. *J Bone Joint Surg [Am]* 2016;98:527–535.
43. Tarallo L, Mugnai R, Rocchi M, Capra F, Catani F. Mason type III radial head fractures treated by anatomic radial head arthroplasty: is this a safe treatment option? *Orthop Traumatol Surg Res* 2017;103:183–189.
44. Gauci M-O, Winter M, Dumontier C, Bronsard N, Allieu Y. Clinical and radiologic outcomes of pyrocarbon radial head prosthesis: midterm results. *J Shoulder Elbow Surg* 2016;25:98–104.
45. Moghaddam A, Raven TF, Dremel E, et al. Outcome of radial head arthroplasty in comminuted radial head fractures: short and midterm results. *Trauma Mon* 2016;21:20201.
46. Levy JC, Formaini NT, Kurowicki J. Outcomes and radiographic findings of anatomic press-fit radial head arthroplasty. *J Shoulder Elbow Surg* 2016;25:802–809.
47. Kodde IF, Heijink A, Kaas L, et al. Press-fit bipolar radial head arthroplasty, midterm results. *J Shoulder Elbow Surg* 2016;25:1235–1242.
48. Heijink A, Kodde IF, Mulder PGH, Van Dijk CN, Eygendaal D. Cemented bipolar radial head arthroplasty: midterm follow-up results. *J Shoulder Elbow Surg* 2016;25:1829–1838.
49. Abdulla IN, Molony DC, Symes M, Cass B. Radial head replacement with pyrocarbon prosthesis: early clinical results. *ANZ J Surg* 2015;85:368–372.
50. Laun R, Wild M, Hakimi M. One-year results of cemented bipolar radial head prostheses for comminuted radial head fractures. *GMS Interdiscip Plast Reconstr Surg DGPW* 2015;4:D–12.
51. Mou Z, Chen M, Xiong Y, et al. Comminuted radial head fractures treated by the Acumed anatomic radial head system. *Int J Clin Exp Med* 2015;8:6327–6333.
52. Allavena C, Delclaux S, Bonnevalle N, et al. Outcomes of bipolar radial head prosthesis to treat complex radial head fractures in 22 patients with a mean follow-up of 50 months. *Orthop Traumatol Surg Res* 2014;100:703–709.
53. Berschback JC, Lynch TS, Kalainov DM, et al. Clinical and radiographic comparisons of two different radial head implant designs. *J Shoulder Elbow Surg* 2013;22:1108–1120.
54. El Sallakh S. Radial head replacement for radial head fractures. *J Orthop Trauma* 2013;27:137–140.
55. Sarris IK, Kyrkos MJ, Galanis NN, et al. Radial head replacement with the MoPyC pyrocarbon prosthesis. *J Shoulder Elbow Surg* 2012;21:1222–1228.
56. Ricón FJ, Sánchez P, Lajara F, et al. Result of a pyrocarbon prosthesis after comminuted and unreconstructable radial head fractures. *J Shoulder Elbow Surg* 2012;21:82–91.
57. Zunkiewicz MR, Clemente JS, Miller MC, et al. Radial head replacement with a bipolar system: a minimum 2-year follow-up. *J Shoulder Elbow Surg* 2012;21:98–104.

58. **Katthagen JC, Jensen G, Lill H, Voigt C.** Monobloc radial head prostheses in complex elbow injuries: results after primary and secondary implantation. *Int Orthop* 2013;37:631–639.
59. **Rotini R, Marinelli A, Guerra E, Bettelli G, Cavaciocchi M.** Radial head replacement with unipolar and bipolar SBI system: a clinical and radiographic analysis after a 2-year mean follow-up. *Musculoskelet Surg* 2012;96(Suppl 1):S69–S79.
60. **Ha AS, Petscavage JM, Chew FS.** Radial head arthroplasty: a radiologic outcome study. *AJR Am J Roentgenol* 2012;199:1078–1082.
61. **Muhm M, de Castro R, Winkler H.** Radial head arthroplasty with an uncemented modular metallic radial head prosthesis: short- and mid-term results. *Eur J Trauma Emerg Surg* 2011;37:85–95.
62. **Maghen Y, Leo AJ, Hsu JW, Hausman MR.** Is a silastic radial head still a reasonable option? *Clin Orthop Relat Res* 2011;469:1061–1070.
63. **Lamas C, Castellanos J, Proubasta I, Dominguez E.** Comminuted radial head fractures treated with pyrocarbon prosthetic replacement. *Hand (N Y)* 2011;6:27–33.
64. **Celli A, Modena F, Celli L.** The acute bipolar radial head replacement for isolated unreconstructable fractures of the radial head. *Musculoskelet Surg* 2010;94(Suppl 1):S3–S9.
65. **Fehringer EV, Burns EM, Knierim A, et al.** Radiolucencies surrounding a smooth-stemmed radial head component may not correlate with forearm pain or poor elbow function. *J Shoulder Elbow Surg* 2009;18:275–278.
66. **Shore BJ, Mozzon JB, MacDermid JC, Faber KJ, King GJ.** Chronic posttraumatic elbow disorders treated with metallic radial head arthroplasty. *J Bone Joint Surg [Am]* 2008;90-A:271–280.
