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REVIEW

Metaphyseal cones and sleeves in revision total knee arthroplasty: Two sides of the same coin? Complications, clinical and radiological results—a systematic review of the literature

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Abstract

Revision total knee arthroplasty (rTKA) is increasing of relevance in orthopaedic surgeon daily practice and this trend is likely to continue in the years ahead. The aim of this systematic review of English literature is to summarize and compare indications, complications, clinical and radiological results of metaphyseal cones and sleeves in management of bone loss in rTKA. Retrospective or prospective studies with at least 1 year of follow-up (FU) were included. The PRISMA 2009 flowchart and checklist were considered to edit the review. Clinical and radiological results, rates of intraoperative fractures, aseptic loosening, periprosthetic joint infection, septic failure, reoperations and re-revisions were extrapolated by the papers. Thirty-seven articles were included in the systematic review. Results of 927 cones (mean FU of 3.6 ± 1.4 years) and 1801 sleeves (mean FU of 4.5 ± 1.6 years) were analysed. The studies showed good clinical and functional outcomes. Cones and sleeves allowed a stable metaphyseal fixation. The aseptic survivorship of the implants was 97.3% in cones group and 97.8% in sleeves group. Metaphyseal cones and sleeves represent a viable option in management of type IIb and III AORI bone defects in aseptic and septic TKAr with overlapping survival rate. Further high-quality long-term studies would better clarify complications, clinical and radiological results of these promising techniques in revision total knee arthroplasty.

Keywords Revision total knee arthroplasty · Bone defect · Metaphyseal sleeves · Metaphyseal cones · Results · Complications

Introduction

The number of primary total knee arthroplasties (TKA) has increased dramatically in recent years. A commensurate rise of revision procedures is estimated in the years ahead. In the USA, the projections report an increase in 601% of revision total knee arthroplasties (rTKA) between 2005 and 2030 [1].

The goals of revision surgery are to preserve viable host bone, reconstruct bone deficiencies, restore joint line, achieve neutral alignment and optimize soft tissue balance [2, 3]. Management of massive bone defects classified as Anderson Orthopaedic Research Institute (AORI) [4] type 2B and 3 in rTKA can be challenging, and the optimal treatment method has not yet been established. Several strategies are described in the literature with mixed results: diaphyseal fixation with cemented or cementless stems bypasses bone defects, impaction of bone grafting with or without mesh augmentation, bulk allografts or allograft prosthetic composites, custom-made prostheses, modular metal augmentation of prostheses and tumour-type or hinged implants [2, 3, 5, 6]. Studies concerning the use of structural allograft in rTKA report a considerable incidence of complications and reoperations, related to infection (4–8%), nonunion (0–4%) and graft failure and resorption (8–23%) [3, 6, 7]. Similar unsatisfactory results were reported with tumour-type and hinged implants [8, 9].

The use of metaphyseal porous metal devices (cones and sleeves) in rTKA has gained recent popularity in the last years with promising short- and mid-term results [10–12].

The body of the literature and interest surrounding metaphyseal porous metal devices increase dramatically in

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recent years, but a systematic and exhaustive evaluation of the existing evidence has not yet been performed. The purpose of this systematic review is to summarize and compare indications, complications, clinical and radiological results of metaphyseal cones and sleeves in management of bone loss in rTKA.

Materials and methods

A systematic review of the literature was performed with a primary search on Medline through PubMed used the following strategy: ((((((((((revision[All Fields] AND ("arthroplasty, replacement, knee" [MeSH Terms] OR ("arthroplasty" [All Fields] AND "replacement" [All Fields] AND "knee" [All Fields]) OR "knee replacement arthroplasty" [All Fields] OR ("knee" [All Fields] AND "arthroplasty" [All Fields]) OR "knee arthroplasty" [All Fields])) AND ("arthroplasty, replacement, knee" [MeSH Terms] OR ("arthroplasty" [All Fields] AND "replacement" [All Fields] AND "knee" [All Fields]) OR "knee replacement arthroplasty" [All Fields] OR ("knee" [All Fields] AND "replacement" [All Fields]) OR "knee replacement" [All Fields])) AND ("bone diseases, metabolic" [MeSH Terms] OR ("bone" [All Fields] AND "diseases" [All Fields] AND "metabolic" [All Fields]) OR "metabolic bone diseases" [All Fields] OR ("bone" [All Fields] AND "loss" [All Fields]) OR "bone loss" [All Fields]))) OR metaphyseal sleeves)) OR tantalum cones)) OR trabecular cones)) OR metaphyseal cones.

The inclusion criteria were: studies providing clinical, radiological results and complications about metaphyseal cones and sleeves in rTKA; retrospective or prospective clinical studies including randomized controlled trials, nonrandomized trials, cohort studies, case-control studies and case series with a minimum follow-up of 1 year; papers in English without any restriction on publication date. The exclusion criteria were: articles that did not provide complications, clinical and radiological results about metaphyseal cones and sleeves in rTKA; studies concerning predominately complex primary TKA; experimental biomechanical or in vitro studies; surgical technique papers, case reports and reviews or meta-analyses.

