Clinical and radiological outcomes of jumbo cup in revision total hip arthroplasty: A systematic review

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Introduction: Many studies have reported the clinical outcomes of a jumbo cup in revision total hip arthroplasty (rTHA) with acetabular bone defect. We conducted a systematic review to access the survivorship and clinical and radiological outcomes of a jumbo cup in rTHA.

Methods: A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. A comprehensive literature search from PubMed, MEDLINE, EMBASE, and the Cochrane Database of Systematic Reviews was performed with the keywords ("revision" OR "revision surgery" OR "revision arthroplasty") AND ("total hip arthroplasty" OR "total hip replacement" OR "THA" OR "THR") AND ("jumbo cup" OR "jumbo component" OR "extra-large cup" OR "extra-large component"). Studies reporting the clinical or radiological outcomes were included. The basic information and radiological and clinical results of these studies were extracted and summarized for analysis.

Results: A total of 19 articles were included in the systematic review. The analysis of clinical results included 953 hips in 14 studies. The re-revision-free survivorship of the jumbo cup was 95.0% at a mean follow-up of 9.3 years. Dislocation, aseptic loosening, and periprosthetic joint infection were the top three complications with an incidence of 5.9%, 3.0%, and 2.1%, respectively. The postrevision hip center was relatively elevated 10.3 mm on average; the mean postoperative leg-length discrepancy was 5.4 mm.

Conclusion: A jumbo cup is a favorable option for acetabular bone defect reconstruction in rTHA with satisfying survivorship and acceptable complication rates.

KEYWORDS
jumbo cup, acetabular bone defect, revision total hip arthroplasty, survivorship, rotation hip center

Introduction

Reconstruction of an acetabular bone defect is a difficult procedure in revision total hip arthroplasty (rTHA) (1). In rTHA, the primary goal of acetabular reconstruction is creating sufficient mechanical support and bone contact for the acetabular cup, thereby achieving bone ingrowth or ongrowth and attaining stability of the acetabular cup (2). In
addition, the position of the rotation hip center is also an important factor to consider. Due to the complexity and variety of the acetabular bone defect, it is highly possible for unexpected challenges to occur beyond the preoperative plan. Moreover, many patients who accept revision arthroplasty are at an advanced age with underlying diseases; therefore, there is need for enhancing surgical efficiency and limiting damage control. These factors all bring significant challenges to surgeons.

Before performing rTHA, an evaluation of the acetabular bone defect is necessary. The Paprosky classification, American Academy of Orthopaedic Surgeons (AAOS) classification, and Gross system are the most commonly used in preoperative planning (3, 4). Many new methods of evaluation have also been developed to help surgeons make better surgical strategy (5–9). Currently, the Paprosky type IIA and IIB and AAOS type III and IV are regarded as the most challenging conditions, which involve extensive bone loss of the acetabular rim and columns, and even pelvic discontinuity (10, 11). Several methods of reconstruction have been developed for severe acetabular bone loss in rTHA, such as structural allografts, impaction bone grafting, the jumbo cup, the highly porous metallic augments and hemispherical cup, the cup-cage system, custom monolangled acetabular components, and the cup-on-cup technique (12–20). Many studies as well as systematic reviews have reported the clinical results of these reconstruction techniques (21–24), but the most effective solution remains controversial.

Using a jumbo cup is one of the most commonly recommended reconstruction methods for severe acetabular bone defect in rTHA. It was first reported by Jasty in 1998 (25). There is no strict definition for the jumbo cup. Most papers define the jumbo cup as a diameter of over 66 or 64 mm for males and over 62 or 60 mm for females. The advantages of the jumbo cup include the obvious simplified surgical procedure, more contact area with the host bone, and less requirement for bone graft (26). However, there are also some limitations in using the jumbo cup for reconstruction. For example, it may result in further bone loss (27), which may delay the full weight-bearing time and even cause a protrusion of the jumbo cup into the pelvic cavity. Therefore, the jumbo cup is usually applied in Paprosky type I–III acetabular bone defect and rarely used alone for pelvic discontinuity (11). In many cases, jumbo cups have to be set in a high position to provide sufficient contact with the host bone and mechanical support, which may lead to rotation center elevation, leg-length discrepancy (LLD), and soft tissue imbalance (28). Although many studies have reported the clinical results of the jumbo cup in rTHA, no systematic review has been conducted to date. In this context, the aim of this study is to systematically summarize the current evidence of the jumbo cup in rTHA, including survivorship and failure, radiological outcome, hip function, and complications.

Materials and methods

Literature search strategy

We conducted a comprehensive literature search from the electronic databases PubMed, EMBASE, Web of Science, and Cochrane Library. The last literature search was on 15 April 2022. The search project was based on the following keywords: ("revision" OR "revision surgery" OR "revision arthroplasty") AND ("total hip arthroplasty" OR "total hip replacement" OR "THA" OR "THR") AND ("jumbo cup" OR "jumbo component" OR "extra-large cup" OR "extra-large component"). The language was limited to English. If the abstract was not sufficient for us to include or exclude a study, we would download the full text. The literature search process was carried out on the basis of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (29).

