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KNEE REVISION SURGERY

Metaphyseal sleeves in total knee arthroplasty revision: complications, clinical and radiological results. A systematic review of the literature

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Abstract

Introduction Total knee arthroplasty revision (TKAr) is increasing of relevance in orthopaedic surgeon daily practice and will become more and more relevant in the future. The aim of this study is to summarize indications, complications, clinical and radiological mid-term results of metaphyseal sleeves in management of bone defects in TKAr.

Methods A systematic review of English literature was performed on Medline. Retrospective or prospective studies with 2 years of follow-up (FU) were included. The PRISMA 2009 flowchart and checklist were considered to edit the review. Rates of intraoperative fractures, aseptic loosening, periprosthetic joint infection (PJI), reoperations and re-revisions were extrapolated by the papers.

Results 13 articles with a level of evidence of IV were included in the systematic review. 1079 TKAr (1554 sleeves) with a mean FU of 4.0 ± 1.1 years were analysed. The studies showed good clinical and functional outcomes. Sleeves allowed a stable metaphyseal fixation and osseointegration with an implant and sleeves aseptic survival rate of 97.7 and 99.2%, respectively. The incidence of PJI was 2.7 ± 2.4%. The estimated rate of reoperations and re-revisions were 14.2 ± 9.2 and 7.1 ± 4.8%, respectively.

Conclusion Metaphyseal sleeves represent a viable option in management of types IIb and III AORI bone defects in TKAr. Further high-quality log-term studies would better clarify complications, clinical and radiological results of this promising technique in total knee arthroplasty revision.

Keywords Metaphyseal sleeves · Total knee arthroplasty revision · Bone defect · Results · Complications

Introduction

Total knee arthroplasty revision (TKAr) is increasing of relevance in orthopaedic surgeon daily practice and will become more and more relevant in the future. The growth of primary total knee arthroplasty in younger and active patients and longer life expectation will continue to increase the need for revisions. In the USA, the projections estimate an increase of 601% of TKAr between 2005 and 2030 [1]. In UK, the National Joint Register reports an increase of 9.3% of knee joint revision operations between 2008 and 2015 [2]. A major challenge in TKAr is the management of bone loss. The aetiology is often multifactorial and may include aseptic loosening (AL), subsidence, wear and osteolysis, chronic periprosthethic joint infection (PJI) and iatrogenic bone loss due to implant removal. The management of bone loss is dependent on the size and location of the defects, the quality of remaining bone and aims to obtain a stable implant fixation with joint line restoration. There are many options for reconstruction such as cement, cement and screws, bone grafts (morcellized or structural autograft/allograft), bone composites, metal augments (stems, wedges, cones and metaphyseal sleeves), mega-prostheses and modular endoprostheses [3–5]. Metaphyseal sleeves were introduced in the late 1970s with the original rotating hinge. More recently, the use of these devices in conjunction with revision implants with different level of constraint has gained popularity in the management of metaphyseal bone loss. In the literature, short-term results of sleeves have been promising in terms of safety and efficacy [6, 7]. Recently, several mid-term follow-up reports were published. Considering these new data, the purpose of this systematic review is to summarize and critically analyse indications, complications, clinical

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and radiological results of metaphyseal sleeves in total knee arthroplasty revision.

Materials and methods

A systematic review of the literature was performed with a primary search on Medline through PubMed used the following strategy: metaphyseal[All Fields] AND sleeves[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 ("total"[All Fields] AND "knee"[All Fields] AND "arthroplasty"[All Fields]) OR "total knee arthroplasty"[All Fields]).