One reviewer applied the previously determined criteria to select potentially relevant papers. Articles were initially identified based on title and abstract; fulltext versions of relevant trials were then obtained and evaluated. References of the identified articles were checked not to miss any further relevant articles. The PRISMA 2009 flow chart and checklist were considered to edit the review.

The Level of Evidence (LOE) of the studies was assigned based on the 2011 Oxford Centre for Evidence-based Medicine Levels of Evidence [13].

The following data, when available, were extracted from the articles: number of patients, number of treated knees, mean number of previous surgeries/revisions/total knee arthroplasties, mean age population (years), preoperative diagnosis, classification and types of bone defects, number of cones or sleeves used, type of fixation (cemented, uncemented sleeves/cones and/or diaphyseal stems), level of constraint of the final implant, mean FU (years), drop-out rate, global rate of intraoperative fractures (ratio between cases and number of implants), rate of intraoperative fractures during cones/sleeves preparation and insertion (ratio between cases and number of cone/sleeves), global rate of aseptic loosening of the implants (ratio between cases and number of implants), rate of aseptic loosening of cone/sleeves (ratio between cases and number of cone/sleeves), rate of infection (ratio between cases and number of implants), septic failure rate (ratio between cases of re-infections and cases with preoperative diagnosis of periprosthetic joint infection) and reoperations/re-revisions rate (ratio between cases and number of implants). Every new surgery was considered as reoperations; re-revisions instead included every prosthetic components revision excluded polyethylene exchange. In the evaluation of drop-out rate of each paper, patients underwent re-revisions and/or reoperations before the minimum FU were considered in the cumulative analysis of study population.

The studies that did not declare a specific variable were excluded by the global evaluation of that parameter (e.g. number of fracture in sleeves/cones preparation and insertion).

Categorial variables were expressed as number of cases or percentage. Continuous variables were reported as mean ± standard deviation (SD). The lower and upper limits of 95% confidence intervals (CI) were calculated.

Results

A total 37 articles were finally included in the systematic review: 21 concerning metaphyseal cones (MC) [7, 14–33] and 16 regarding metaphyseal sleeves (MS) [34–49]. The PRISMA 2009 diagram illustrates the studies that have been identified, included and excluded as well as the reason for exclusion (Fig. 1). Most of papers were rated as level IV according to 2011 Oxford Center for Evidence-based Medicine Levels of Evidences; just two case-control studies (MC vs. femoral head allograft [31] and MC vs. hybrid stem fixation [14]) were rated level III.

Tables 1 and 2 summarize data extracted from included papers.