Inclusion and exclusion criteria

Only those clinical studies that met the following criteria were included in this systematic review: (1) rTHA with acetabular bone defect; (2) using a jumbo cup for acetabular reconstruction; and (3) reporting clinical results or radiological data. Reviews, conference abstracts, non-English written articles, letters, case reports, experiment studies, and simulation studies were excluded from this systematic review.

Data extraction

Two researchers separately extracted all data according to the rules described above. We developed an extraction table for data extraction including the following: (1) basic information of each study; (2) radiological results evaluating the implant position; and (3) clinical results including studying the accuracy of the preoperative plan, intraoperative details, and postoperative function complications. All data were extracted by two investigators; any disagreement was solved by an expert surgeon and a third researcher to make a final decision.

Quality assessment

We used the Methodological Index for Non-Randomized Studies (MINORS) for quality assessment (30). This evaluation system involves 12 items for comparative studies and 8 items for noncomparative studies, with total scores of 24 and 16, respectively. The item was separately scored with 0, 1, and 2 corresponding to nonreported information,
Results

Literature selection

The literature search initially identified 101 articles and finally included 19 articles in this systematic review according to the inclusion and exclusion criteria (31–49) (Figure 1). Among the 19 articles, 2 articles were pure radiological studies (31, 40). There were three pairs of cognate articles (six articles) that were published in different years (38, 39, 41, 45, 48, 49). For these coupled cognate articles, the results of the more recent articles were adopted.

Quality assessment

Except for the two pure radiological studies, the remaining 17 clinical studies were included in the quality assessment (32–39, 41–44, 46, 47) (Table 1). Only one study was a comparative study and its quality was high (21/24) (33). The other 16 studies were noncomparative studies, with a mean MINORS score of 10.5, which indicated that the general quality of these studies was relatively low. Therefore, a further meta-analysis was not conducted.

Demographics and characteristics

A total of 1,406 hips were initially included in the review (Table 2). To analyze the clinical results, the two pure radiological studies were removed and the results of the cognate articles were merged and adjusted. As a result, 953 hips in 14 studies were included in the analysis of clinical results (32–39, 41–44, 46, 47) (Tables 3–5). The patients who underwent rTHA had a mean age of 62.5 years. The mean follow-up was 9.3 years. In the radiological result analysis part, 631 hips in 11 studies were included (31–34, 37, 40, 43, 44, 47–49). The data of the hip center position and leg-length discrepancy were extracted and analyzed (Table 6).

Definition of the jumbo cup

There were two main definitions of the jumbo cup among the studies. One was a diameter >66 mm for males and >62 mm for females and was usually adopted in European and American studies (35, 36, 39–42, 45, 46, 48). The other was a diameter >64 mm for males and >60 mm for females and was usually adopted in Asian studies (31–33, 44). Other definitions included diameter >60 mm (34, 47), >64 mm (43), >65 mm (38), >66 mm (49), and diameter >10 mm than templated contralateral hip (37).

Clinical analysis

Bone defect evaluation

All 14 studies reported the severity of acetabular bone defect. The Paprosky classification was adopted in 13 studies of 881 hips (32–37, 39, 41–44, 46, 47). Paprosky type IIB accounted for the largest proportion (26.6%, 234/881), followed by type IIA (22.5%, 198/881), type IIIA (21.6%, 190/881), type IIC (18.5%, 163/881), type IIIB (7.4%, 65/881), and type I (3.5%, 31/881). The AAOS classification was utilized in five studies with 372 hips (41, 43, 46, 48, 49). AAOS type III occupied the most (62.1%, 231/372), followed by type II (30.1%, 112/372), type I (7.3%, 27/372), and type IV (0.5%, 2/372). In most studies, additional procedures such as structural bone grafting and press-fit bone grafting were also performed to fill the severe acetabular bone defect.

Reoperation

All 14 clinical studies reported the rate of reoperation. The overall reoperation rate was 8.6% (82/953). The most common reasons for reoperation were aseptic loosening and dislocation with an incidence of 3.6% and 2.1%, respectively. Removal of the jumbo cup was defined as failure. The failure rate of the jumbo cups was 5.0% (48/953). Among the 48 failed jumbo cups, 22 were removed for aseptic loosening, 18 were removed for periprosthetic joint infection (PJI), and 8 were removed for dislocation. The survivorship of the jumbo cups was 95.0% in the mean follow-up of 9.3 years.

Complications

All 14 clinical studies reported complications. Due to the lack of a clear definition of complication, the overall complication rate was not calculated. Dislocation was the most common complication with a rate of 5.9%, followed by aseptic loosening (3.0% in acetabular and 2.4% in femoral) and PJI (2.1%).