The inclusion criteria were: studies providing clinical, radiological results and complications about the use of metaphyseal sleeves in total knee arthroplasty revision; retrospective or prospective studies including randomized controlled trials, nonrandomized trials, cohort studies, case–control studies and case series with a minimum mean follow-up (FU) of 2 years; papers in English without any restriction on publication date. One reviewer applied the previously determined criteria to select potentially relevant papers. Articles were initially identified based on title and abstract; full text versions of relevant trials were then obtained and evaluated. References of the identified articles were checked in order not to miss any relevant articles. The following data, when available, were extracted from the articles: number of patients, number of treated knees, mean number of previous surgeries and revisions, mean age population (years), indications for revision, classification and types of bone defects, number of sleeves used, type of fixation (cemented, uncemented sleeves and/or diaphyseal stems), level of constraint of the final implant, mean FU (years), number of patients lost at the follow-up, global rate of intraoperative fractures (ratio between cases and number of implants), rate of intraoperative fractures during sleeves preparation and insertion (ratio between cases and number of sleeves), global rate of aseptic loosening of the implant (ratio between cases and number of implants), rate of aseptic loosening of sleeves (ratio between cases and number of sleeves), infection (ratio between cases and number of implants) and reoperations/re-revisions rate (ratio between cases and number of implants). Every new surgery was considered as reoperations, re-revisions instead included every components revision. The studies that did not declare a specific datum were excluded by the global evaluation of that parameter (e.g., number of fracture in sleeves preparation and insertion). The level of evidence (LOE) of the studies was assigned based on the 2011 Oxford Centre for Evidence-based Medicine Levels of Evidence [8]. The PRISMA 2009 flowchart and checklist were considered to edit our review. Categorial variables were expressed as number of cases or percentage. Continuos variables were reported as mean ± standard deviation (SD).

Results

A total 13 articles were finally included in our systematic review [4–7, 9–17]. The PRISMA 2009 diagram illustrates the studies that have been identified, included and excluded as well as the reason for exclusion (Fig. 1). All studies were rated as level IV according to the 2011 Oxford Center for Evidence-based Medicine Levels of Evidence.

Demographic data

Pooling the available data from the included studies, 1063 patients (1079 knees), with a mean age of 68.7 ± 4.1 years, underwent TKAr with metaphyseal sleeves. The mean follow-up was 4.0 ± 1.1 years. The data of three articles [10, 13, 16] were processed because the authors excluded patients underwent re-revisions and/or reoperations before the minimum FU established from the analysis; in our opinion, this involved a methodological error that underestimated the complication rate and the implant survival rate. Considering the data declared by the authors these patients were considered in our cumulative analysis and only 19 patients (21 knees) were considered lost at FU.

Eleven studies used Anderson Orthopaedic Research Institute (AORI) classification [18] with relevant part of bone defects classified as types II and III at femoral and tibial side. Two articles did not declare the number of sleeves, type of classification of bone defects used and grade of bone loss [5, 15]. Only in six studies the authors reported the mean number of knee revisions and/or surgeries [9–11, 13, 14, 16].

Aseptic loosening (AL) and chronic periprosthetic joint infection (PJI) were predominant indications for TKAr in the series, other reported reasons were instability, tibiofemoral malalignment, polyethylene (PE) wear, trauma, stiffness, implant failure and pain. In cases of PJI, a staged revision was always performed. One study did not declare the indications for TKAr [15].

Implant features

1554 sleeves were implanted: 44 on femoral side (2.8%), 420 on tibial side (27.0%) and 1090 on both sides (70.2%). Only in one study [4] sleeves were most commonly cemented (55% femoral, 72% tibial) in combination with cemented or uncemented diaphyseal stems. Jones et al. [15] used cemented sleeves and uncemented stems in 47% of the implants and employed an uncemented metaphyseal and diaphyseal fixation in the remainders. Bugler

