Review

Outcome of cages in revision arthroplasty of the acetabulum: a systematic review

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Summary. *Background and aim of the work:* To investigate the clinical, radiological and functional outcomes of acetabular revisions with acetabular reinforcement rings and cages. *Methods:* A comprehensive literature study of international databases was performed. Inclusion criteria were cementless revisions, use of reinforcement rings, radiological and clinical follow-up, availability of full text in English, publication between January 1990 and July 2018. In a second further analysis, we selected only studies describing patients with more severe acetabular defects (AAOS 3, AAOS 4, Paprosky III). Data extracted included mean follow-up period, radiographic follow-up, functional scores, implant failures and survival rate. *Results:* We included in our review 1327 acetabular revisions described in 28 articles. The most commonly used reinforcement rings were Burch-Schneider ring, the Muller ring and the Ganz ring. Mean follow-up for all patients together was 8.8 years. Clinical or radiological signs of loosening were reported in 191 patients, 83 patients needed further acetabular revision for aseptic loosening and 41 patients received additional surgeries for septic loosening. The mean value of the Harris Hip Score reported at the last follow-up was 76.3. Nineteen articles fulfilled the criteria for further analysis about high-grade acetabular bone defects. We analyzed 649 revisions with mean follow-up period of 8.2 years. Clinical or radiological loosening was reported in 90 patients, additional acetabular revision was performed in 39 patients and 25 patients needed further surgeries for deep infection. *Conclusion:* Acetabular revisions with cages are characterized by good survival rates and functional scores with a mean follow-up period of 8 years. (www.actabiomedica.it)

Key words: revision arthroplasty, acetabulum, cage, reinforcement ring, acetabular bone defect, acetabular revision outcomes

Introduction

Total hip arthroplasty (THA) is a successful procedure to relieve pain and improve function in patients with end-stage degenerative hip joint diseases. Kurtz et al. (1,2) estimated that, in the USA, the number of THA will go beyond 50,000 per year by 2020 and will grow to 572,000 per year by 2030.

With the constant increase of THA and the increasing of life expectancy, the number of revision surgeries will rise as well and is estimated to increase by 137% by 2030 (2).

The main causes for acetabular revisions are aseptic loosening, infection, recurrent dislocations due to malposition of the components or abductor mechanism failure, periprosthetic fractures and mechanical failure of fixation (3, 4).

Acetabular revision is one of the most challenging procedures in hip arthroplasty surgery due to bone loss, poor quality of residual bone stock, poor soft tissue and migration of acetabular components (5). This loss of bone stock results from the initial disease, bone removal at the time of primary surgery and lysis caused by micromotion of prosthetic components and wear particles (6, 7).

Several reconstruction methods for acetabular revision and management of bone loss are reported in literature including: uncemented hemispherical acetabular components, impaction bone grafting with cemented a polyethylene component, structural allograft, jumbo revision shells, trabecular metal components, oblong shells, acetabular reinforcement rings and cages with or without bone grafts, custom-made triflange shells, stemmed shells, and tantalum augmentation with cementless cup (3, 8, 9). The goal of all of these techniques is to provide firm fixation of the acetabular components, preservation or reconstitution of the bone stock and positioning the acetabular component in the correct anatomical position to restore the correct center of rotation (10-12).

The aim of this systematic review is to evaluate the clinical, radiological and functional outcomes of revision THAs utilizing acetabular reinforcement rings or cages.

The rationale for the use of acetabular cages is to provide mechanical stability to the acetabular construct, protect bone graft/cup/augments transmitting the load to the host bone through the cage. Usually cages are indicated in segmental bone loss involving more than half of the acetabular surface, deficit of anterior and posterior columns and pelvic discontinuity (AAOS III-IV) (9).

Materials and methods

Search strategy

A comprehensive literature search of the Medline, PubMed Database (US National Library of Medicine, National Institutes of Health), Embase and Google Scholar was performed using defined search phrases.

Headings used for the search were "Cementless Acetabular Revision", "Acetabular revision AND reinforcement ring" and "Acetabular revision AND cementless AND reinforcement rings".

This initial research included articles published between January 1990 and July 2018 evaluating clinical and radiological outcomes and failure rate of THA revisions with reinforcement rings and cages.