Dislocation

Dislocation was the most frequent complication with a prevalence of 5.9% (56/953). Of the 56 dislocations, 20 (35.7%) accepted reoperation, with 7 re-revisions of the acetabular cup [five studies (36, 39, 41, 44, 46)], 7 femoral and liner re-revisions [three studies (39, 41, 42)], 4 femoral head and/or liners exchange [four studies (36, 39, 41, 42)], one femoral re-revision [one study (39)], and 1 resection arthroplasty [one study (41)].
Aseptic loosening

The incidence of jumbo cup aseptic loosening was 3.0% [29 of 953 hips, 10 studies (33, 35–37, 39, 41–43, 46, 47)]. Among these cases, 22 were managed with acetabular re-revision, 5 refused reoperation, and 2 could not receive re-revision for medical problems.

Periprosthetic joint infection

PJI was the third most common complication after dislocation and aseptic loosening, with a rate of 2.1% [20 of 953 hips, 10 studies (32, 33, 36, 38, 39, 41–44, 47)]. Only one patient was treated with antibiotics only for his poor physical condition as he could not tolerate re-revision. The remaining 19 cases of PJI were treated with re-revision and the jumbo cups were removed.

Harris Hip Score

Eleven studies (687 hips) reported the pre- and postoperative Harris Hip Score (HHS) (32–36, 38, 39, 41, 43, 46, 47). The mean preoperative HHS was 49.4 (poor) and improved to 78.2 (fair) at the latest follow-up.
| Author/year | Clearly stated study aim | Inclusion of consecutive patients | Prospective collection of data | Appropriate endpoints | Unbiased assessment of endpoint | Appropriate follow-up period | Loss to follow-up less than 5% | Prospective calculation of study size | Adequate control group | Contemporary groups | Baseline equivalence of groups | Adequate statistical analyses | Total score |
|-------------|--------------------------|---------------------------------|-------------------------------|-----------------------|--------------------------------|-----------------------------|-----------------------------|-----------------------------------|-----------------------|-----------------|------------------------|------------------------|------------|
| Zhang 2019  | 2                        | 2                               | 2                             | 2                     | 1                             | 2                           | 0                           | 0                                 | NA                    | NA              | NA                     | NA                     | 9/16       |
| Zhou 2018   | 2                        | 2                               | 2                             | 2                     | 1                             | 2                           | 2                           | 0                                 | 2                     | 2               | 2                      | 2                      | 22/24      |
| Salem 2018  | 2                        | 1                               | 2                             | 2                     | 0                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 11/16      |
| Moon 2018   | 2                        | 1                               | 2                             | 2                     | 0                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 11/16      |
| McLaughlin  | 2                        | 2                               | 2                             | 2                     | 0                             | 2                           | 0                           | 0                                 | NA                    | NA              | NA                     | NA                     | 10/16      |
| Jo 2016     | 2                        | 1                               | 2                             | 2                     | 0                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 11/16      |
| von Roth 2015| 2                      | 2                               | 2                             | 2                     | 0                             | 2                           | 0                           | 0                                 | NA                    | NA              | NA                     | NA                     | 10/16      |
| Garde 2014  | 2                        | 2                               | 2                             | 2                     | 0                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 12/16      |
| Lachiewicz  | 2                        | 2                               | 2                             | 2                     | 1                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 12/16      |
| Wedemeyer 2008 | 2                   | 1                               | 2                             | 2                     | 0                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 11/16      |
| Fan 2008    | 2                        | 2                               | 2                             | 2                     | 1                             | 1                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 12/16      |
| Hendricks 2006 | 2                   | 1                               | 2                             | 2                     | 0                             | 2                           | 0                           | 0                                 | NA                    | NA              | NA                     | NA                     | 9/16       |
| Garde 2004  | 2                        | 1                               | 2                             | 2                     | 0                             | 2                           | 0                           | 0                                 | NA                    | NA              | NA                     | NA                     | 9/16       |
| Patel 2003  | 2                        | 1                               | 2                             | 1                     | 0                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 10/16      |
| Obenaus 2003 | 2                      | 1                               | 2                             | 2                     | 0                             | 2                           | 0                           | 0                                 | NA                    | NA              | NA                     | NA                     | 9/16       |
| Whaley 2001 | 2                        | 2                               | 2                             | 2                     | 0                             | 2                           | 2                           | 0                                 | NA                    | NA              | NA                     | NA                     | 12/16      |
| Doehorn 2000 | 2                      | 2                               | 2                             | 2                     | 0                             | 2                           | 0                           | 0                                 | NA                    | NA              | NA                     | NA                     | 10/16      |