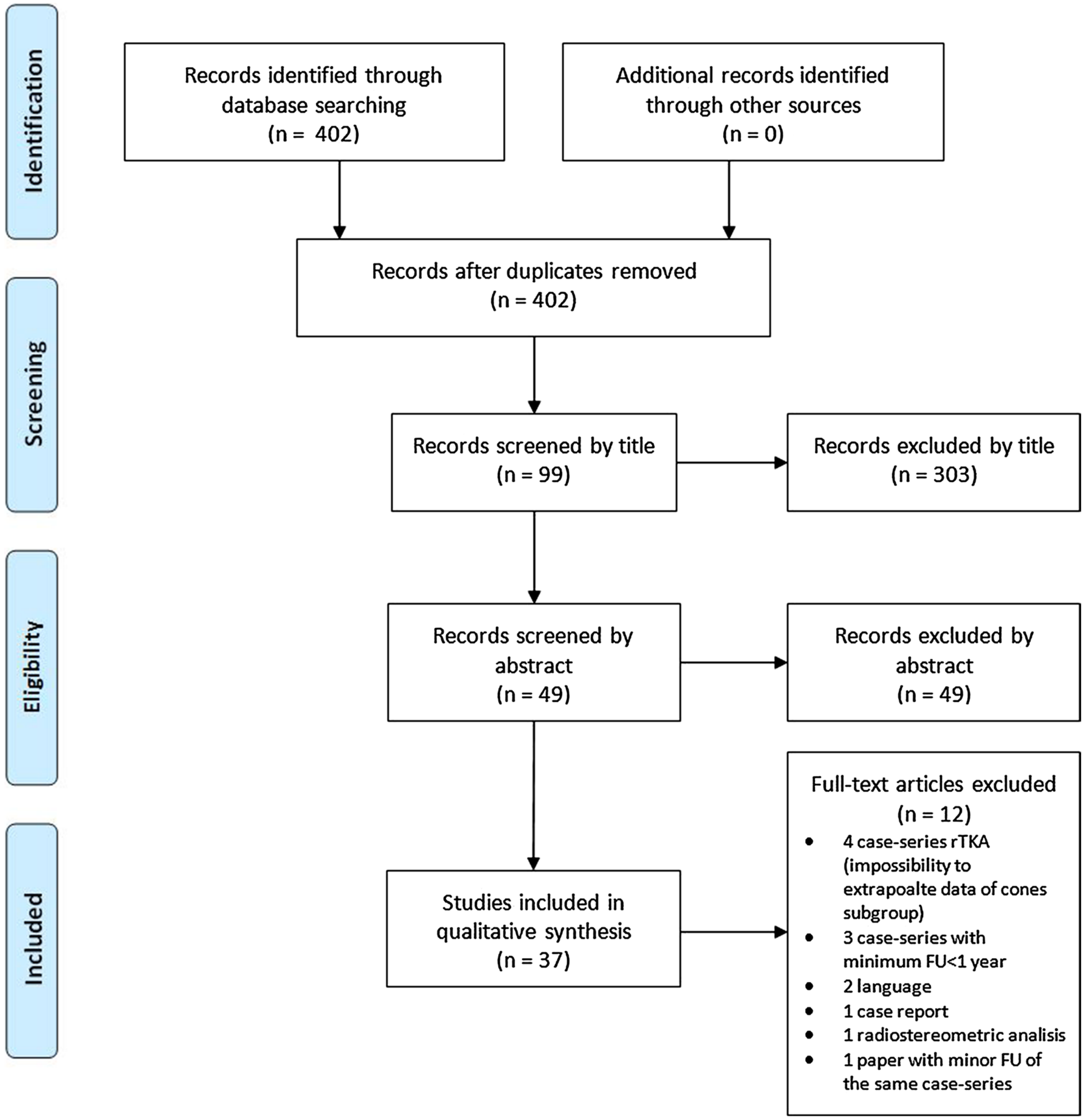

Fig. 1 The PRISMA flow diagram illustrates the studies that have been identified, included and excluded as well as the reason for exclusion

Demographic data

The data of 778 knees (769 patients—mean age of 68.0 ± 3.4 years) were analysed for metaphyseal cones group with a mean follow-up of 3.6 ± 1.4 years. 1219 knees (1200 patients—mean age of 68.9 ± 3.9 years) with a mean follow-up of 4.5 ± 1.6 years were included in the analysis for metaphyseal sleeves.

Most of the papers used AORI classification with relevant part of bone defects classified as type II and III at femoral and tibial side. Two articles did not declare type of classification of bone defects used and grade of bone loss [39, 44].

Aseptic loosening (AL) and chronic periprosthetic joint infection (PJI) were predominant indications for TKAr in the series, other reported reasons were instability, tibiofemoral malalignment, prosthetic components malrotation, polyethylene (PE) wear, osteolysis, trauma and periprosthetic fracture, stiffness, implant failure and pain. In cases of PJI, a staged revision was usually performed. One study did not declare the indications for TKAr [44]. Also complex primary TKA is a minor indication for the use of metaphyseal porous metal devices in the series [16, 29, 48].

Implant fixation

A total of 927 MC were implanted: 339 on femoral side (36.6%), 341 on tibial side (36.8%) and 247 on both sides (22.6%). In 4 series a two-stacked cones technique has been

