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Metaphyseal fixation in revision knee arthroplasty: a systematic review of the literature and meta-analysis of mid-long-term outcomes of metaphyseal sleeves and cones

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Metaphyseal augmentation has in recent years formed a key strategy in management of bone loss in revision knee arthroplasty. There are studies reporting excellent short-term results, however long-term data is lacking. There is also a paucity of studies comparing the most frequently utilised augments, metaphyseal sleeves, and cones. We conducted a systematic review and meta-analysis to evaluate and compare the mid to long term outcomes of metaphyseal cones and sleeves. We conducted systematic search of 4 databases (Medline, Embase, CINALH and PubMed). Seventeen studies were found to be eligible for inclusion of which ten investigated metaphyseal sleeves and the remaining seven investigated cones. Mean follow up across all studies was 6.2 years. The total number of patients included in the studies was 1319 and the number of knees operated on was 1431. We noted a higher revision rate of metaphyseal cones when compared to sleeves 10.85% vs 6.31 (p=0.007). Reoperation rates were also higher in cones compared to sleeves, 13.78% vs 3.68% (p<0.001). Prosthetic joint infection was the most common reason for revision. The difference in conversion rates, based on augment location was statistically significant p=0.019. When undertaking further sub-analysis; there was no statistically significant difference when comparing revision rates of; tibial vs femoral augments p=0.108, tibial vs tibial & femur p=0.54 but a difference was seen between femoral vs tibial & femoral augments p=0.007. Based on our data, metaphyseal sleeves demonstrate significantly lower revision rates compared to metaphyseal cones. However overall, both demonstrate reliable mid to long-term outcomes.

Keywords : Revision TKR; metaphyseal sleeves; metaphyseal cones; bone loss in revision arthroplasty.

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INTRODUCTION

Bone loss presents a common yet challenging obstacle to the success of revision total knee arthroplasty (TKA). Successful management of bone loss is key to providing a stable foundation for component placement, accurate joint alignment and creating a durable fixation *(1)*. Management of bone loss is dependent on size and location of the defect *(2)*. Morgan-Jones et al *(3)* introduced the concept of zonal fixation as a tool for planning reconstruction during revision TKA. They divided

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the distal femur and proximal tibia into 3 zones, with zone 1 encompassing the epiphysis, zone 2 the metaphysis and zone 3 the diaphysis. The conclusion being that where zone 1 augmentation is required, fixation in another zone is necessary. Being closer to the articular surface, fixation in the metaphyseal region allow more reliable restoration of the joint line and increased rotational stability *(4)*. Metaphyseal fixation has been shown to reduce the stress shielding effects brought on by zone 3 fixation. Whilst most studies appear to recommend the additional use of a stem, fixation closer to the articular surface allows for a shorter stem to be used potentially reducing the incidence of stem tip pain *(3)*, while also reducing the stress shielding effect at the epiphysis *(5)*; though this is disputed. Metaphyseal sleeves have the additional advantage of allowing defect filling and implant fixation to occur in a single step. The interface between sleeve and implant is created via a morse taper junction unlike metaphyseal cones where the interface is created via cement, creating two points of potential failure *(6)*. Metaphyseal sleeves also act as a cutting guide for intramedullary drills, thereby enhancing component alignment *(6)*. Unlike cones, metaphyseal sleeves cannot be contoured to provide a custom fit to the bony defect *(7)*. Other concerns include the challenge of removal in revision scenario, intra-operative fracture, and the potential for rotational stress with the use of more constrained implants. Despite these concerns both porous metaphyseal cones and sleeves have demonstrated excellent short-term survivorship *(8-12)* however data on longer term follow up is insufficient. Data comparing revision rates of cones and sleeves is lacking. The purpose of this review was to analyse the mid to long term results of porous metaphyseal cones and sleeves as well as compare their outcomes.