MINORS, Methodological Index for Non-Randomized Studies.
| Author/Year | Definition of jumbo cup | Study design | Hips of initial/ final cohort | Patients | Gender (M/F) | Age (y) | BMI | Follow-up | Acetabular bone defect classification | Revision reason |
|-------------|-------------------------|--------------|-----------------------------|----------|--------------|--------|-----|-----------|-------------------------------------|-----------------|
| Peng 2021   | Male: ≥64 mm; Female: ≥60 mm | Pure radiological | 88/88 | 88 | 44/44 | 61 ± 11 (32–85) | NA | Postoperative 1 week | NA | NA |
| Zhang 2019  | Male: ≥64 mm; Female: ≥60 mm | Retrospective | 73/63 | 61 | 29/32 | 59.4 ± 11.4 | 3.8 | 5.7 years (2–16) | Paprosky type IIA 16, IIB 9, IIC 24, IIIA 8, IIIB 6 | Aseptic loosening 55, second stage of a two-stage revision for PJ 6, wear and osteolysis 2 |
| Zhou 2018   | Male: ≥64 mm; Female: ≥60 mm | Retrospective comparative study | 80/77 | 77 | 43/34 | 60.6 ± 10.4 | 3.4 | 52 months (24–104) | Paprosky type IIA 18, IIB 12, IIC 25, IIIA 14, IIIB 8 | Aseptic loosening 61, PJ 6, fracture 1, dislocation 2, others 7 |
| Salem 2018  | >60 mm | Case series | 17/17 | 17 | 9/8 | 52 (40–61) | NA | 3.5 years (2–6) | Paprosky type IIB 4, IIIA 13 | Aseptic loosening all |
| Moon 2018   | Male: ≥66 mm; Female: ≥62 mm | Retrospective | 85/80 | 80 | 47/33 | 57.7 (30–78) | 23.7 (19.2–28.3) | 10.4 years (5–16.1) | Paprosky type IIA 16, IIB 17, IIC 22, IIIA 19, IIIB 6 | Aseptic all |
| McLaughlin 2018 | Male: ≥66 mm; Female: ≥62 mm | Case series | 61/30 | 28 | 14/14 | 71 (36–79) | 33 | 13 years (10–16) | Paprosky type I 2, II A 4, IIB 11, IIC 12, IIIA 1 | Aseptic loosening 26, recurrent dislocation 3, severe osteolysis 1 |
| Jo 2016     | >10 mm than templated contralateral hip | Retrospective | 60/51 | 51 | 22/29 | 60.7 (30–81) | 23.2 (15.3–36.1) | 51 months (12–154) | Paprosky type IIA 8, IIB 19, IIC 13, IIIA 11 | Aseptic loosening 39, second stage of a two-stage revision for PJ 5, acetabular protrusion 5, recurrent dislocation 2 |
| von Roth 2015 | Male: ≥66 mm; Female: ≥62 mm | Retrospective | 89/89 | 89 | 46/43 | 59 (30–83) | 30 (19–37) | Clinical: 20 years (14–27); Radiographic; 19 years (10–25) | Paprosky type I 6, II A 11, IIB 26, IIC 17, IIIA 25, IIIB 4 | Acetabular loosening 38, aseptic acetabular and femoral loosening 42, aseptic acetabular loosening with femoral periprosthetic fracture 5, other indications 4 |
| Nwankwo 2014 | Male: ≥66 mm; Female: ≥62 mm | Pure radiological | 98/98 | 98 | 57/41 | 62.4 ± 12.2 | NA | Radiographic; 6 weeks | NA | NA |
| Gustke 2014 | Male: ≥66 mm; Female: ≥62 mm | Retrospective | 216/199 | 189 | 71/118 | 66 | NA | 10 years (2–19) | Paprosky type I 14, IIA 52, IIB 65, IIC 18, IIIA 34, IIIB 16 AAOS type I 8, II 74, III 115; pelvic discontinuity 2 | Aseptic loosening of the acetabular component 148, septic loosening 21, recurrent dislocations 18, failed bipolar arthroplasties 4, persistent pain 2, excessive |