Table 1 Summary and main features of the included cones's studies

Authors	LOE	Knees (patients)	Mean age (years)	Preoperative diagnosis	Bone defects classification	No. of cones (F/T/FT)	Fixation method	Mean FU (years)	Drop-out rate
Bohl et al. [14]	III	49 (49)	69 ± 9.4	16 AL, 12 PJI, 12 instability, 6 stiffness, 2 malrotation, 1 PPF	AORI 16 T1, 16 T2a, 16 T2b, 1 T3, 9F1, 16 F2a, 21 F2b, 3 F3	56 (3/39/14)	U cones + U/C stems +/− augments (AC) [−]	3.4 ± 1.4	0
Boureau et al. [15][a]	IV	7 (7)	65 (51–79)	4 AL, 3 PJI	AORI 2 F2b, 5 F3 SoFCOT 2 type B, 5 type C	14[a] (14/0/0)	U cones +/− bone graft + stems (−) [−]	1.4 (1–2.1)	0
Brown et al. [16]	IV	83 (83)	69 (32–91)	30 AL, 21 PJI, 16 instability, 6 stiffness, 3 PPF, 2 malalignment, 1 traumatic arthrotomy, 4 primary TKA	AORI 13 type 1, 28 type 2a, 47 type 2b, 6 type 3	94 (7/65/22)	U cones +/− bone graft + C stems (−) [−]	3.3 (2–7)	0
Burastero et al. [17][a]	IV	60 (60)	67.9 ± 8.8	60 PJI	AORI 3 T1, 10 T2a, 30 T2b, 17 T3, 1 F1, 16 F2a, 27 F2b, 14 F3	94[a] (9/21/64)	U cones + U/C stems +/− augments (−) [T: 75–155 mm; F: 75–200 mm]	3.6 ± 1.5	0
De Martino et al. [18][a]	IV	18 (18)	73 (55–84)	13 PJI, 5 AL	AORI 3 T2b, 9 T3, 3 F2b, 10 F3	26[a] (6/5/15)	U cones +/− bone graft + U/C stems (AC) [T/F: 100–155 mm]	6 (5–8)	0
Derome et al. [19]	IV	29 (29)	(–)	20 AL/PE wear, 7 PJI, 2 PPF	AORI T2b, T3, F2b, F3	33 (12/13/8)	U cones +/− bone graft + U stems +/− augments (AC) [−]	2.8 (1.1–6.1)	0
Fosco et al. [20]	IV	11 (10)	62 (43–75)	5 AL, 4 PJI, 1 implant failure, 1 malrotation	AORI 5 T2b, 1 T3, 5 F2b, 1 F3	12 (5/5/2)	U/C cones +/− bone graft + U/C stems (AC) [−]	3.2 (2–6.5)	0
Girerd et al. [21]	IV	52 (51)	68 (42–89)	22 AL, 19 PJI, 3 osteolysis/PE wear, 2 extensor mechanism abnormality, 2 pain, 1 implant failure, 1 instability,1 stiffness, 1 other	AORI 2 T2a, 21 T2b, 15 T3, 10 F2b, 24 F3	73 (14/17/42)	U cones + U stems (−) [T/F: 100–200 mm]	2.8 (2–4.3)	0
Howard et al. [22]	IV	24 (24)	64 (46–79)	11 AL, 7 PJI, 3 osteolysis, 2 PPF, 1 instability	AORI F2b, F3	24 (24/0/0)	U cones + bone graft or demineralized bone matrix + C stems (−) [−]	2.8 (2–4.2)	0
Jensen et al. [23]	IV	36 (36)	69 (51–84)	15 AL, 15 PJI, 5 instability, 1 pain	AORI 27 T2, 9 T3	38 (0/34/4)	U cones + bone graft + U stems (AC) [−]	3.3 (1–7)	27.8%
Kamath et al. [24]	IV	66 (63)	67 (41–83)	26 PJI, 15 AL, 12 instability, 10 osteolysis, 2 implant failure, 1 PPF	AORI 17 T2a, 25 T2b, 24 T3	66 (0/66/0)	U cones + bone graft or demineralized bone matrix + U/C stems (AC) [T: 30–155 mm]	5.8 (5–8.8)	20.6%

Table 1 (continued)

Authors	LOE	Knees (patients)	Mean age (years)	Preoperative diagnosis	Bone defects classification	No. of cones (F/T/FT)	Fixation method	Mean FU (years)	Drop-out rate
Lachiewicz et al. [7]	IV	27 (27)	64.6 (49–84)	13 PJI, 10 AL, 4 osteolysis and PE wear,	AORI 4 T2b, 20 T3, 9 F3	33 (3/18/12)	U cones + U/C stems (AC) [F: 90–175; T: 35–145 mm]	3.3 (2–5.7)	0
Long et al. [25]	IV	16 (15)	66.1 (48–83)	13 AL, 3 PJI	AORI 2 T2a, 3 T2b, 4 T3a, 7T3b, 2 F3	18 (0/14/4)	U cones + bone graft or demineralized bone matrix + U/C stems +/− augments (AC) [T: 75–200 mm]	2.6 (2–3.2)	0
Meneghini et al. [26]	IV	15 (15)	68.1 (41–81)	5 PJI, 4 AL, 3 osteolysis, 2 PPF, 1 instability	AORI 7T2b, 8 T3	15 (0/15/0)	U cones +/− bone graft or demineralized bone matrix + U/C stems (AC) [T: 30–155 mm]	2.8 (2–3.9)	0
Mozella et al. [27]	IV	10 (10)	71.1 (59–80)	3 PJI, 3 malalignment, 2 osteolysis, 1 PE wear, 1 AL	AORI 3 T2a, 3 T2b, 3 T3, 2 F2b, 1 F3	12 (1/7/4)	C cones + bone graft + C stems +/− augments (AC) [−]	2.9 (2.2–3.8)	10%
Potter GD et al. [28][b]	IV	159 (157)	64 (24–85)	75 PJI, 56 AL, 26 osteolysis, 26 implant failure, 11 instability, 1 PPF[b]	AORI 127 F2b, 32 F3	159 (159/0/0)	U cones + bone graft + C stems (AC) [F: 30–155 mm]	5 (2–10)	1.3%
Rajgopal et al. [29][a]	IV	16 (16)	63.8 (42–84)	5 PJI, 3 AL, 3 PPF, 5 primary TKA	AORI 7 F2b, 9 F3	32[a] (32/0/0)	U cones + bone graft + C stems (−) [−]	4.75 (−)	0
Rao et al. [30]	IV	26 (26)	72 (62–84)	14 AL, 9 PJI, 3 PPF	AORI 13 T2a, 4 T2b, 8 T3, 3 F2a, 1 F3	29 (22/1/6)	U cones + bone graft + U stems (−) [30–130 mm]	3 (2–4.1)	0
Sandiford et al. [31][c]	III	15 (14)	71 (44–84)	37 AL, 2 PJI, 2 PPF, 2 instability[c]	AORI 4 T2a, 2 T2b, 1 F2a, 7 F2b	16 (5/9/2)	U cones + U/C stems (−) [−]	7.2 (5–9)	0
Schmitz et al. [32]	IV	38 (38)	72 (44–85)	38 AL	AORI 9 type 2a, 10 type 2b, 19 type 3	54 (13/9/32)	U cones + bone graft + C stems (AC) [−]	3.1 (2.7–4)	0
Villanueva-Martinez et al. [33]	IV	21 (21)	73.3 (62–86)	16 AL, 5 PJI	AORI 3 T2a, 3 T2b, 5 T3, 3 F2b, 14 F3,	29 (10/3/16)	U cones + bone graft + U/C stems +/− augments (not all) [−]	3 (−)	0