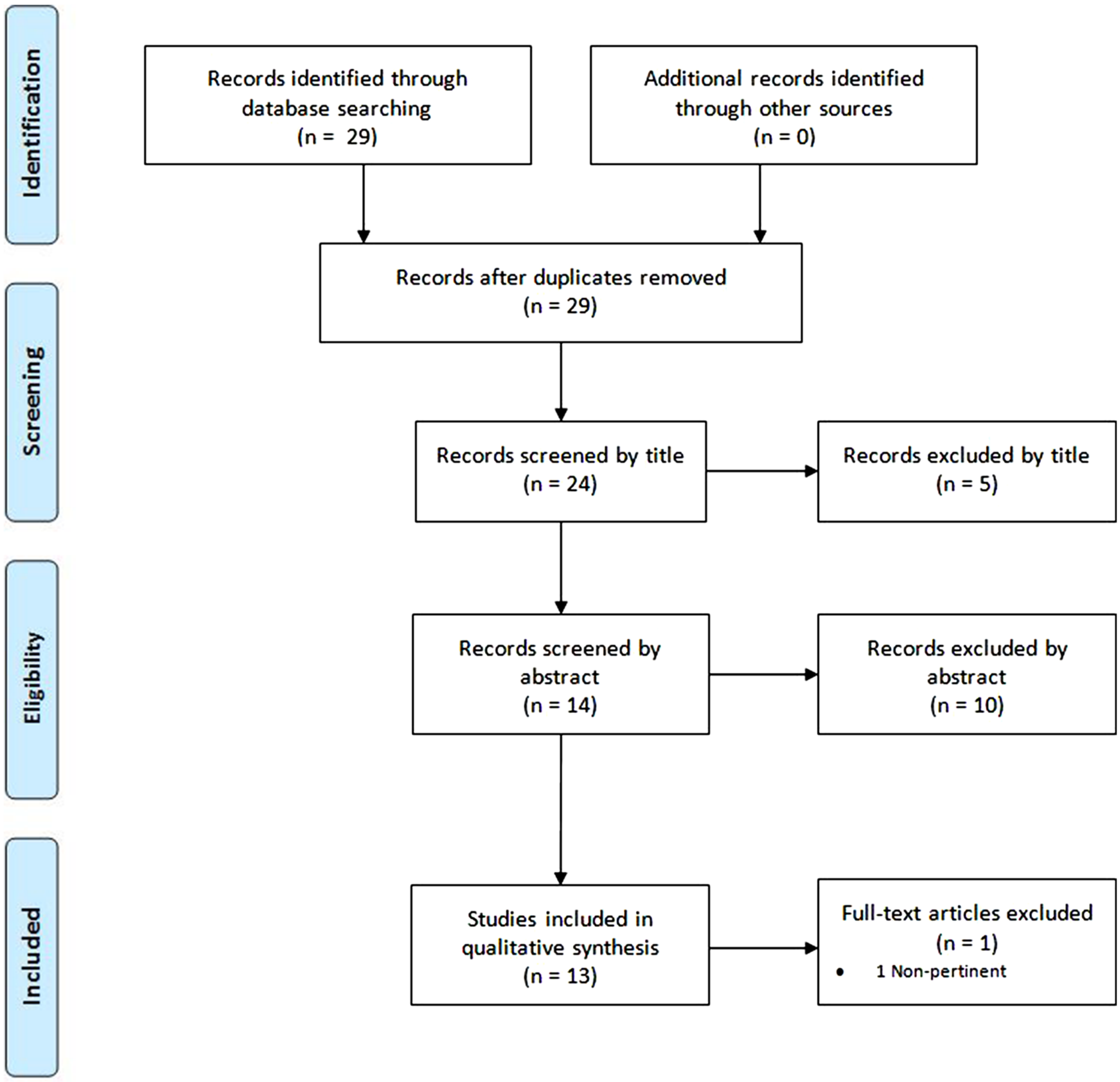

Fig. 1 The PRISMA flow diagram illustrates the studies that have been identified, included and excluded as well as the reason for exclusion

et al. [11] did not declare the method of sleeves and stems fixation. In ten reports, the authors chose a press-fit metaphyseal sleeves [5–7, 9, 10, 12–14, 16, 17]. The use of additional uncemented diaphyseal stems was reported in some TKAr in 9 series [5–7, 9, 10, 12, 14, 16, 17]. Only an author employed press-fit sleeves without stems [13]. Additionally, augments were used to obtain implant stability and joint line restoration in two articles [11, 12]. Revision implants with different level of constraint were employed in the series: cruciate retaining, posterior stabilized, constrained nonhinged (varus–valgus constraint), hinged. The majority of the authors used a tibial-rotating platform.

Clinical and radiological outcomes

In 11 studies [5–11, 13–17], a clinical evaluation was performed. Range of Motion (ROM), Knee Society Score (KSS), Harvard Knee Score, Oxford Knee Score (OKS), SF-12, SF-36, Western Ontario and McMaster Universities Arthritis Index (WOMAC) and satisfaction rate were the scores differently used in the included papers. In 12 studies [5–7, 9–17], the authors radiologically evaluated osseointegration, periprosthetic radiolucencies and implant subsidence or migration. In 4 papers [6, 15–17], implant osseointegration was graded according Engh criteria [19]. Only four authors [7, 12, 15, 16] performed an exhaustive and complete analysis of TKAr with Knee Society Total Knee Arthroplasty Roentgenographic Evaluation and Scoring System [20].