Inclusion criteria were: cementless revisions (between cage and host bone), acetabular revision with the use of reinforcement rings, both radiological and clinical follow-ups, and availability of the full text in English.

We excluded from our study review articles, single case report and THA revisions due to deep infection.

Studies were first screened based on the title and abstract. Full text analysis confirmed the inclusion in the review. Citations within selected papers were reviewed to identify additional studies.

In a second analysis we selected only studies about patients with more severe acetabular defects (AAOS 3, AAOS 4 and Paprosky III). AAOS 3 defects are combined cavitary and segmental defects. AAOS 4 correspond to pelvic discontinuity. Paprosky III defect included major destruction of supporting structures and acetabular rim.

We defined the failure of the acetabular component as the need for a new revision or radiological signs of loosening of the implant. The criteria for radiographic loosening included: horizontal or vertical migration bigger than 2-5 mm, a change in acetabular tilt >3°-5°, progressive radiolucent lines, breaking of screws or reinforcement rings (8, 13-17). We classified failure into septic and aseptic.

Data extraction

Data extracted from the selected studies included authors, journal and year of publication, number of included THA revisions, mean follow-up (FU), mean patient age at time of surgery, radiographic FU, postoperative functional score, implant failure and survival rate.

Results

After the exclusion of duplicates, there were a total of 679 abstracts (634 - "cementless acetabular revision"; 42 - "acetabular revision and reinforcement rings"; 3 - "acetabular revision and cementless and reinforcement rings"). 644 publications were excluded based on title and abstract and 7 more articles were excluded after analyzing the full text. Consequently, we included in our review 28 articles.

For the second analysis based on severe acetabular defect only 19 publications fulfilled the inclusion criteria.

Due to the nature of the study, all the articles were retrospective cases of THA revisions using reinforcement rings. Randomized control trials (RCTs) were not available.

All cases (All bone defects)

We analyzed 28 articles published between 1990 and 2018 that reported the outcomes of ten different kinds of reinforcement rings (Table 1). The most commonly used reinforcement rings were the Burch-Schneider ring (13 articles), the Muller ring (12 articles), and the Ganz ring (4 articles). All the other reinforcement rings (Custom-made cage, KT Plates, MRS-Titan, Murata-Chiba support ring, ZCA Reconstruction cage, Kerboull ring) were analyzed in only 1 article each except for Contour reinforcement and reconstruction rings that were described in 2 different studies.

We included in our review 1327 patients who had had acetabular revision with reinforcement rings and in 83.3% of them (1106 patients) one of the three most commonly used reinforcement rings was used.

Analyzing all the patients together, the mean follow-up period was 8.8 years (0,5-22,9) and the mean age at the time of acetabular revision was 64.5 years (26-95). Clinical or radiological signs of loosening were reported in 191 (14,4%) patients. Eighty-three (6,3%) patients needed further acetabular revision for aseptic loosening and 41 (3.1%) patients received additional surgeries for septic loosening.

The most commonly reported functional score was the Harris Hip Score (HHS) and the mean value at the time of FU was 76.3. All the authors that used the HHS for the clinical FU reported a significant increase of the score after the acetabular revision (5, 6, 8, 11, 14, 15, 18-26).

Five hundred and three patients (37.9%) had had a Muller ring placed. These patients had a mean FU period of 5.9 years, a mean age at the time of surgery of 65.3 years and a rate of loosening of 11.9%. A Burch-Schneider ring was placed in 399 patients (30%) with a mean FU period of 5.6 years, mean age of 57.3 years and a rate of loosening of 15.8%. The Ganz ring was used in 204 THA revisions (15.4%). The mean FU period was 10.3 years, the mean age at surgery was 64.1 years and the rate of loosening was 16.2% (table 2).

High-grade bone defect cases

Nineteen articles published between 1992 and 2018 fulfilled the criteria for our further analysis (table 3).

There were 649 revision THAs described with a preoperative acetabular bone defect classified as AAOS 3-4 or Paprosky IIIa-IIIb. The mean age at surgery was 66.7 years and the mean FU period was 8.2 years. Clinical or radiological loosening was reported in 90 patients with a consequently rate of loosening of 13.9%. Additional acetabular revision was performed in 39 patients (6%) and 25 (3.9%) patients needed further surgeries for deep infection.