AC antibiotic cement, *AL* aseptic loosening, *AORI* Anderson Orthopaedic Research Institute classification, *C* cemented, *F* femoral, *FU* follow-up, *LOE* level of evidence, *PE* polyethylene, *PJI* periprosthetic joint infection, *PPF* periprosthetic fracture, *T* tibial, *TKA* total knee arthroplasty, *U* uncemented, +/− with or without, (−) not declared

[a]Two-stacked cones femoral or tibial construct

[b]Some cases had more 1 indications for revision

[c]Preoperative diagnosis included also head allograft group

Table 2 Summary and main features of the included studies concerning sleeves

Authors	LOE	Knees (patients)	Mean age (years)	Preoperative diagnosis	Bone defects classification	No. of sleeves (F/T/FT)	Fixation method	Mean FU (years)	Drop-out rate
Agarwal et al. [34]	IV	104 (103)	69 (48–92)	43 AL, 31 PJI, 12 instability, 10 stiffness, 7 pain, 1 failed UKA	AORI 27 T2a, 39 T2b, 11 T3, 2 F1, 6 F2a, 46 F2b, 2 F3	164 (3/41/120)	U sleeves +/− U stems (−) [−]	8.0 (7.3–9.6)	14%
Alexander et al. [35]	IV	30 (28)	71 (48–83)	15 AL, 8 PJI, 5 osteolysis, 2 instability	AORI T2b, T3	30 (0/30/0)	U sleeves + U stems (−) [75–150 mm]	2.8 (2–4.3)	0
Barnett et al. [36]	IV	36 (36)	66 (49–88)	10 flexion laxity, 9 PJI, 6 AL, 3 PPF, 3 pain / stiffness, 2 PE wear, 2 osteolysis, 1 malposition /malalignment	AORI 14 T2a, 15 T2b, 5 T3	36 (0/36/0)	U sleeves +/− U stems (−) [−]	3.2 (2–5.2)	0
Bugler et al. [37]	IV	35 (34)	72 (55–86)	16 AL, 9 PE wear, 6 malalignment, 2 instability, 2 pain	AORI 20T 1, 13 T2, 2 T3, 17 F1, 16 F2, 0 F3	59 (1/10/48)	U sleeves +/− stems +/− augments +/− bone graft (−) [mainly 75 mm]	3.3 (2–5.2)	0
Chalmers et al. [38]	IV	227 (227)	66 (31–90)	84 PJI, 33 instability, 28 F AL, 33 T AL, 21 TF AL, 12 osteolysis/PE wear, 9 arthrofibrosis, 7 PFF	AORI 44T 1, 74 T2a, 64 T2b,17 T3, 11 F1, 30 F2a, 71 F2b, 11 F3	322 (28/104/190)	U/C sleeves + U/C stems (−) [−]	3.2 (2–8)	0
Dalury et al. [39]	IV	40 (40)	73 (50–80)	27 AL, 6 PJI, 5 instability, 2 PPF	–	–	U sleeves + U stems (−) [−]	4.8 (4–12)	0
Fedorka et al. [40]	IV	50 (50)	65.6 (41–90)	25 PJI, 12 AL, 6 osteolysis, 4 pain, 3 instability	AORI 1 T1, 30 T2a, 2 T2b, 17T 3, 5 f1, 8 F2a, 31 F2b, 6 F3	79 (1/20/58)	U sleeves +/− U stems +/− augments (−) [−]	4.9 (2.2–7.8)	8%
Gøttsche et al. [41]	IV	71 (71)	64 (46–79)	32 AL, 18 pain, 16 PJI,2 stiffness, 1 instability, 1 PPF, 1 PE wear	AORI 63% T2b, 19% T3, 56% F2b, 5% F3	128 (4/10/114)	U sleeves (−) [/]	5 (4–6)	5.6%
Graichen et al. [42]	IV	121 (121)	74 ± 9	41 instability, 24 malalignment, 23 AL, 15 PE wear, 4 trauma, 9 stiffness, 3 implant failure, 2 pain	AORI 77 T2a, 37 T2b, 7 T3, 93 F2b, 28 F3	193 (2/47/144)	U sleeves +/− U stems (AC) [−]	3.6 (2–6.1)	0
Huang et al. [43]	IV	83 (79)	63.5	51 AL, 20 PJI, 18 pain, 6 instability, 4 PPF, 2 stiffness	AORI 9 T1, 1 T2a, 68 T2b, 5 T3, 4 F1, 25 F2b, 7 F3	119 (0/47/72)	U sleeves + U stems (−) [−]	2.4 (2–3.7)	0
Jones et al. [44]	IV	30 (29)	66 (33–83)	–	–	–	U/C sleeves + U stems +/− bone graft (AC) [−]	4.1 (2–6.1)	0
Klim et al. [45]	IV	56 (56)	73 ± 10	56 PJI	AORI 20 T2a, 37 T2b, 8 T3, 13 F2a, 26 F2b, 4 F3	108[a] (−)	U sleeves + U stems +/− augments (AB) [−]	5.3 (2–11.2)	0