Complications

The mean rate of intraoperative fractures during implant removal and sleeves preparation and insertion was 2.4 ± 2.9%, if considering only fractures during sleeves preparation and insertion (with number of sleeves as denominator) the available datum was 1.0 ± 2.1%.

The global datum of implant AL was 2.3 ± 2.1% with an implant aseptic survivorship rate of 97.7%. AL of sleeves (with number of sleeves as denominator) was 0.8 ± 1.0% with a sleeves aseptic survivorship rate of 99.2%. The mean rate of PJI was 2.7 ± 2.4%. The mean rate of reoperations and re-revisions calculated were 14.2 ± 9.2% and 7.1 ± 4.8%, respectively. Only one case of morse-taper rupture was reported by Barnett et al. [10].

Tables 1 and 2 summarized data extracted from the included studies.

Discussion

The most important findings of this study are: (1) metaphyseal fixation with cemented or uncemented sleeves should be considered an useful option in complex TKAr (AORI types II and III), (2) uncemented sleeves provide optimal intraoperative implant stability and bone ingrowth ensures secondary stability, and (3) metaphyseal sleeves achieve good short- to mid-term radiographic and clinical outcomes with an aseptic survival rate of 99.2%.

More and more active or high demanding patients undergo total joint arthroplasty [21, 22]. Although the optimal outcomes, the projection of arthroplasty revisions will increase in future years. In these surgical settings, large bone defects and compromised bone stock can make reconstruction and fixation challenging [23]. While in primary TKA the fixation is mainly at solid bone cuts on the joint surface (Zone 1), in revisions this zone is mostly compromised and can therefore not be reliably used. Based on the concept of zonal fixation, additional fixation in the diaphysis (Zone 3) and/or metaphysis (Zone 2) is recommended to achieve implant stability and stable fixation with the restoration of an optimal joint line [24]. For diaphyseal fixation cemented and cementless stems can be used with both advantages and disadvantages. Cemented stems have good mid- and long-term survival rates, but they are often difficult to remove in case of revision [14, 25]. Furthermore, these are not canal filling and can lead to implant malalignment. Another problem is the effect of stress shielding and thus bone resorption at the metaphysis [26]. Because of these problems cementless stems gained popularity. The mainly polished titanium stems do not provide osseointegration with a high rate of radiolucent lines and problems of long-term stability [25]. Another problem of straight canal-filling stems can be misguidance into pre-existing misaligned bones with canal geometry deviations [14]. Furthermore, in up to 10% of cases, these canal-filling cementless stems can cause end-stem pain [27, 28]. Metaphyseal fixation with porous-coated sleeves is an option to obtain implant stability and to overcome previously mentioned problems. Metaphyseal sleeves can be cemented or uncemented and are generally combined with diaphyseal stems. Some authors suggested that with a stable fixation in zone 2, fixation in zone 3 might become less relevant and that fulfils only the role of guidance for alignment and further for support for osseointegration of uncemented sleeves in the first 3 months; therefore, the stem size and percentage of canal filling can be reduced with decreasing of stem-related pain [3, 5, 13, 14, 16].

Metaphyseal sleeves are available in various sizes and lengths for both tibial and femoral components. 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 [3, 6, 17]. The surgical techniques described by the different authors contemplate first tibial preparation using sequential broaches to compact cancellous bone. Offsetted preparation could be used if needed. The sleeves' size is determined when the trial broach gives rotational and axial stabilities and can also be used as guide for proximal tibial resection. The femur is prepared in a similar way. Some authors suggested to obtain as much bone coverage of uncemented sleeves as possible with a minimum of 70–75% to achieve an optimal osseointegration due to stress distribution into the metaphysis and stimulation of bone growth towards the sleeves [5, 14]. Primary stability, either axial and or rotational, is achieved intraoperatively with press-fit technique, the bone ingrowth ensures the secondary stability. Additionally, if a significant bone loss is present, augments can be used to improve implant stability and stable fixation [11, 12].