(continued)
| Author/Year | Definition of jumbo cup | Study design | Hips of initial/final cohort | Patients | Gender (M/F) | Age (y) | BMI | Follow-up | Acetabular bone defect classification | Revision reason |
|-------------|-------------------------|--------------|------------------------------|----------|--------------|---------|-----|-----------|------------------------------------|-----------------|
| Lachiewicz 2013 | Male: ≥66 mm, Female: ≥62 mm | Retrospective | 129/108 | 101 | 52/49 | 63 (33–88) | 27 (16–41) | 8.1 (2–22) | Paprosky type I 1, IIA 22, IIB 23, IIIC 5, IIIA 40, IIIB 17 | polyethylene wear patterns 3 Painful aseptic loosening 89, PJII 10, periprosthetic femoral fracture 4, polyethylene wear 3, recurrent dislocation 1, chronic dislocation with periprosthetic femoral fracture 1 |
| Wedemeyer 2008 | ≥64 mm | Retrospective | 17/17 | 17 | 10/7 | 60 (44–78) | NA | 82 months (33–149) | Paprosky type IIA 5, IIB 3, IIC 4, IIIC 5 | Aseptic prosthesis loosening all |
| Fan 2008 | Male: ≥64 mm, Female: ≥60 mm | Retrospective | 50/47 | 46 | 23/23 | NA | 65 months (48–84) | Paprosky type I 6, IIA 13, IIB 11, IIIC 6, IIIA 5, IIIB 6 | Lossening of the acetabular cups (septic 2 and aseptic 42), insert wear 3 |
| Hendricks 2006 | >65 mm | Retrospective | 24/12 | 12 | NA | NA | NA | 13.9 years (12.3–16.2) | NA | NA |
| Gustke 2004 | Male: ≥66 mm, Female: ≥62 mm | Case series | 166/166 | NA | NA | NA | NA | 6.1 years | Paprosky type I 10, II 119, III 37, AAOS type II combined cavitary and segmental defect >105 | AAOS type I 9, II 11, III 23 |
| Patel 2003 | Male: ≥66 mm, Female: ≥62 mm | Retrospective | 43/43 | 42 | NA | 63 (25–86) | 29 (21–42) | 10 years (6–14) | Paprosky type IIA 21, IIB 6, IICC 10, IIIC 6, AAOS type I 9, II 11, III 23 | Aseptic loosening 29, wear and osteolysis 7, part of a two-stage revision PJII 2, failed resurfacing procedures 5 |
| Obenaus 2003 | ≥60 mm | Retrospective | 99/60 | 59 | NA | 65.2 (39.8–79.5) | NA | 5.6 years (4.1–7.1) | Paprosky type I 2, IIA 12, IIB 28, IICC 7, IIIA 9, IIIB 2 | Aseptic cup loosening with enlargement of the acetabulum |
| Whaley 2001 | Male: ≥66 mm, Female: ≥62 mm | Retrospective | 89/89 | 89 | 46/43 | 59 (30–83) | 30 (19–37) | 7.2 years (5–11.3) | Paprosky type I 6, IIA 11, IIB 26, IICC 17, IIIA 23, IIIB 4, AAOS type I 3, II 10, III 76 | Acetabular loosening 38, aseptic acetabular and femoral loosening 42, aseptic acetabular loosening with femoral periprosthetic fracture 5, other indications 4 |

(continued)
| Author/Year | Definition of jumbo cup | Study design | Hips of initial/final cohort | Patients | Gender (M/F) | Age (y) | BMI | Follow-up | Acetabular bone defect classification | Revision reason |
|-------------|-------------------------|--------------|-----------------------------|----------|-------------|--------|-----|-----------|---------------------------------|----------------|
| Dearborn 2000 | ≥66 mm | Case series | 24/24 | 24 | 18/6 | 58 | NA | 7 years (5–10.3) | AAOS type I, II, 5, III 12 | NA |

BMI, body mass index; AAOS, American Academy of Orthopaedic Surgeons; PJI, periprosthetic joint infection.

**TABLE 3 Additional procedures, survival, and Harris Hip Score.**

| Study | No. of hips | Additional procedure | Survival | Harris Hip Score |
|-------|-------------|----------------------|----------|-----------------|
|        |             |                      | Preoperative | Postoperative |
| Zhang 2019 | 63 | Morselized allografting for acetabular protrusion | 16 years: 96.8% (EP = reoperation) | 46 | 83 |
| Zhou 2018 | 77 | Bulk allograft (2 hips) and impaction bone grafting (12 hips) was used in Paprosky type III acetabular bone loss | 4 years: 94.2% (EP = radiological or clinical failure) | 46.7 ± 13.2 | 83.1 ± 9.0 |
| Salem 2018 | 17 | Particulate bone grafting from the iliac crest | No re-revision at last follow-up (mean 3.5 years) | 42 (24–59) | 85 (72–92) |
| Moon 2018 | 80 | Structural bone allograft (4 hips), morselized bone allograft (47 hips) | 16 years: 85% (worst); 91% (best) | 53 | 77 |
| McLaughlin 2018 | 30 | Packing acetabular deficiencies with allograft bone chips and local bone obtained from reaming | 16 years: 92.6% (EP = re-revision); 97.4% (EP = cup aseptic loosening) | 49 (37–59) | 86 (64–94) |
| Jo 2016 | 51 | Autogenic (ipsilateral iliac crest) or allogenic (fresh-frozen chip bone) morselized bone graft for medial cavitary bone defect | 13 years: 86.3% (EP = implant failure) | NA | No rim fixation: 75 ± 7.6 Rim fixation: 85 ± 8.5 |
| von Roth and Whaley 2001 | 89 | Particulate bone grafting (54 hips), and bulk bone grafting (9 hips) | 20 years: 83% (free from any acetabular revision), 88% (free from aseptic loosening of the metal acetabular component), and 85% (free from aseptic or radiographic definite loosening of the metal acetabular component) | 56 | 71 (30–95) |
| Gustke 2014 and Gustke 2004 | 216 | Particulate autografting (31 hips), particulate allografting (49 hips), bulk allografting (38 hips) | 4 years: 98%; 16y:96% (acetabular component) | 44 | 72 |
| Lachiewicz 2013 | 108 | Bone grafting (108 hips); crushed cancellous allograft only (98 hips), iliac crest autograft (4 hips), both allograft and autograft (5 hips) | 10 years: 97.3%, 15 years: 82.8% (EP = either acetabular cup revision for aseptic loosening or definite radiographic evident of loosening), 10 years: 93.8%, 15 years: 79.8% (EP = acetabular cup removal for any reason), 10 years: 88.5%, 15 years: 56.5% (EP = any reoperation involving the hip) | NA | 88.8, 56.5 |
| Wedemeyer 2008 | 17 | Morselized bone graft (15 hips) | NA | 62 | 83 |
| Fan 2008 | 47 | Allograft bone graft (25 patients) | 5 years: 94.5% (EP = implant failure) | NA | 46.98 |
| Hendricks 2006 and Dearborn 2000 | 24 | Particulate autologous or allograft bone packing acetalular defects | NA | 54 (31–82) | 79 (46–98) |
| Patel 2003 | 43 | Bulk allograft (8 hips), morselized allograft alone (27 hips) | Acetabular shell: 14 years: 92%; Acetabular shell: 13 years: 83% | 48 ± 15 | 81 ± 18 |
| Obenaus 2003 | 60 | Press-fit structural allografting (7 hips), mixture of autologous slurty and allogenic bone chips (10 hips) | NA | 58.7 (28–97.7) | 90.6 (61.1–100) |