67. **Lim Y-J, Chan BK.** Short-term to medium-term outcomes of cemented Vitallium radial head prostheses after early excision for radial head fractures. *J Shoulder Elbow Surg* 2008;17:307–312.
68. **Doornberg JN, Parisien R, van Duijn PJ, Ring D.** Radial head arthroplasty with a modular metal spacer to treat acute traumatic elbow instability. *J Bone Joint Surg [Am]* 2007;89-A:1075–1080.
69. **Wretenberg P, Ericson A, Stark A.** Radial head prosthesis after fracture of radial head with associated elbow instability. *Arch Orthop Trauma Surg* 2006;126:145–149.
70. **Dotzis A, Cochu G, Mabit C, Charissoux JL, Arnaud JP.** Comminuted fractures of the radial head treated by the Judet floating radial head prosthesis. *J Bone Joint Surg [Br]* 2006;88-B:760–764.
71. **Chapman CB, Su BW, Sinicropi SM, et al.** Vitallium radial head prosthesis for acute and chronic elbow fractures and fracture-dislocations involving the radial head. *J Shoulder Elbow Surg* 2006;15:463–473.
72. **Grewal R, MacDermid JC, Faber KJ, Drosdowech DS, King GJ.** Comminuted radial head fractures treated with a modular metallic radial head arthroplasty. Study of outcomes. *J Bone Joint Surg [Am]* 2006;88-A:2192–2200.
73. **Brinkman J-M, Rahusen FTG, de Vos MJ, Eygendaal D.** Treatment of sequelae of radial head fractures with a bipolar radial head prosthesis: good outcome after 1-4 years follow-up in 11 patients. *Acta Orthop* 2005;76:867–872.
74. **Harrington IJ, Sekyi-Otu A, Barrington TW, Evans DC, Tuli V.** The functional outcome with metallic radial head implants in the treatment of unstable elbow fractures: a long-term review. *J Trauma* 2001;50:46–52.
75. **Popovic N, Gillet P, Rodriguez A, Lemaire R.** Fracture of the radial head with associated elbow dislocation: results of treatment using a floating radial head prosthesis. *J Orthop Trauma* 2000;14:171–177.
76. **Stroup DF, Berlin JA, Morton SC, et al.** Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA* 2000;283:2008–2012.
77. **O'Driscoll SW, Herald JA.** Forearm pain associated with loose radial head prostheses. *J Shoulder Elbow Surg* 2012;21:92–97.
78. **Moon J-G, Berglund LJ, Domire Z, An K-N, O'Driscoll SW.** Stem diameter and micromotion of press fit radial head prosthesis: a biomechanical study. *J Shoulder Elbow Surg* 2009;18:785–790.
79. **Shukla DR, Fitzsimmons JS, An K-N, O'Driscoll SW.** Effect of stem length on prosthetic radial head micromotion. *J Shoulder Elbow Surg* 2012;21:1559–1564.
80. **Sahu D, Holmes DM, Fitzsimmons JS, et al.** Influence of radial head prosthetic design on radiocapitellar joint contact mechanics. *J Shoulder Elbow Surg* 2014;23:456–462.
81. **Chanlalit C, Shukla DR, Fitzsimmons JS, et al.** Radiocapitellar stability: the effect of soft tissue integrity on bipolar versus monopolar radial head prostheses. *J Shoulder Elbow Surg* 2011;20:219–225.
82. **Moon J-G, Berglund LJ, Zachary D, An K-N, O'Driscoll SW.** Radiocapitellar joint stability with bipolar versus monopolar radial head prostheses. *J Shoulder Elbow Surg* 2009;18:779–784.
83. **Chanlalit C, Shukla DR, Fitzsimmons JS, An K-N, O'Driscoll SW.** The biomechanical effect of prosthetic design on radiocapitellar stability in a terrible triad model. *J Orthop Trauma* 2012;26:539–544.
84. **Ilahi OA, Bennett JB, Gabel GT, Mehlhoff TL, Kohl HW.** Classification of heterotopic ossification about the elbow. *Orthopedics* 2001;24:1075–1078.
85. **Birkedal JP, Deal DN, Ruch DS.** Loss of flexion after radial head replacement. *J Shoulder Elbow Surg* 2004;13:208–213.
86. **Van Glabbeek F, Van Riet RP, Baumfeld JA, et al.** Detrimental effects of overstuffing or understuffing with a radial head replacement in the medial collateral-ligament deficient elbow. *J Bone Joint Surg [Am]* 2004;86-A:2629–2635.
87. **Giannicola G, Sacchetti FM, Antoniotti G, et al.** Radial head, radiocapitellar and total elbow arthroplasties: a review of recent literature. *Injury* 2014;45:428–436.
88. **Magill P, Blaney J, Hill JC, Bonnin MP, Beverland DE.** Impact of a learning curve on the survivorship of 4802 cementless total hip arthroplasties. *Bone Joint J* 2016;98-B:1589–1596.
89. **Suzuki T, Seki A, Nakamura T, et al.** Re-dislocation after corrective osteotomy for chronic dislocation of the radial head in children. *Bone Joint J* 2015;97-B:1582–1587.
90. **Wagener ML, de Vos MJ, Hannink G, et al.** Mid-term clinical results of a modern convertible total elbow arthroplasty. *Bone Joint J* 2015;97-B:681–688.