The main indication for the use of sleeves is AORI type IIb and type III bone defects. Chalmers et al. [4] used sleeves (33%) also in type I and type IIa of bone loss to enhance metaphyseal fixation in high-risk patients with highly constrained implants.

Pooling the data from the included studies 70.2% were used at both articular sides, 27.0% at tibial side and 2.8% at femoral side. According to the available evidence in the literature, no clear indications in cemented or uncemented sleeves use could be detected. Moreover, no significant differences in clinical and radiological outcomes can be observed.

In the series of Chalmers et al. [4], sleeves were most commonly cemented (55% femoral, 72% tibial) in

Table 1 Summary and main features of the included studies

Authors	LOE	Patients/knees	Mean age (years)	Indications for revision	Bone defects	No sleeves (F/T/FT)	Fixation method	Level of constraint	Mean FU (years)	Patients lost at FU
Agarwal S et al. (2013) [9]	IV	103/104	69 (48–92)	43 AL, 31 PJI, 12 instability, 10 stiffness, 7 pain	AORI F: 2 type 1, 6 type 2a, 46 type 2b, 2 type 3 T: 27 type 2a, 39 type 2b, 11 type 3	164 (3/41/120)	Uncemented sleeves +/− uncemented stems	VVC PS ACR (mobile/fixed bearing)	3.6 (2.5–5.4)	0
Alexander GE et al. (2013) [6]	IV	28/30	71 (48–83)	15 AL, 8 PJI, 5 osteolysis, 2 instability	AORI T: Type 2B or 3	30 (0/30/0)	Uncemented sleeves + uncemented stems	VVC (all mobile bearing)	2.8 (2–4.3)	0
Barnett SL et al. (2014) [10]	IV	36/36	66 (49–88)	10 flexion laxity, 9 PJI, 6 AL, 3 fracture, 3 pain/stiffness, 2 polyethylene wear, 2 osteolysis, 1 malposition / malalignment	AORI T: 14 type 2a, 15 type 2b, and 5 type 3, 2 not declared	36 (0/36/0)	Uncemented sleeves +/− uncemented stems	Hinged VVC PS (all mobile bearing)	3.2 (2–5.2)	0
Bugler KE et al. (2015) [11]	IV	35/35	72 (55–86)	16 AL, 9 PE wear, 6 malalignment, 2 instability, 2 pain	AORI F: 17 type 1, 16 type 2, 0 type 3, 2 not declared T: 20 type 1, 13 type 2,2 type 3	59 (1/10/48)	Not declared cemented/uncemented sleeves and stems +/− augments	VVC (mobile/fixed bearing)	3.3 (2–5.2)	0
Chalmers BP et al. (2017) [4]	IV	227/227	66 (31–90)	84 PJI, 33 instability, 28 F AL, 33 T AL, 21 TF AL, 12 osteolysis and PE wear, 9 arthrofibrosis, 7 periprosthetic fracture	AORI F: 11 type 1, 30 type 2a, 71 type 2b,11 type 3 T: 44 type 1, 74 type 2a, 64 type 2b,17 type 3	322 (28/104/190)	Cemented/uncemented sleeves and stems	Hinged VVC PS (all mobile bearing)	3.2 (2–8)	0
Dalury DF et al. (2016) [5]	IV	40/40	73 (50–80)	27 AL, 6 PJI, 5 instability, 2 fracture	(–)	(–)	Uncemented sleeves + uncemented stems	Hinged VVC PS (all mobile bearing)	4.8 (4–12)	0

Table 1 (continued)