MATERIALS AND METHODS

We prospectively registered the review protocols with Prospero (University of York), with the registration number CRD 42020213778. We used the National Institute of Health and Clinical Excellence (NICE) healthcare databases advanced search to carry out a comprehensive search of four databases (Embase, Medline, CINALH and PubMed) using the search strategy; (Revision OR "Knee Arthroplasty" OR Knee replacement" OR TKR OR TKA) AND (Cone OR Cones OR Sleeve OR Sleeves).

Two authors (M.J and M.S) screened the titles and abstracts to find potentially relevant manuscripts. After removal of duplicates the two authors then independently screened the entire manuscript to judge whether the inclusion criteria were met. This process was overseen by senior authors. The initial search returned 2338 articles. Following removal of duplicates and screening of abstracts 85 manuscripts were selected for full text screening. At the end of this process 17 manuscripts were selected for inclusion in this review. The references of these manuscripts were screened for any further studies that met the inclusion criteria. This process did not return any further manuscripts.

We sought to investigate the use of sleeves in revision knee arthroplasty alone. Bone loss in primary cases or secondary to malignant causes were excluded. Revision rate was our primary outcome measure. Manuscripts were included if the following criteria were met. 1) Report on survivorship or revision rate of porous metaphyseal cones or sleeves in revision knee arthroplasty 2) Mean follow up of ≥5 years 3) English language text 4) Full manuscript available. Where studies included both primary and revision TKAs, the full manuscript was screened to see if they reported the outcomes separately or whether the separate outcomes could be deduced. If they did not, then the manuscript was excluded. Similarly, if the study compared metaphyseal cones or sleeves to another metaphyseal fixation, then the study was excluded if they did not report the outcomes separately. Case reports were also excluded. Two studies found in the literature search had a mean follow up within 2 months of the cut-off of 5 years. Following discussion amongst authors and final arbitration by the senior author (S.K) it was decided to include these two studies *(13,14)* as it was felt the data would be of significant value to the meta-analysis. In situations where two or more

studies were published by the same institution, the authors were contacted to clarify if there was overlap between the cohorts. If we received no response the manuscripts were scrutinized by the authors to judge if it was felt the cohorts overlapped. Final arbitration was with the senior author (S.K).

Two authors (M.J and M.S) independently collected the data from the manuscripts including number of patients, number of knees, survivorship and/or revision rate, level of constraint of prosthesis, Anderson orthopaedic research institute (AORI) grading of bone defects, location of implants, reason for initial revision and reason for re-revision. The data collected independently was compared and any discrepancies were resolved by consensus.

Two authors (M.J and M.S) independently assessed the methodological quality of each study using the modified Coleman Methodology Score (mCMS), (Table I). Each author used the tool to assign a score out of 100 to each study. Again, if there was a disagreement between two authors regarding the score, then the matter was referred to the senior author (S.K) for a final decision. A score of 100 indicates a study that is of high methodological quality and is of low risk of bias.

Statistical analysis on categorical data was performed using Cross tabulation and Chi squared testing for categorical data, or Fisher's exact test where sample size did not permit Chi Squared testing. Between-group comparison of continuous data was performed using a t-test. Confidence intervals were obtained by utilising a one sample proportion test. Data was analysed using IBM SPSS (build version 1.0.0.1447, Armonk, NY, IBM Corp). A p value of < 0.05 was considered statistically significant.

RESULTS

Of the 17 studies included, 14 were retrospective case series and the remaining 3 were prospective cohort studies. There were no randomised controlled trials. The cohorts and outcomes are summarised in Table II. Metaphyseal sleeves were investigated in 10 studies and cones in 7 studies. The mean follow-up across all the studies was 6.2 years (range 4.8-10.5 years).

The median mCMS score of all included studies was 66 (IQR 54-69). Studies that investigated the use of metaphyseal sleaves were generally judged to be of higher methodological quality than those using metaphyseal cones (median 67 vs 55). Common reasons for lower scores were the retrospective nature of most of the studies, lack of description of post-operative rehabilitation and concerns about the procedure for assessing outcomes.