The Burch-Schneider ring was used in 212 patients (32.7%). The mean FU period was 6,1 years and the rate of loosening was 10,4%. In 170 acetabular revisions (26.2%) a Muller ring was used. The average FU time was 7,9 years and the loosening rate was 12.4%. The Ganz ring was used in 99 THAs revisions (15.3%). The mean FU period was 11 years and the rate of loosening was 19.2% (table 4).

Only eight authors reported the Harris Hip Score at the last follow up (5, 14, 15, 18, 19, 25-27). The average HHS at the time of the last FU was 76.5.

Discussion

Our review summarize clinical, radiological and functional outcome of acetabular revisions with deficient bone stock treated with a reinforcement ring.

Acetabular revision is still one of the most challenging procedures in hip arthroplasty surgery due to bone loss, poor quality of residual bone stock, poor soft tissue and migration of acetabular components (5). Deficiency of bone stock results from the initial osteoarthritic process, bone reaming at the time of primary surgery and lysis caused by micromotion of prosthetic components and wear particles (7, 11, 22, 28).

Several surgical techniques are reported in literature for acetabular revision and the management of bone loss (3, 8, 9). More recently, cages are usually indicated in severe acetabular bone loss involving more than half of the acetabular surface , medial wall deficiency, pelvic discontinuity and when it is not pos-