Authors	LOE	Patients/knees	Mean age (years)	Indications for revision	Bone defects	No sleeves (F/T/FT)	Fixation method	Level of constraint	Mean FU (years)	Patients lost at FU
Fedorka CJ et al. (2017) [12]	IV	50/50	65.6 (41–90)	25 PJI, 12 AL, 6 osteolysis, 4 pain, 3 instability	AORI F: 5 type 1, 8 type 2a, 31 type 2b, 6 type 3 T: 1 type 1, 30 type 2a, 2 type 2b, 17 type 3	79 (1/20/58)	Uncemented sleeves + uncemented stems +/− augments	(–) (all mobile bearing)	4.9 (2.2–7.8)	4
Gøttsche D et al. (2016) [13]	IV	71/71	–	32 AL, 18 pain, 16 PJI,2 stiffness, 1 instability, 1 fracture, 1 PE wear	AORI F: 56% type 2b, 5% type 3 T: 63% type 2b, 19% type 3	128 (4/10/114)	Uncemented sleeves without stems	VVC (–)	5 (4–6)	5
Graichen H et al. (2015) [14]	IV	121/121	74 ± 9	41 instability, 24 malalignment, 23 AL, 15 PE wear, 4 trauma, 9 stiffness, 3 implant failure, 2 pain	AORI F: 93 type 2b, 28 type 3 T: 77 type 2a, 37 type 2b, 7 type 3	193 (2/47/144)	Uncemented sleeves +/− uncemented stems	Hinged VVC PS (all mobile bearing)	3.6 (2–6.1)	0
Huang R et al. (2014) [7]	IV	79/83	63.5	51 AL, 20 PJI, 18 pain, 6 instability, 4 fracture, 2 stiffness	AORI F: 4 type 1, 25 type 2b, 7 type 3 T: 9 type 1, 1 type 2a, 68 type 2b, and 5 type 3	119 (0/47/72)	Uncemented sleeves + uncemented stems	VVC PS (all mobile bearing)	2.4 (2–3.7)	0
Jones RE et al. (2001) [15]	IV	29/30	66 (33–83)	(–)	(–)	(–)	Cemented/uncemented sleeves + uncemented stems	Hinged (all mobile bearing)	4.1 (2–6.1)	0
Martin-Hernandez C et al. (2016) [16]	IV	136/136	75 (51–88)	121 AL, 14 PJI, 1 fracture, 2 not declared	AORI F: 70 type 1, 30 type 2a, 34 type 2bT: 63 type 1, 32 type 2a, 39 type 2b	272 (0/0/272)	Uncemented sleeves + uncemented stems	VVC (all mobile bearing)	6 (3–8.9)	0
Watters TS et al. (2017) [17]	IV	108/116	63.7	29 AL, 28 PJI, 18 osteolysis and PE wear, 13 pain/stiffness, 21 instability, 7 others	AORI F: 3 type 2a, 34 type 2b, 4 type 3 T: 5 type 2a, 89 type 2b, 17 type 3	152 (5/75/72)	Uncemented sleeves + uncemented stems	Hinged VVC PS (all mobile bearing)	5.3 (2–9.6)	10 (12 knees)

Table 1 (continued)

ACR anterior cruciate retaining, *AL* aseptic loosening, *F* femoral, *FU* follow-up, *LOE* level of evidence, *PJI* periprosthetic joint infection, *PS* posterior stabilized, *T* tibial, *VVC*: Varus–Valgus Constraint, +/− with or without, (−) not declared

combination with cemented or uncemented diaphyseal stems. In this study, survivorship was not significantly affected by type of fixation (cemented vs cementless) of the sleeve or the stem. The decision to use a cemented versus a cementless sleeve was based on several factors, namely surgeon preference for both sleeve and stem fixation. The authors argued that the preference for stem fixation also played a role in type of sleeve fixation. They suggested, therefore that more severe or uncontained defects were more amenable to cementless fixation. Jones et al. [15] used cemented sleeves and uncemented stems in 47% of the implants, in other cases employed an uncemented metaphyseal and diaphyseal fixation. In other reports, the authors chose a press-fit metaphyseal sleeves [5–7, 9, 10, 12–14, 16, 17]. The use of additional uncemented diaphyseal stems was reported in nine series [5–7, 9, 10, 12, 14–17]. The absence of detailed information about length, diameter and design (slotted/non-slotted) of the stems did not allow a careful correlation between stem features and aseptic survivorship of the implant or incidence of end-stem pain. Alexander et al. [6] found that stem length and design were not statistically significant with stem-related pain, whereas diameter was ($P = 0.05$). Only a group [13] employed press-fit sleeves without stems but they reported a large number of knees with non-optimal alignment with poor results in term of pain, satisfaction and function; for this reason they advocated the use of stem as guidance for proper implant alignment.