Table 2 (continued)

Authors	LOE	Knees (patients)	Mean age (years)	Preoperative diagnosis	Bone defects classification	No. of sleeves (F/T/FT)	Fixation method	Mean FU (years)	Drop-out rate
Martin-Hernandez et al. [46]	IV	138 (136)	75 (51–88)	121 AL, 14 PJI, 1 PPF, 2 not declared	AORI 63 T1, 32 T2a, 39 T2b, 70 F1, 30 F2a, 34 F2b	276 (0/0/276)	U sleeves + U stems +/− bone graft (−) [F/T: 75 mm]	6 (3–8.9)	0
Stefani et al. [47]	IV	51 (51)	71 (52–87)	26 AL, 17 PJI, 3 stiffness, 3 PE wear, 1 PPF, 1 implant failure	AORI 13 T1, 31 T2, 2 T3, 11 F1, 27 F2, 3 F3	87 (5/10/72)	U sleeves (AC) [−]	3.1 (2–4.8)	7.8%
Thorsell et al. [48]	IV	31 (31)	69 (54–89)	8 PJI, 7 AL, 6 instability, 1 PPF, 9 primary TKA	AORI 9 T1, 5 T2, 17 T3, 12 F1, 3 F2, 16 F3	48 (3/11/34)	U sleeves +/− U stems (−) [F: 75–150 mm; T: 75–175 mm]	7.4 (5–12)	0
Watters et al. [49]	IV	116 (108)	63.7	29 AL, 28 PJI, 18 osteolysis and PE wear, 13 pain / stiffness, 21 instability, 7 others	AORI 5 T2a, 89 T2b, 17 T3, 3 F2a, 34F2b, 4 F3	152 (5/75/72)	U sleeves + U stems (−) [−]	5.3 (2–9.6)	10.3%

AC antibiotic cement, *AL* aseptic loosening, *AORI* Anderson Orthopaedic Research Institute classification, *C* cemented, *F* femoral, *FU* follow-up, *LOE* level of evidence, *PE* polyethylene, *PJI* periprosthetic joint infection, *PPF* periprosthetic fracture, *T* tibial, *TKA* total knee arthroplasty, *U* uncemented, *UKA* unicompartmental knee replacement, +/− with or without, (−) not declared

[a]Included metaphyseal sleeves used in re-revisions

used for metaphyseal and metaphyseal-dyaphyseal filling of severe defects [15, 17, 18, 21]. A total of 99.8% of metaphyseal cones were press-fit; only Fosco et al. [20] reported two femoral cones that were cemented to the surrounding bone. Some authors used bone graft and/or demineralized bone matrix to fill any areas or voids in the cone–host bone interface to improve primary stability and to prevent any egress of cement that could interfere in osseointegration [15, 16, 18–20, 22–30, 32, 33]. The metaphyseal portions of the implants were cemented to the internal surface of the cones.

In MC group, a diaphyseal fixation was always used: 6 authors cemented the entire length of the stems [16, 22, 27–29, 32], in 10 series the decision of full-stem cementation was chosen case-by-case [7, 10, 17, 18, 20, 24–26, 31, 33] in the remainder a press-fit diaphyseal fixation was adopted.

Additionally, augments were used to obtain implant stability and joint line restoration in 5 series [17, 19, 25, 27, 33].

A total of 1801 MS were implanted: 52 on femoral side (2.9%), 441 on tibial side (24.5%), 1200 on both sides (66.6%) and 108 (6.0%) not defined. Two articles did not declare the number of sleeve used [39, 44].