Table 1

Author	Reinforcement ring	Hips (N°)	Mean FU (years)	Mean age (years)	Loosening (clinical / radiological)	Revision - Aseptic Loosening	Revision - Septic Loosening	Functional Score (mean score)	Survival rate
Beckmann [5]	Ganz	119	16 (15-18)	65 (26-90)	19	15	4	HHS 77; womuoi 64,5; sf12 PCS 32 MCS 55.9; NRS > 50% no pain	survival rate 90,1% (82,6-94,4%)
Berry [7]	Burch-Schneider	42	5 (2-11)	61,7	12	5	5	Merle d'Aubignè (pain score 3.2 to 4,8; walking score 4,4 to 5; motion score 4,2 to 5,1)	
Bohm [29]	Muller	39	4,2 (1-13)	61 (31-86)	2	1	1	X	worst-case criterion survival rate (revision\deep infection\loss to FU) 84% at 13 years
Bohm [29]	Burch-Schneider	26	5,3 (0,5-11)	61 (31-86)	2	1	1	X	survival rate 89% at 11 years survival rate worst-case criterion (revision\deep infection\loss to FU) 83% 11 years
Bruggemann [4]	Muller	96	12 (2,3-17)	69 (40-95)	9	8	1	X	
Eggli [18]	Ganz	5	8 (4,5-10,9)	61,7 (50-72)	2	2	0	Merle d'Aubignè from 7,5 to 13.2; HHS from 33 to 73	
Eggli [18]	Muller	2	8 (4,5-10,9)	61,7 (50-72)	0	0	0	Merle D'Aubignè from 7,5 to 13.2 HHS from 33 to 73	
Gaiani [19]	Burch-Schneider	46	6 (2-10)	82 (78-85)	0	0	0	HHS from 28,2 to 82,5 (62,2-94,8) 1 severe pain, 4 moderate pain	
Garbuz [20]	Burch-Schneider	8	7,5 (5-11)	60 (32-85)	1	0	1	HHS from 29 to 73	
Gerber [17]	Ganz	50	9 (7,8-11,6)	69 (53-86)	7	3	1	Merle d'Aubignè from 11 to 16	survival rate 81% at FU survival rate 85% at 10 years for adequate reconstruction survival rate 57% at 10 years for inadequate reconstruction
Goodmann [30]	Burch-Schneider	42	4,6 (2-19)	65,2 (33-93)	9	4	2	X	76% success: no dislocation, no loosening, no revisions
Goodmann [30]	Contour	19	4,6 (2-19)	65,2 (33-93)	9	4	2	X	
Ilchmann [21]	Burch-Schneider	40	4,7 (2,3-6,9)	70 (36-81)	16	2	0	HHS 72 at last FU	
Jain [22]	Muller (22) Burch-Schneider (2)	24	2,8 (1,1-4,5)	72,7 (66,3-79,1)	1	1	0	HHS 44,2 (SD 23.3) SF36: all parameters worst than general population	
Kokubo [14]	KT Plates (34) Muller (8) Kerboull (5)	47	15,6 (10-32)	65,8 (45-85)	12	8	0	HHS from 40.9 (18-58) to 72.1 (32-92)	
Korovessis [32]	Muller	10	2,5 (1-5)	61 (31-83)	0	0	0	Mayo Clinic Hip scale: 60% good-excellent; 40% moderate-fair	
Levai [35]	Muller	28	3,1 (3-4)	66,1 (55-76)	2	2	0	Merle D'Aubignè from 9,1 to 14.9	
Levai [35]	Burch-Schneider	2	3,1 (3-4)	66,1 (55-76)	0	0	0	Merle D'Aubignè from 9,1 to 14.9	
Li [15]	custom cages	24	5,6 (2-10)	65 (54-79)	1	0	0	HHS from 36 (20-49) to 82 (60-96)	
Makinen [34]	ZCA Reconstruction Cage+ porous metal augment	22	3 (2-4,6)	70 (27-85)	3	2	0	Oxford hip score from 13,9 (2-23) to 28,7 (13-38)	loosening: patients with previous oncological resection of acetabulum survival rate 90,9% at 36 months; 75,7% at 55 months
Murali Krishnan [11]	Contour reinforcement ring (23) Contour reconstruction ring (22)	45	7,1 (3,5-8,8)	75,6 (31-95)	2	0	3	HHS: 16 excellent-good, 6 fair, 4 poor	
Ochs [23]	Burch-Schneider	79	2,6 (1,2-4,2)	71,2 (46-90)	20	0	0	HHS 70,4 (1,5-97,1)	
Panski [28]	Muller	11	3,3 (0,5-7)	61,3 (42-86)	1	1	0	9 patients satisfied at FU	
Rosson [6]	Muller	46	5 (2-10)	63 (32-79)	10	5	0	HHS 87 (61-100) at FU	
Rosson [6]	Burch-Schneider	20	5 (2-10)	62 (22-73)	0	0	0	HHS 81 (56-99)	
Schatzker [24]	Muller	57	8,3	62,9	9	8	1	HHS from 42,7 to 84,8 SF36 40 physical e 56 mental	survival rate 92,3% at 10 years
Schatzker [24]	Burch-Schneider	38	6,6	66,8	2	0 (2 awaiting revision)	0	HHS from 45,9 to 82,8 SF36 physical 41, mental 54	survival rate 91,7% at 10 years
Schlegel [27]	Muller	109	6 (2-17)	69 (29-92)	12	6	7	HHS 70 (20-100) at FU 52% HHS<70 poor score Merle d'Aubignè 7 (0-12)	survival rate 95% at 5 years, 90% at 8 years aseptic survival rate 98% at 5 years, 95% at 8 years
Schmolders [25]	MRS-Titan	39	2,6 (1-4,3)	67 (43-88)	6	1	5	HHS from 27 (13-41) to 76 (61-91)	survival rate 84% al FU
Stockl [33]	Muller	49	6,4 (5,9-9)	67,8 (43,5-84)	8	2	2	30% no support for walking 59% mild pain	survival rate 92,9% at FU
Uchiyama [12]	Ganz	30	8 (3-17,8)	60,8 (41-80)	5	0	0	X	survival rate 96% at 5 years, 80,2% at 10 years
van der Linde [16]	Burch-Schneider	16	11,7 (6,8-16,2)	67,4 (37-83)	1	0	1	Merle d'Aubignè from 9,8 to 14,4	
van del Linde [16]	Muller	26	9,2 (6,4-13,2)	67,7 (45-87)	3	1	2	Merle d'Aubignè from 9,5 to 14	
Winter [26]	Burch-Schneider	38	7,3 (4,2-9,4)	76 (49-83)	0	0	0	HHS 82,6 (58,2-94,9)	survival rate 100% at FU
Yoshino [8]	Murata-Chiba support ring	33	17,6 (15-22,9)	54,1 (42,9-65,3)	5	1	2 (resection Arthroplasty)	HHS from 44,3 (7.79) to 77,2 (55-97)	survival rate 90,6% at 15 years (100% AAOS II; 97,6% AAOS III)