In these series of TKAr, good clinical and radiological results were reported [5–7, 9–17]. Gøttsche et al. [13] found that pain and satisfaction were closely related. A similar result was not seen analysing function–satisfaction, AORI bone defect grade—pain and AORI bone defect grade—function. Several studies demonstrated radiographic osseous in-growth with well-fixed sleeves [6, 10–12, 14, 15, 17]. The global datum of implant AL in this series was 2.3 ± 2.1% with an implant aseptic survivorship rate of 97.7%. Analysing aseptic loosening of sleeves we recorded a 0.8 ± 1.0% with a sleeves aseptic survivorship rate of 99.2%. The absence of detailed information about level of constraint of the implants did not allow a careful analysis to correlate these data with aseptic survivorship of the implant and of the sleeves. Chalmers et al. [4] reported that aseptic survivorship was not significantly affected by preoperative surgical indication, preoperative bone loss as classified by the AORI and level of constraint of the implant.

A feared complication in TKAr was intraoperative fracture. The mean rate of intraoperative fractures during implant removal and sleeves preparation and insertion was 2.4 ± 2.9%, if considering only fractures during sleeves preparation and the available datum was 1.0 ± 2.1%.

The lack of a clear distinction of septic failure and infection, being PJI one of the most important indications for

Table 2 Rate of intraoperative fracture, aseptic loosening, periprosthetic joint infection, reoperations and rerevisions extrapolated from the included studies

Authors	Rate intraop. fracture (no. cases/no. implants) (%)	Rate intraop. fracture sleeves preparation/insertion (no. cases/n° sleeves) (%)	Rate implant AL (no. cases/no. implants) (%)	Rate slevees AL (no. cases/no. sleeves) (%)	Rate of periprosthetic joint infection (%)	Rate of reoperations (rate of rerevisions) (%)
Agarwal S et al. (2013) [9]	0	0	1.9	1.2	0	1.9 (1.9%)
Alexander GE et al. (2013) [6]	0	0	0	0	3.3	30 (10%)
Barnett SL et al. (2014) [10]	2.8	0	5.6	0	0	13.9 (11.1%)
Bugler KE et al. (2015) [11]	2.9	(–)	0	0	0	11.4 (0%)
Chalmers BP et al. (2017) [4]	6.6	(–)	1.3	0.6	5.3	19.4 (6.6%)
Dalury DF et al. (2016) [5]	0	0	2.5	(1 case sleeves AL)*	0	7.5 (2.5%)
Fedorka CJ et al. (2017) [12]	0	0	6.5	2.7	4.3	30.4 (15.2%)
Gøttsche D et al. (2016) [13]	0	0	3.0	(–)	1.5	9.1 (7.6%)
Graichen H et al. (2015) [14]	1.7	1.0	3.3	2.1	3.3	(–) (11.4%)
Huang R et al. (2014) [7]	0	0	3.6	1.7	7.2	16.9 (10.8%)
Jones RE et al. (2001) [15]	6.7	(–)	0	0	3.3	10 (6.7%)
Martin-Hernandez C et al. (2016) [16]	8.1	6.7	0	0	1.5	3 (1.5%)
Watters TS et al. (2017) [17]	2.6	2.0	1.7	0.7	5.2	16.4 (–)
Total	2.4 ± 2.9	1.0 ± 2.1	2.3 ± 2.1	0.8 ± 1.0	2.7 ± 2.4	14.2 ± 9.2 (7.1 ± 4.8%)

AL aseptic loosening, (–) not declared, * not available number of sleeves used

TKAr of the series, did not allow an interesting analysis of the rates related to these two entities.

Conclusion

The current review about the use of metaphyseal sleeves in TKAr is 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 sleeves represent a viable and feasible option in total knee arthroplasty revision with types IIb and III AORI bone defects. Primary stability, either axial and or rotational, is achieved intraoperatively, the bone ingrowth ensures the secondary stability in uncemented sleeves. If a stable fixation in metaphysis is obtained, diaphyseal fixation might become less relevant. Diaphyseal stems could fulfil only the role of guidance for alignment of the implants. The studies demonstrate radiographic osseous in-growth with well-fixed sleeves and an implant and sleeves aseptic survivorship rate of 97.7 and 99.2%, respectively, in short- to mid-term follow-up. 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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