In 14 papers, the authors chose a press-fit metaphyseal sleeves [34–37, 39–43, 45–49]. Two authors used cemented sleeves: Chalmers et al. [38] most commonly cemented MS (55% femoral, 72% tibial) in combination with cemented or uncemented diaphyseal stems; Jones et al. [44] used cemented sleeves in 47% of the implants. In 8 studies [35, 38, 39, 43–46, 49], a stem was always associated to metaphyseal fixation (only one author adopted cemented diaphyseal stem [38], the remainders preferred press-fit stem), in 6 series a press-fit diaphyseal fixation was usually performed [34, 36, 37, 40, 42, 48] and 2 surgeons employed press-fit sleeves without stems [41, 47]. Cement was used only for fixation of the final components on the baseplate in the majority of the series [34, 36, 39–45, 47–49].

Some series additionally used metal augments [37, 40, 45] and bone grafting [37, 44, 46].

Clinical and radiological outcomes

Metaphyseal cones and sleeves achieved good short- to mid-term radiographic and clinical outcomes. Knee Society Score (KSS) is the most adopted clinical evaluation tool; range of motion (ROM), Harvard Knee Score, Oxford Knee Score (OKS), SF-12, SF-36, Western Ontario and McMaster Universities Arthritis Index (WOMAC) and satisfaction rate were other frequently used scores in the included papers.

The radiological evaluation concerned osseointegration, periprosthetic radiolucencies and implant alignment, subsidence or migration. Some authors [18, 20, 23, 24, 26, 28, 32, 40, 43, 44, 46, 48] performed an exhaustive and complete analysis of rTKA with Knee Society total knee arthroplasty roentgenographic evaluation and scoring system [50].

Complications

The mean rate of intraoperative fractures during implant removal and metaphyseal porous metal devices preparation and insertion were 3.0% ± 10.4% in MC group and 2.2% ± 3.2% in MS group. Considering only fractures during cones preparation and insertion, the available datum was 1.2% ± 4.8%; in sleeves population the rate was 0.54% ± 1.2%.

In metaphyseal cones group, the global datum of implant AL was 2.7% ± 3.3% with an implant aseptic survivorship rate of 97.3%. AL of MC was 1.5% ± 2.3% with a cones aseptic survivorship rate of 98.5%. In metaphyseal sleeves population implant AL and MS AL were 2.2% ± 2.5% and 1.1% ± 1.9%, respectively. The aseptic survivorship of the implants and of the sleeves was 97.8% and 98.9%, respectively.

The mean rate of PJI was 8.5% ± 5.9% in MC group and 4.7% ± 4.2% in MS. The mean datum of septic failure in cones group was 18.8% ± 18.9%, in sleeves group 15.7% ± 9.6%.

The mean rate of reoperations and re-revisions calculated in MC population were 17.0% ± 16.7% and 7.7% ± 5.9%, respectively. In sleeves population, the data were 14.4% ± 8.9% and 7.5% ± 6.3%, respectively.

Table 3 summarizes data extracted from the included studies.

Table 3 Mean ± standard deviation [95% confidence intervals]

	Metaphyseal cones	Metaphyseal sleeves
Rate intraop. fractures %	3.0 ± 10.4 [– 1.7 to 7.7]	2.2 ± 3.2 [0.4 to 3.9]
Rate intraop. fractures cones/sleeves preparation/insertion %	1.2 ± 4.8 [– 1.0 to 3.5]	0.5 ± 1.2 [– 0.2 to 1.3]
Rate implants AL %	2.7 ± 3.3 [1.2 to 4.2]	2.2 ± 2.5 [0.9 to 3.5]
Rate cones/slevees AL %	1.5 ± 2.3 [0.5 to 2.6]	1.1 ± 1.9 [0 to 2.2]
Rate of PJI %	8.5 ± 5.9 [5.8 to 11.2]	4.7 ± 4.2 [2.5 to 7.0]
Rate of septic failure %	18.8 ± 18.9 [9.1 to 28.5]	15.7 ± 9.6 [3.9 to 27.6]
Rate of reoperations %	17.0 ± 16.7 [9.4 to 24.5]	14.4 ± 8.9 [9.6 to 19.1]
Rate of revisions %	7.7 ± 5.9 [5.0 to 10.4]	7.5 ± 6.3 [4.0 to 11.0]

Rate of intraoperative fracture, aseptic loosening, periprosthetic joint infection, septic failure, reoperations and re-revisions extrapolated from the included studies concerning metaphyseal cones and sleeves