The total number of patients included in the studies was 1319 across the 17 studies and the number of knees operated on was 1431. However, only 1364 were included in statistical analysis, after accounting for losses to follow-up. This included 350 knees with cones and 1014 knees with sleeves.

The age of participants was available in 13 of the studies and the mean of this was 69.4 years. Where the data was provided, the mean age of the patients in the studies that looked at cones was 68.3 years and the mean age for all patients in studies that looked at sleeves was 70.4 years. This difference in mean age was not statistically significant ($p=0.338$). Of the original cohort 581/1319 patients were male.

We identified from the studies, where possible, the number / location of implants used. There was a total of 377 metaphyseal cones inserted across 7 studies. There were 125 used solely in the tibia, 202 solely in the femur and there were 25 knees where tibial and femoral cones were used; 50 cones were used across those 25 knees.

There were a total of 1643 metaphyseal sleeves inserted across 9 studies. This total excludes the contribution from Dalury et al *(14)* as it was not stated whether it was one (tibial or femoral) or both (tibial and femoral) sleeves used. Both Dalury et al *(14)* and Watters et al *(15)* did not specify the location of their sleeves and therefore could not be used for this analysis. Where this information could be deduced, we calculated there were 300 sleeves used solely in the tibia, 15 solely in the femur and there were 588 knees where tibial and femoral sleeves were used (1176 sleeves).

Five studies either did not include information on the class of bone defects seen in their cohorts or

Table I. – Modified Coleman methodology score

Part A: Only one score to be given for each of the 7 sections	
Study size: Number of patients	
<30	0
31-50	4
51-100	7
>100	10
Mean follow up	
<12 month	0
12-36 months	4
37-60 months	7
>61 months	10
Surgical approach	
Different approach used and outcome not reported separately	0
Different approaches used and outcome reported separately	7
Single approach used	10
Type of study	
Retrospective cohort study	0
Prospective cohort study	10
Randomised control trial	15
Description of diagnosis	
Described without percentage specified	0
Described with percentage specified	5
Descriptions of surgical technique	
Inadequate (not stated, technique unclear)	0
Fair (technique only stated)	5
Adequate (technique stated, details of surgical procedure given)	10
Description of post-operative rehabilitation	
Not described	0
Described	5
Part B: Scores may be given for each option in each of the 3 sections if applicable	
Outcome criteria	
Outcome measures clearly defined	2
Timing of outcome clearly stated	2
Use of outcome criteria that has reported reliability	3
General health outcome measure included	3
Procedure of assessing outcomes	
Participants recruited	5
Investigator independent of surgeon	4
Written assessment	3
Completion of assessments by patient themselves with minimal investigator assistance	3
Description of subject selection process	
Selection criteria reported and unbiased	5
Recruitment rate reported	
<90%	0
>90%	5

did not provide the full breakdown across all AORI categories *(14,16-19)*. Across the 12 studies that did, 87 femoral deficits were AORI type 1, 76 were AORI 2A, 403 AORI 2B, 66 AORI 3. In the tibial there were 66 AORI type 1 defects, 175 AORI type 2A, 336 AORI type 2B and 78 type 3.

When considering the bone defects and the implants used in these instances, defects were grouped according to AORI classification for analysis. This was on the basis that there was no way amongst all papers to differentiate contained versus uncontained defects, however, all type 1 will by virtue of their morphology be contained and all type 3 uncontained. Type 2A and B, with the possibility of being either, is where the resulting difficulty in interpretation arises.