Table 2

Reinforcement ring	Hips (N°)	Mean FU (years)	Mean age (years)	Loosening (clinical / radiological)	Revision - Aseptic Loosening	Revision - Septic Loosening
Ganz (4)	204	10,3	64,1	33	20	5
Burch-Schneider (13)	399	5,6	57,3	63	12	10
Contour (2)	64	5,85	70,4	11	4	5
Custom Cages (1)	24	5,6	65	1	0	0
KT Plates (1)	34	15,6	65,8	5	3	0
MRS-Titan (1)	39	2,6	67	6	1	5
Muller (12)	503	5,9	65,3	60	36	14
Murata-Chiba support ring (1)	33	17,6	54,1	5	1	2
ZCA Reconstruction Cage (1)	22	3	70	3	2	0
Kerboull (1)	5	15,6	65,8	4	4	0
TOTAL	**1327**	**8,8 (0,5-22,9)**	**64,5 (26-95)**	**191**	**83**	**41**

Table 3

Author	Reinforcement ring	Hips (N°) AAOS 3-4 / Paprosky IIIa-IIIb	Mean FU (years)	Mean age (years)	Loosening (clinical / radiological)	Revision - Aseptic Loosening	Revision - Septic Loosening	Functional Score
Beckmann [5]	Ganz	68	16 (15-18)	65 (26-90)	12	X	X	HHS 77; womuoi 64,5; sf12 PCS 32 MCS 55.9; NRS > 50% non dolore
Berry [7]	Burch-Schneider	42	5 (2-11)	61,7	12	5	5	Merle d'Aubignè (pain score 3.2 to 4,8; walking score 4,4 to 5; motion score 4,2 to 5,1)
Bohm [29]	Muller	14	4,2 (1-13)	61 (31-86)	1	1	0	X
Bohm [29]	Burch-Schneider	20	5,3 (0,5-11)	61 (31-86)	1	1	0	X
Bruggemann [4]	Muller	32	12 (2,3-17)	69 (40-95)	1	1	0	X
Eggli [18]	Ganz	5	8 (4,5-10,9)	61,7 (50-72)	2	2	0	Merle D'Aubignè from 7,5 to 13.2 HHS from 33 to 73
Eggli [18]	Muller	2	8 (4,5-10,9)	61,7 (50-72)	0	0	0	Merle D'Aubignè from 7,5 to 13.2 HHS from 33 to 73
Gaiani [19]	Burch-Schneider	46	6 (2-10)	82 (78-85)	0	0	0	HHS from 28,2 to 82,5 (62,2-94,8)
Garbuz [20]	Burch-Schneider	8	7,5 (5-11)	60 (32-85)	1	0	1	X
Gerber [17]	Ganz	26	9 (7,8-11,6)	69 (53-86)	5	3	1	Merle d'Aubignè from 11 to 16
Goodmann [30]	Burch-Schneider	35	4,6 (2-19)	65,2 (33-93)	8	3	2	X
Goodmann [30]	Contour	13	4,6 (2-19)	65,2 (33-93)	9	4	2	X
Kokubo [14]	KT Plates (34) Muller (8) Kerboull (5)	47	15,6 (10-32)	65,8 (45-85)	12	8	0	HHS from 40.9 (18-58) to 72.1 (32-92)
Levai [35]	Muller	6	3,1 (3-4)	66,1 (55-76)	1	1	0	X
Levai [35]	Burch-Schneider	2	3,1 (3-4)	66,1 (55-76)	0	0	0	X
Li [15]	Custom Cages	24	5,6 (2-10)	65 (54-79)	1	0	0	HHS from 36 (20-49) to 82 (60-96)
Makinen [34]	ZCA Reconstruction Cage+ porous metal augment	22	3 (2-4,6)	70 (27-85)	3	2	0	Oxford hip score from 13,9 (2-23) to 28,7 (13-38)
Murali Krishnan [1	Contour reinforcement ring (13) Contour reconstruction ring (18)	31	8 (3,5-8,8)	75,6 (31-95)	0	0	0	X
Rosson [6]	Muller	1	5 (2-10)	63 (32-79)	1	1	0	X
Rosson [6]	Burch-Schneider	15	5 (2-10)	62 (22-73)	0	0	0	X
Schlegel [27]	Muller	100	6 (2-17)	69 (29-92)	12	6	7	HHS 70 (20-100) at FU 52% HHS<70 poor score Merle d'Aubignè 7 (0-12)
Schmolders [25]	MRS-Titan	39	2,6 (2-4,3)	67 (43-88)	6	1	5	HHS from 27 (13-41) to 76 (61-91)
van der Linde [16]	Burch-Schneider	6	11,2 (8,5-13,9)	61 (37-77)	0	0	0	Merle d'Aubignè from 9,8 to 16
van del Linde [16]	Muller	7	9,7 (8,3-13,2)	65 (51-78)	2	0	2	Merle d'Aubignè from 8,6 to 13,4
Winter [26]	Burch-Schneider	38	7,3 (4,2-9,4)	76 (49-83)	0	0	0	HHS 82,6 (58,2-94,9)