AL aseptic loosening, *PJI* periprosthetic joint infection

Discussion

More and more active or high-demanding patients undergo total joint arthroplasty [51, 52]. In spite of the optimal outcomes, the projection of arthroplasty revisions will increase in future years. In rTKA, the metaphyseal area (zone 2) is usually preserved and offers better bone quality for fixation compared to epiphyseal surface (zone 1) that is deficient and unsupportive. Metaphyseal cones and sleeves while filling up bone defects allow fixation in zone 2 loading the metaphysis, reducing the stress shielding and providing greater rotational stability compared to a diaphyseal fixation alone [2, 3, 5, 6, 34]. Moreover, fixation closer to articulation facilitates restoration of the joint line and more control of rotational alignment of the prosthetic components [2, 34]. In rTKA, the pattern and the extension of bone loss are often underestimated preoperatively, metaphyseal devices provide an easy, efficacious and modular solution to manage severe bone defects [33]. Structural allografts have the advantages of biologic ingrowth and potential for bone stock restoration but present technical difficulties with long operative times and risk of disease transmission, nonunion, resorption and collapse. Metaphyseal cones and sleeves have a surface with high coefficient of friction to guarantee a primary stability and high degree of porosity to ensure, also due to load transfer, bone ingrowth and long-term stability. However, MC and MS in some situations need to remove more bone to adapt to the residual anatomy and are relatively expensive and difficult to remove in re-revisions.

There are currently no randomized studies that have directly compared the two fixation methods. The choice between a metaphyseal cone or sleeve is currently largely dictated by surgeon preference, and arguably by the shape and size of the bone defect. The main differences between metaphyseal metal devices are noted: sleeves, unlike cones, are bonded to implant with a morse–taper junction instead of cement, removing a possible source of failure at the cement–implant interface and are for this reason implant specific. Rupture of the morse–taper junction is a theoretical mode of failure exclusively related to sleeves. Moreover, MC is produced in different sizes and shapes allowing for better modularity.

The evidence of literate demonstrates that metaphyseal cones and sleeves can be adopted in septic and aseptic revisions. The main indication for the use of cones and sleeves is AORI type IIb and type III bone defects. Several authors report use of metaphyseal metal devices also in type I and type IIa of bone loss to enhance metaphyseal fixation in high-risk patients with highly constrained implants or poor bone quality [14, 17, 38, 53]. However, the absence of detailed information about level of constraint of revision implants do not allow a careful analysis to correlate the role of cones and sleeves with aseptic survivorship of the implant.

In the literature, cones are predominantly (99.8%) press-fit. In sleeves population, two authors report predominately cemented devices [38, 44]. The uncemented metaphyseal porous metal devices guarantee primary stability with press-fit technique and bone ingrowth ensures secondary stability. According to the available evidence in the literature, no clear indications in cemented or uncemented sleeves use can be detected. Moreover, no significant differences in clinical and radiological outcomes can be observed. Chalmers et al. [38] argue that the preference for stem fixation also plays a role in type of sleeve fixation and that more severe or uncontained defects are more amenable to cementless fixation.

Some authors suggest that with a stable fixation in zone 2, fixation in zone 3 might become less relevant fulfilling only the role of guidance for implant alignment and supporting osseointegration of cones and sleeves in the first months; therefore, the stem size and percentage of canal-filling could be reduced with reduction in the incidence of stem-related pain [5, 39, 41, 42, 46]. In MC group, a diaphyseal press-fit or cemented fixation is always used. In sleeves population, 6 authors decide case-by-case the use of stem [34, 36, 37, 40, 42, 48]; in 2 series press-fit sleeves without stems are employed with contradictory results [41, 47]. Gøttsche et al. [41] report a large number of knees with nonoptimal alignment with poor results in terms of pain and function; Stefani et al. [47] instead report satisfactory results. The absence of detailed information about length, diameter and design of the stems do not allow a careful correlation between stems features and aseptic survivorship of the implant or incidence of end-stem pain.

To our knowledge, this is the first systematic review that analyses and compares results of metaphyseal sleeves and cones in rTKA. This analysis is predominately based on level IV studies, and affected by poor quality evaluation, high amount of biases and methodological inaccuracies, and short- to mid-term follow-up. Despite these limitations, metaphyseal cones and sleeves seem to provide good clinical and radiological results. The aseptic survivorship of the implants was 97.3% in cones group and 97.8% in sleeves group. As demonstrated by the articles of Agarwal et al., the same case series at 3.6 years of follow-up and at 8 years of FU presents significative differences in rates of reoperations and re-revisions [34–54]. Further high-quality log-term studies better clarify results of these promising techniques.

Conclusion

Metaphyseal cones and sleeves represent a viable and feasible option in aseptic and septic revision total knee arthroplasty with type IIb and III AORI bone defects. Both methods allow proper bone defects management with comparable clinical and radiological result and survival rate. A fixation closer to articulation facilitates restoration of the joint line and more control of rotation alignment of the components. Primary stability, either axial and or rotational, is achieved intraoperatively with press-fit technique, the bone ingrowth ensures the secondary stability. In the literature, metaphyseal sleeves are also cemented. We strongly advocate further high-quality log-term studies to better clarify complications, clinical and radiological results of this promising technique in total knee arthroplasty revision.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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