When considering AORI grade and the use of cones versus sleeves, there was a statistically significant difference between groups, with cones more likely to be utilised for uncontained defects than sleeves:

Tibia - [Cones AORI (1/2/3 – 0% / 62.38% / 37.2%)] vs [Sleeves AORI (1/2/3 11.79% / 79.82% / 8.39%)] p<0.001

Femur [Cones AORI (1/2/3 0% / 79.57% / 20.43%)] vs [Sleeves AORI (1/2/3 17.71% / 71.17% / 10.11%)] p<0.001

Considering revisions across all studies:

There were 102 revisions across all 1364 knees (7.48% [95%CI 6.14%-9.00%])

Out of 350 knees with cones there were 38 revisions (10.85% [95%CI 7.80%-14.60%]) Out of these, 20 knees (46.5% of all revisions) required revision for prosthetic joint infection (PJI) and 18 for aseptic causes. Out of 1014 knees with sleeves there were 64 revisions (6.31% [95% CI 4.90%-7.99%]). Out of these, 37 revisions were for PJI and 27 aseptic for aseptic causes. The higher revision rate for cones, compared with sleeves, was statistically significant at p=0.007. There was no difference when comparing aseptic revision vs PJI between cones and sleeves (p=0.74).

We considered the revision rates based on location of the implants (Tibial/Femoral/Tibial & Femoral). However, only 9 of the 17 papers reported data that described *(14-16,20-6)*; preoperative location and revision by location, that could be used in subsequent analysis. Within these 9 papers there were 606 knees, representing 44.4% of all knees included in this review. Out of these 606 knees, there were 48 knees revised. Out of the 606 knees, the revision rate by location of the augment (tibia, femur, tibia & femur) was 9/133 (6.77% [95% CI 3.14%-12.46%]), 25/206 (12.14% [95% CI 8.01%-17.39%]) and 14/267 (5.24% [95% CI 2.90%-8.64%]) respectively. The difference in conversion rates, based on augment location was statistically significant p=0.019 with the number of femoral revisions exceeding the expected count. When undertaking further sub-analysis; there was no statistically significant difference when comparing revision rate of; tibial vs femoral augments (p=0.108) or tibial vs tibial & femur (p=0.54), but a difference was seen between femoral vs tibial & femoral augments (p=0.007).

When considering cones implanted by their location; 5 papers included data that could be used for analysis encompassing 304 knees *(16,20-23)*. Out of these, 35 were revised. Out of the 304 knees the revision rate by location of the cone (tibia, femur, tibia & femur) was 5/94 (5.3% [95%CI 1.75%-11.98%]), 24/202 (11.88 % [95%CI 7.76%-17.16%]) and 6/8 (75% [95%CI 34.91%-96.81%]) respectively. This difference was statistically significantly at (p<0.001)[a].

When undertaking further sub-analysis a; there was no statistically significant difference when comparing revision rate of; tibial vs femoral cones (p=0.063), but a difference was seen between tibial vs tibial & femoral (p<0.001) and femoral vs tibial & femoral cones (p<0.001). ([a] – note small values in individual groups may reduce the validity of statistical analysis)

When considering sleeves implanted and their location; 4 papers included data that could be used for analysis encompassing 302 knees *(15,24-26)*. Out of these, 13 were revised. Out of the 302 knees the revision rate by location of the sleeve (tibia, femur, tibia & femur) was 4/39 (10.26% [95%CI 2.87%-24.22%]), 1/4 (25% [95%CI 6.31%-80.59%]) and 8/259 (3.09 % [95%CI 1.34%-5.99%]) respectively. This difference was statistically significantly dif-