EP, ending point.
Radiological measurements

Vertical position of the hip center
Seven studies (461 hips) reported the postoperative vertical distance of hip center elevation relative to the contralateral hip center (31–33, 37, 40, 47, 49). The postrevision hip center was elevated 10.3 mm on average. Five studies (293 hips) compared the pre- and postoperative vertical positions of the hip center (32, 33, 43, 44, 48). Compared with the preoperative condition, the postrevision hip center dropped 6.2 mm on average in the vertical position.

Horizontal position of the hip center
Four studies (279 hips) reported the postoperative lateral migration of the hip center relative to the contralateral hip center (31–33, 37). The revision hip center moved 0.4 mm laterally on average. Four studies compared the pre- and postoperative horizontal positions of the hip center (32, 33, 43, 48). The postoperative hip center migrated 1.4 mm laterally on average compared with the preoperative position.

Leg-length discrepancy
Three studies reported an improvement of LLD (32–34). The mean LLD was corrected from a preoperative 18.8 mm to a postoperative 5.4 mm.

Discussion
The jumbo cup has been used for acetabular bone defect reconstruction in rTHA for a long time. To the best of our knowledge, this is the first systematic review to evaluate the evidence of a jumbo cup in rTHA. In general, the results indicated that the jumbo cup was a favorable option for acetabular reconstruction in rTHA for satisfying survivorship and acceptable complication rates.

As was summarized previously, there was no unified definition for the jumbo cup. The definition differed between the studies and could be influenced by the factors of time, race, and surgeon preference. Therefore, to a greater extent, the jumbo cup represents a special idea for acetabular reconstruction. By using a “very large” cup in this study, the
contact area with the host bone increased; thereby, the goal of three-point stability and bone ingrowth was achieved.

With respect to postoperative complications, dislocation occupied the first position, with the highest rate of 5.9%. Therefore, we should lay emphasis on this complication and try to place the large diameter femoral head component to reduce the rate of dislocation. We should also identify the patients with high risk of dislocation in advance according to the reported risk factors related to dislocation after rTHA, such as advanced age, history of instability, and prior revision history (50). However, this rate of dislocation (5.9%) is also acceptable because the rate of dislocation is naturally high after rTHA, with 5%–35% in various studies (51–54). In a meta-analysis by Guo et al. that included 4,656 rTHAs, the accumulated incidence of postoperative dislocation was 9.04% (55). Many factors contribute to the high rate of dislocation after rTHA. Due to the extensive exposure in revision arthroplasty, the soft tissue deconstruction process is more severe, especially in revision for PJI because of the thorough debridement procedure. In addition, the posterolateral approach is commonly applied in rTHA, which also leads to injuries of the abduction muscles and an increased risk of dislocation (56, 57). Moreover, the rotation center may not restore in its original position and the offset may also be unsatisfying after rTHA. All these factors may lead to soft tissue imbalance and further postoperative dislocation.

However, most dislocations can be addressed by conservative therapy; dislocation is just the second cause for reoperation. Therefore, it is also unnecessary to harbor too much fear for dislocation.

The rate of reoperation was 8.6% and the re-revision of the jumbo cups was 5.0%. Aseptic loosening was the primary mode of failure leading to reoperation and re-revision of the jumbo cups. This may be related to the fixation mechanism of the