sible to achieve primary stability with hemispherical cemented or uncemented cups (16). The rationale for the use of cages is to obtain mechanical stability to the prosthetic acetabulum and to protect the allograft or the augments transmitting the load through the cage to the pelvic host bone (9, 15, 18, 21). Two main kinds

Table 4

Reinforcement ring	Hips (N°) AAOS 3-4 / Paprosky IIIa-IIIb	Mean FU (years)	Mean age (years)	Loosening (clinical / radiological)	Revision - Aseptic Loosening
Burch-Schneider (9)	212	6,1	66,1	22	9
Contour (2)	44	6,3	70,4	9	4
Custom Cages (1)	24	5,6	65	1	0
Ganz (3)	99	11	65,2	19	5
KT Plates (1)	34	15,6	65,8	5	3
MRS-Titan (1)	39	2,6	67	6	1
Muller (8)	170	7,9	65,1	21	11
Kerboull (1)	5	15,6	65,8	4	4
ZCA Reconstruction Cage (1)	22	3	70	3	2
TOTAL	**649**	**8,2**	**66,7**	**90**	**39**

of acetabular cages are described in literature: antiprotrusio cages and acetabular roof rings. The antiprotrusio cages are characterized by double flanges for the ilium and the ischium. Whereas, acetabular roof rings may or may not have a hook for cotyloid notches and usually do not have flanges for the ilium (9). Van der Linde et al. (16) reported that the only absolute indication for antiprotusio cages is pelvic discontinuity while for other acetabular defects the selection of the reinforcement rings depends on which fit best in the acetabulum. Other authors (6, 12, 29, 30) instead, underline that in the presence of segmental medial defects acetabular roof rings are insufficient to guarantee mechanical stability to the construct.

Obtaining the proper anatomical position of the socket is fundamental to re-establish the right center of rotation of the hip, but can be challenging in acetabular revision in cases with severe bone loss. Shutzer and Harris (31) in 1994 suggested high placement of the acetabulum to obtain sufficient contact between the prosthesis and the host bone. Instead, several more recent articles reported a higher incidence of acetabular loosening in these cases (11, 12, 15, 18-21, 24,25, 32, 33). In these cases, the use of graft and reinforcement rings to reestablish the right center of rotation is strongly suggested.

In our review we analyzed 1327 acetabular revisions reported in 28 articles with a mean follow-up of 8.8 years. Clinical or radiological sign of loosening was present in 14.4% of cases and 6.3% of patients underwent further acetabular revision for aseptic loosening. The most commonly reported functional score was the Harris Hip Score (HHS) and the mean value at the time of FU was 76.3 (poor results were considered to be inferior to 70 points). All the authors that used the HHS for the clinical FU reported a significant increase of the score after the acetabular revision (6, 8, 10, 11, 14, 15, 18-27). In our further analysis, we considered only acetabular revisions with high-grade bone defect. We did not encounter significant differences in the loosening rate and the need of further acetabular revision between the "all defect group" and the "high-grade defect group". In both groups, the Ganz ring was characterized by a higher loosening rate.

Recently, newer porous metal implants have been introduced. Their advantages are porous surfaces, lower modulus of elasticity and higher coefficients of friction. All of these characteristics are thought to increase and accelerate bone ingrowth. Trabecular metal hemispherical cup and augments could be an alternative solution to cages in high grade bone defect acetabular revision (34). Beckmann et al. (10], in their review, reported a lower loosening rate of trabecular metal cups compared with acetabular cages. The authors strongly suggest the use of trabecular metal cups also in high-grade bone defect acetabular revision. However, long-term results are not yet available in literature.

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