Table II. — Study information

	Location of implant					AORI classification (based on original outcomes)								Manufacturer of metaphyseal fixation device
Study (year)	Knees (n)	Sleeve Vs Cone	Tib	Fem	Tib+ fem	1	2A	2B	3	Mean f/u (years	Aseptic loosening	Infection	All cause revision	
Bloch et al (18) (2019)	319	Sleeves	173	0	146	Not recorded				7.6	1	3	4	Depuy Synthes, Warsaw, IN
Scrior et al(17)(2019)	85	Sleeves	2	6	77	Not specifically recorded				5	1	4	5	Depuy Synthes, Warsaw, IN
Wirries et al(24)(2019)	62 [47][i]	Sleeves	22	3	37	12	33	43	6	5	3	3	6	Depuy Synthes, Warsaw, IN
Dalury et al(14)(2015)	40	Sleeves	Unable to deduce from study			Not recorded				4.8	1	1	1	Depuy Synthes, Warsaw, IN
Fedorka et al (29)(2016)	46	Sleeves	17	1	28	6	38	33	23		2	3	5	Depuy Synthes, Warsaw, IN
Martin Hernandez et al (25) *(2016)	134	Sleeves	0	0	134	133	62	73	0	6	0	2	2	Depuy Synthes, Warsaw, IN
Watters et al (15)(2017)	104	Sleeves	Unable to deduce from study			0	8	123	21	5.3	0	2	3	Depuy Synthes, Warsaw, IN
Agarwal et al (30)(2018)	104	Sleeves	41	3	60	2	33	85	13	8	7	3	23	Depuy Synthes, Warsaw, IN
Floria-Arnal et al (26) (2020)	60	Sleeves	45	2	46	0	0	120	0	5	0	0	0	Depuy Synthes, Warsaw, IN
Klim et al (28) (2020)	100	Sleeves	45	2	46	0	39	80	12	6.3	0	15	17	Depuy Synthes, Warsaw, IN
Panda et al (19))	59	Cones	26	23	10	0	0	26	33	6.9	0	1	2	Zimmer, Warsaw, IN
Abdelaziz et al (20) (2019)	25	Cones	9	9	7	0	6	17	9	10.5	5	3	8	Zimmer, Warsaw, IN
Sandiford et al (23)	15	Cones	9	5	1	0	5	9	0	7.3	0	0	1	Zimmer, Warsaw, IN
David Potter 3rd et al (21) (2016)	157	Cones	0	157	0	0	0	127	32	5	6	14	23	Zimmer, Warsaw, IN
Martino et al (27) (2015)	18	Cones	5	6	7	0	0	0	19	6	0	1	1	Zimmer, Warsaw, IN
Kamath et al (22) (2015)	66	Cones	66	0	0	0	17	25	24	5.8	1	1	3	Zimmer, Warsaw, IN
Lachiewicz (16)but there are few published results. QUESTIONS/PURPOSES: We therefore asked (1 et al (2015)	10	Cones	10	0	0	0	0		10	5	0	0	0	Zimmer, Warsaw, IN

[n] where reported cohort size and size used for statistical analysis differs. * patients who sustained PJI within 12 months were excluded from final analysis.

ferent at p=0.021a and both the number of tibial and femoral revision exceeded the expected counts on analysis. When undertaking further sub-analysis[a]; there was no statistically significant difference in revision rate between tibial vs femoral sleeves (p=0.40), femoral vs tibial & femoral p=0.13 but there was a difference between tibia vs tibial and femoral (p=0.034).([a] – note small values in individual groups may reduce the validity of statistical analysis)

We defined reoperation as any additional procedures carried out where the metaphyseal device was retained. Out of the 350 knees with cones there were 43 reoperations. Excluding the 38 revisions, this gave a reoperation rate of 43/312 (13.78% [95%CI 10.16%-18.11%]). Out of the 1014 knees with sleeves there were 35 reoperations excluding the 64 revisions, this gave a reoperation rate of 35/960 (3.68% [95%CI 2.55%-5.03%]). This difference was statistically significant at p<0.001.

In two studies, the level of constraint of the revision implant used with the metaphyseal fixation could not be deduced *(14,18)*. Across the remaining 15 studies *(15,16,26-30,17,19-25)* a constrained non-hinged design was used in 979 knees, a posterior stabilised prosthesis was used in 150 knees, a constrained hinged design was used in 96 knees, a rotating hinge design in 109 knees, a cruciate retaining implant was used in 5 knees across two studies *(15,19)* and finally, 5 patients in one study *(17)* had a tibial metaphyseal sleeve with a distal femur replacement.

Nine of the ten studies *(14,15,18,24-16,28,29)* investigating sleeves specified they used a mobile bearing tray with all tibial sleeve fixations. In one study *(15)* two patients who received a sleeve on the femoral side received a fixed bearing tray.