| Study                  | No. of hips | Overall reoperation | Reasons for reoperation | Cup re-revision |
|------------------------|-------------|---------------------|-------------------------|----------------|
|                        |             |                     | Dislocation | Aseptic loosen | PJI | Osteolysis | Fracture | Others |                     |
| Zhang 2019             | 63          | 2                   | 0          | 0              | 1   | 0         | 1        | 0      | 1 (1 PJI)         |
| Zhou 2018              | 77          | 2                   | 0          | 1              | 1   | 0         | 0        | 0      | 2 (1 PJI, 1 aseptic loosen) |
| Salem 2018             | 17          | 0                   | 0          | 0              | 0   | 0         | 0        | 0      | 0                  |
| Moon 2018              | 80          | 2                   | 0          | 1              | 0   | 2         | 0        | 0      | 1 (1 aseptic loosen, due to osteolysis) |
| McLaughlin 2018        | 61          | 5                   | 2          | 1              | 2   | 0         | 0        | 0      | 4 (2 PJI, 1 aseptic loosen, 1 dislocation) |
| Jo 2016                | 51          | 4                   | 0          | 4              | 0   | 0         | 0        | 0      | 4 (4 aseptic loosen) |
| von Roth 2015 and Whaley 2001 | 89  | 18                  | 4          | 10 (5 A, 5 F)  | 1   | 1         | 1        | 1      | 7 (5 aseptic loosen, 1 PJI, 1 dislocation) |
| Gustke 2014 and Gustke 2004 | 216 | 8                  | 7          | 3              | 1   | 0         | 0        | 0      | 7 (3 aseptic loosen, 3 dislocation, 1 PJI) |
| Lachiewicz 2013        | 108         | 20                  | 3          | 8 (3 A, 5 F)   | 4   | 2 (F)     | 3        | 0      | 7 (3 aseptic loosen, 4 PJI) |
| Wedemeyer 2008         | 17          | 2                   | 0          | 1              | 1   | 0         | 0        | 0      | 2 (1 aseptic loosen, 1 PJI) |
| Fan 2008               | 47          | 3                   | 2          | 0              | 1   | 0         | 0        | 0      | 3 (2 dislocation, 1 PJI) |
| Hendrickis 2006 and Dearborn 2000 | 24 | 8 | 1 | 0 | 5 | 1 (F) | 0 | 1 (nonunion) | 5 (5 PJI) |
| Patel 2003             | 43          | 5                   | 1          | 3 (2 A, 1 F)   | 0   | 0         | 0        | 1      | 3 (2 aseptic loosen, 1 dislocation) |
| Obenaus 2003           | 60          | 3                   | 0          | 1              | 2   | 0         | 0        | 0      | 2 (1 aseptic loosen, 1 PJI) |
| Total                  | 953         | 82/953              | 20/953     | 34/953         | 19/953 | 6/953 | 5/953 | 3/953 | 48/953 (18 PJIs, 22 aseptic loosenings, 8 dislocations) 5.0% |

PJI, periprosthetic joint infection.

TABLE 5 Terms of reoperation and revision.
| Study               | Hips | Vertical position of hip center (mm) | Horizontal position of hip center (mm) | Leg-length discrepancy (mm) |
|---------------------|------|-------------------------------------|---------------------------------------|----------------------------|
|                     |      | Preoperative | Postoperative | Contralateral | Preoperative | Postoperative | Contralateral | Preoperative | Postoperative | Contralateral | Preoperative | Postoperative | Contralateral | Preoperative | Postoperative | Contralateral | Preoperative | Postoperative | Contralateral |
| Peng 2021           | 88   | NA          | 23.0 ± 6.1    | 15.4 ± 3.4  | NA           | 36.4 ± 4.6    | 35.9 ± 4.4  | NA           | -16.8 ± 17.1 | -5.6 ± 11.8  |
| Zhang 2019          | 63   | 29.7 ± 10.4 | 22.3 ± 7.6    | 14.0 ± 3.7  | 30.8 ± 6.6   | 29.5 ± 3.7   | 30.3 ± 3.3  | -18.8 ± 16.1 | -6.2 ± 15.5  |
| Zhou 2018           | 77   | 30.3 ± 10.4 | 24.1 ± 8.4, +9.6 ± 8.7 relative to the contralateral | 30.5 ± 6.9   | 31.1 ± 4.8, -0.5 ± 8.2 relative to the contralateral | -18.8 ± 16.1 | -6.2 ± 15.5  |
| Salem 2018          | 17   | NA          | NA           | NA           | NA           | NA           | NA          | NA           | NA           | NA           |
| Jo 2016             | 51   | Superior migration of 12.1 ± 4.5 mm in rim fixation group, 11.3 ± 5.6 mm in no rim fixation group | Lateral migration of 3.0 ± 1.3 mm in rim fixation group, 2.3 ± 1.5 mm in no rim fixation group | -26 (-20 to 30) | -1 (-5 to 0) |
| Nwankwo 2014        | 98   | NA          | 32.6 ± 9.6    | 21.7 ± 8    | NA           | NA           | NA          | NA           | NA           | NA           |
| Wedemeyer 2008      | 17   | 35 ± 8      | 31 ± 9        | NA          | 34.5 ± 7.2   | 36.2 ± 6.8   | NA          | NA           | NA           | NA           |
| Fan 2008            | 47   | 31          | 27            | NA          | NA           | NA          | NA          | NA           | NA           | NA           |
| Obenaus 2003        | 60   | NA          | 11.4 mm (0–41) above anatomic rotation center | NA          | NA           | NA          | NA          | NA           | NA           | NA           |
| Whaley 2001         | 89   | 40 (17–67)  | 33 (10–58)    | NA          | 39           | 43          | NA          | NA           | NA           | NA           |
| Dearborn 2000       | 24   | NA          | Elevated averagely 4 mm | NA          | NA           | NA          | NA          | NA           | NA           | NA           |
The radiological outcome indicated that the rotation center position was elevated postoperatively compared with the original anatomical position. This is quite understandable for the combination of the rotation center elevation technique to achieve successful bone ingrowth as mentioned before. Another finding is that the elevation of the rotation center position has already existed preoperatively due to the acetabular bone defect, which also attained a certain degree of correction through the rTHA. The mean postoperative LLD was only 5.4 mm, which is quite acceptable and has no adverse influence on the patient’s feeling and limb function. The Harris Hip Score also improved significantly, which indicated that the general condition (pain, activity, deformity, and range of motion) of the hip improved after rTHA. The revised hip could be regarded as meeting the need for daily life, as the mean postoperative HHS was up to the fair level. Thus, although in situ reconstruction of the rotation center is the gold standard in rTHA, good clinical results can also be received in the condition of rotation center elevation.

PJI is a disastrous complication that keeps troubling arthroplasty surgeons. For rTHA, the risk of PJI is higher than in primary THA. The rate of PJI in postrevision THA was in the range of 1.3%–17.3% from different registers (58–60). Fröschen et al. retrospectively analyzed 68 rTHAs using custom-made acetabular implants for Paprosky IIIA or IIIB acetabular bone defect reconstruction; the rate of postoperative PJI was unexpectedly up to 22% (61). In systematic reviews of other reconstruction methods for acetabular bone defect, the PJI rates of the custom triflange acetabular component and cup-cage technique were 6.2% and 3.3%, respectively (21, 22). In our systematic review of the jumbo cup for rTHA, the rate of PJI was only 2.1%, which can be regarded as relatively low. We speculate that this reduced rate of PJI may be due to the simplified procedure in acetabular reconstruction of jumbo cups, which may save surgical time and lower the risk of PJI. Another reason is that the jumbo cup method requires a smaller amount of implant compared with other methods, such as porous metallic augments, cup-cage, and monoflanged acetabular component. However, many factors can affect the rate of PJI, such as femoral revision or no revision, use of antibiotics, type of material, and implant coating design. Therefore, we still recommend that this relatively low rate of PJI should be treated with caution because of some existing bias and the relatively simple statistical method.

There are also some controversies on using the jumbo cup for rTHA. In 2016, Lachiewicz and Watters pointed out that although the jumbo cup had shown excellent 10-year survivorship, the late loosening of “first-generation” porous surfaces and wear with periprosthetic osteolysis of traditional polyethylene liners had also been reported and needed more attention (27). They also recommended the use of enhanced porous coatings, highly cross-linked polyethylene liners, and large femoral heads in jumbo cup reconstruction. Zhou et al. retrospectively compared 74 consecutive rTHAs using metal augments with a cementless hemispherical cup and 77 consecutive rTHAs using the jumbo cup (33). The biomechanical parameters of the metal augment group, such as rotator center position, leg-length discrepancy, head-cup difference, and femoral offset, are all superior to those of the jumbo cup group. In recent years, many advanced reconstruction techniques such as 3D printing, custom prosthesis, and robot-assisted arthroplasty have been developed and seem to stand for the future direction of rTHA (62–64). Even so, the results of our systematic review have already supported the jumbo cup as a successful method for acetabular reconstruction in rTHA. The development of advanced biomaterials will further improve the performance of the jumbo cup.

Our study also has several limitations, some of which are listed here. First, the quality of the included studies is relatively low, and most of these are of a single-arm design. Second, the sample size is also relatively limited. In addition, the acetabular bone defects of many included cases are mild-to-moderate and relatively easy to reconstruct. In fact, the reconstruction for severe acetabular bone defect is the real hot spot and core problem in rTHA. Therefore, if only the performance of the jumbo cup for severe acetabular defect is discussed, the results may not be presented as well as those in our study. Unfortunately, most papers report the overall survivorship and failure and do not report the relation with the extent of bone defect. Therefore, this relation was not explored in this systematic review. Certainly, on the other hand, the results can also indicate that the jumbo cup is a good option for mild-to-moderate acetabular bone defect at least.

## Conclusion

In summary, according to this systematic review, the jumbo cup is a recommended method for acetabular reconstruction in...
rTHA. The clinical outcomes and survivorship of the jumbo cup are satisfying. However, in most cases, the acetabular bone defects are mild to moderate. Further research is still required to review its performance for severe or extreme acetabular bone defect reconstruction.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Author contributions

WG and WW set the topic and designed the protocol. QZ and JG conducted the literature search and quality assessment. QYW, QW, and PL extracted and analyzed the data and wrote the manuscript. All authors contributed to the article and approved the submitted version.

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