Revision rate per level of constraint for cones was 0% for non-hinged design, 13.8% for hinge design and 2.6% for rotating hinge.

For metaphyseal sleeves the revision rate for non-hinged design was 3.6% and 9.5% for rotating hinge. Only 3 knees had a hinged design with a metaphyseal sleeve of which none were revised.

DISCUSSION

We aimed to evaluate the existing body of evidence for mid-long-term results of porous metaphyseal fixation devices. To the best of our knowledge, this is the only review looking at long term outcomes and the only meta-analysis on the topic. We do acknowledge a number of publications representing short-term term follow up *(8,31)*. Divano et al *(32)* described a rate of aseptic loosening of 1.98% at 3.65 years, with an all cause revision rate of 8.19%. An earlier review by Beckmann et al *(11)* also found low revision rates for loosening associated with cones (0.9%), however they had an even shorter mean follow up of 2.8 years. The purpose of their review was to compare the use of metaphyseal cones with bulk allografts; to which they compared favourably *(11)*. While we acknowledge bulk allografting can be used in metaphyseal defects, their use in larger defects is limited to small numbers in a few specialist centres *(7)*, therefore not investigated in this review. With regards to sleeves, Bonanzinga et al *(8)* found an aseptic loosening rate similar to ours of 0.7% in their systematic review; four of their studies met the criteria for inclusion in this review *(15,25,29,30)*.

Both metaphyseal cones and sleeves demonstrated low revision rate and consistently showed significant improvement in post-operative knee function and general health. We found that metaphyseal sleeves did have an overall lower rate of revision compared to cones (p=0.007). There are several possible reasons for this. It has been postulated that the use of cement between the metaphyseal cones and the implant creates an additional point of potential failure which is not present in metaphyseal sleeves, which have a direct interface between implant and bone. The broaching technique itself in the insertion of metaphyseal sleeves is one that is familiar to arthroplasty surgeons, which could therefore result in improved initial fixation and stability. A portion of the cases of aseptic loosening in sleeves were directly attributable to technical errors of the surgeon. In Wirries et al's *(24)* study, both aseptic failures occurred with unusual defect morphology

resulting in the additional use of polymethylmethacrylate (PMMA). In Agarwal et al's *(30)* study 3/6 cases of tibial sleeve loosening were due to technical errors where cement was found in around the porous coating of the sleeve. It was not reported whether this was the case for metaphyseal cones that required revision. The indications for sleeves and cones may also be slightly different (6). Cones have been advocated for more peripheral defects while sleeves more central. Cones can also be used to transform an uncontained to a contained defected (6). Across the seventeen studies in this review, we found that cones are significantly more like to be used for uncontained defects (2B or 3) compared to sleeves (92% vs 58%, p=0.001). This may in part explain the revision rate for cones is significantly higher than sleeves as cones are being used in more complex defects. This does make it difficult to draw firm conclusions regarding the superiority of one fixation over the other and ultimately the fixation chosen should be tailored to the patient. Further studies comparing the use of cones and sleeves specifically in uncontained defects may be of interest.

The authors recognise the significant limitations of the sub-analysis of revision, based on location, for cones and sleeves individually, due to the limited numbers of papers and low patient numbers potentially reducing the validity of the analysis. However, when considering the data for all patients, augments placed in the femur had a higher risk of revision compared to the tibia (p =0.019) and sub-analysis revealed further significance when considering augments in the femur vs tibia + femur (p=0.007). The reasons for this are not well elucidated in the literature. One possible explanation is the femoral defects may be larger than tibial defects owing to the size of the potential space making the implant more prone to loosening. Secondly, the distal femur bone-implant interface is subjected to more shear stress during cyclical loading compared to the tibial implant for example during knee flexion, while the tibia is subjected to more compression. Two studies (20,33) postulated shear stress at the bone implant interface to be a risk factor for failure in relation to the level of constraint of the implant used. In these studies, they found cones implanted in hinged designs were more likely to require revision due to aseptic loosening compared to rotating hinge designs (20,33). Given the significantly higher risk of revision rate with femoral augmentation the surgeon may consider utilising a femoral mega-prosthesis such as a distal femur replacement in cases of uncontained femoral defects. However, mega-prothesis are generally performed in low numbers and are more appropriately indicated in low-demand patients and those with malignant pathology or un-reconstructable fractures (34). We therefore recommend this decision be made on an individualised basis. It should also be noted that despite higher revision rates being reported in femoral augmentation, the absolute risk remains low. Therefore, the number needed to treat to avoid a revision may be relatively high such that an individual surgeon's practice may not be affected.

Preparation of the defect to receive the sleeve does carry a risk of fracture (15). There were low intraoperative rates reported in this review with 14 cases across two studies all with the use of metaphyseal sleeves (15,25). The majority (93%) occurred during broaching of the metaphysis. Post-operatively only 4 of the reported revisions were due to periprosthetic fracture (3 sleeves and 1 cone). Though the variable quality of the studies included in this review may mean this complication is underreported particularly in the intraoperative phase. Other studies not eligible for inclusion have shown similarly low periprosthetic fracture rates [4]. With metaphyseal sleeves, the broach is impacted into the metaphysis prior to sleeve implantation to achieve a press fit, which does carry a risk of fracture. The reported rates of fracture during sleeve implantation is variable ranging from 0% in the majority of the studies in our review to 6.5% reported in other studies not eligible for inclusion in this review, such as Chalmers et al (35). However, it should be noted in their study only 2/15 intraoperative fractures required any additional treatment or weightbearing precautions and none of these 15 cases subsequently required revision for aseptic loosening at a mean follow up of 3 years (35). Other studies have reported careful preparation is key to avoiding fracture

(36). Iatrogenic fractures have also been reported with the use of metaphyseal cones (1,37) though none were observed in any of the studies included in this review.

Only four periprosthetic fractures were reported in the follow up period across all studies, 3 sleeves and 1 cone (17,22,24,28) demonstrating that concerns regarding potential stress shielding effects of metaphyseal fixation in the long term remain unproven (7).

This study has several limitations. First, there were significant differences in the way the studies presented their data which meant that not all relevant data could be accounted for in the pooled analysis of revision rate. This is a common problem encountered when attempting a meta-analysis. Although, the results of the comparisons between metaphyseal sleeve and cone revisions were highly significant (p=0.007), as were the comparisons between rates femoral implant and tibial implant revisions. This suggest that had all the data been available the overall result would have unlikely differed. Second, some studies reported only revision rates while other reoperations as well as revision. Reoperation rates may therefore have been underreported. Third, most studies included were deemed of low methodological quality based on our methodological quality assessment tool. There was a notable lack of prospective studies and no randomized control trials. Moreover, we did not include a cut-off mCMS score for exclusion and did not make any adjustments to the analysis based on methodological quality of the study. Fourth given the heterogeneity of the studies in reporting radiographic analysis and patient reported outcome measures (PROMs), it was not possible to conduct a meta-analysis comparing these outcomes. Fifth, cones were more likely to be used in uncontained defects compared to sleeves, suggesting the cohorts were not necessarily evenly distributed. Finally, we only included published studies and did not investigate unpublished studies or other grey literature.

CONCLUSION

Although the majority of the studies conclude that at least one of the meteorological variables have an influence on pain in OA patients, no general conclusion can be drawn. Repetition of a particular study design on the same geographic location or in the same climate would be required. Possible explanations for greater pain intensities due to cold weather are central sensitization mechanisms and the function of the TRPA-1 channel. Other treatments than TJA might be required if centrally mediated pain is present, due to possible persistency of centrally mediated pain after TJA. Further research is needed on this topic. In addition, further research is needed on the treatment of cold hyperalgesia caused by the function of the TRPA-1 channel and possible treatment options in this area.

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