Original article

Reprint

Comparative evaluation of bone defect replacement methods in revision total knee arthroplasty

Mikhail V. Girkalo✉, Ivan N. Shchanitsyn, Vladimir V. Ostrovskiy, Maxim N. Kozadaev, Alexander V. Derevyanov
✉ girkalo@mail.ru

Scientific Research Institute of Traumatology, Orthopedics and Neurosurgery at V.I. Razumovsky State Medical University of Saratov, Saratov, Russia

Received 12 Decembero 2022, Accepted 10 March 2023

Abstract:
Objective: to evaluate the immediate and long-term outcomes of revision total knee arthroplasty using porous metaphyseal sleeves and cones.
Materials and Methods. The study included 134 patients who underwent revision total knee arthroplasty. The patients were distributed among two groups based on the type of metaphyseal fixator: sleeves (Group I, n=97 patients) and cones (Group II, n=37 patients). Surgical outcomes were assessed upon discharge from the hospital (after the hospital stay of 7-12 days), as well as after 6, 12 and 24 months after surgery. The survival rate of endoprostheses was analyzed using the Kaplan–Meier method. A revision with total replacement of the endoprosthesis or its components was considered a critical event.
Results. The analysis of the survival rate of endoprostheses in the form of various metaphyseal fixators showed that the groups of sleeves and cones did not differ statistically significantly as suggested by the logrank test (Mantel–Cox): p=0.108.
Conclusion. The midterm follow-up revealed no difference in clinical, functional, or radiological outcomes of revision total knee arthroplasty performed for types 2A, 2B, and 3 of bone defect replacement (sensu Anderson Orthopaedic Research Institute classification) using trabecular metal metaphyseal cones vs. sleeves.

Keywords: revision arthroplasty, knee joint, bone defects

Cite as: Girkalo MV, Shchanitsyn IN, Ostrovskiy VV, Kozadaev MN, Derevyanov AV. Features of erythrocyte electrophoretic mobility in programmed hemodialysis patients. *Saratov Medical Journal* 2023; 4 (1): e0104. https://doi.org/10.15275/sarmj.2023.0104

Background

Total knee arthroplasty (TKA) is an orthopedic surgery in high demand. Consequently, the number of revision interventions is increasing and further growth is expected in the next decade [1]. It is predicted that up to 286 thousand TKAs will be performed annually in North America by 2030, which, compared with the current number of performed procedures, implies an increase of over 600% [2].

The clinical outcome of TKA and primary survival of endoprostheses are relatively successful and predictable [3]. However, repeated revision interventions after TKA account for approximately 10% of all knee arthroplasties [4]. The leading reasons for revision TKA are aseptic loosening of endoprosthesis components and periprosthetic joint infection, which are associated with the formation of bone defects of varying severity. Substantial bone defects resulting from aseptic loosening of the components of a compromised endoprosthesis can threaten the correct orientation and fixation of the revision prosthesis. The strategy for the latter was formulated in the concept of zonal fixation, described by R. Morgan-Jones et al. [5], according to which additional fixation in the metaphyseal zone is recommended in all cases of revision TKA for types 2 and 3 defects sensu the Anderson Orthopaedic Research Institute (AORI) classification. For this purpose, metaphyseal fixators have become widespread: sleeves and cones made of trabecular metal, which have a number of advantages over bone allografts: no risk of transmitting viral or bacterial infections, elimination of the likelihood of graft material resorption, shorter duration of surgery and, possibly, more durable primary fixation (*Figure 1*).

Metaphyseal sleeves and cones made of trabecular metal have similar indications for use but different implantation techniques and treatment outcomes, which determines the interest in comparing results of their use in revision TKA. As clinical data accumulated, it became possible to conduct a systemic analysis to resolve the problem of choosing the optimal metaphyseal fixator.

According to 2021 systematic literature review by R.P. Roach et al., which included 12 studies on the use of sleeves and 15 studies on the use of cones in revision TKA [6], the revision rate was almost twice as high when using cones vs. sleeves: 18.7% vs. 9.7%, respectively; albeit the variability of the selected studies and the likely multifactorial nature of unsuccessful outcomes did not allow any definitive conclusions to be drawn. This review solely highlighted the need for more research examining metaphyseal prostheses in revision TKA.

Figure 1. X-ray of the knee joint after revision arthroplasty: on the left, with metaphyseal sleeves; on the right, with metaphyseal cone

In 2022, P. Byttebier et al. published the largest systematic analysis and the only meta-analysis (77 articles, 4,391 knee joints) of the early and midterm clinical outcomes of the use of sleeves and cones, compared with the use of various bone grafting options and structural grafts [7]. When comparing all porous implants and grafts, no significant differences in prosthesis survival after 5-10 years were revealed. When comparing survival of cones and sleeves, the latter had a lower risk of revision (OR 1.72, 95% CI 0.88-2.57) vs. the cones (OR 3.04, 95% CI 1.71-4.37). The authors concluded that the volume and quality of publications on metaphyseal bone defects was progressively improving. Porous prostheses (sleeves and cones) are effective in metaphyseal bone defect replacement with a good survival rate at midterm follow-up. However, the lack of clear indications for choosing one or another method of metaphyseal fixation depending on the bone defect severity leaves the issue of the optimal metaphyseal prosthesis for revision TKA debatable [8].

Objective – to evaluate the immediate and long-term outcomes of revision total knee arthroplasty using metaphyseal sleeves and cones made of trabecular metal.

Materials and Methods

Our study was conducted at the Department No. 3 of Traumatology and Orthopedics of Scientific Research Institute of Traumatology, Orthopedics and Neurosurgery of Saratov State Medical University. In 2013 – 2015, 134 patients underwent revision TKA using semiconstrained revision endoprostheses with increased frontal stability. Metaphyseal sleeves and metaphyseal cones were employed in 97 and 37 cases, respectively. A retrospective cohort trial was performed on the basis of a prospectively completed database of patients after revision arthroplasty [9]. *Figure 2* presents the study design.

Inclusion criteria for the study were as follows: revision TKA for periprosthetic joint infection or aseptic loosening of the tibial, femoral, or both components of the endoprosthesis; and the presence of types 2A, 2B and 3 defects in the femur or tibia sensu the AORI classification. Exclusion criteria were as follows: uncorrected severe concomitant pathology (cardiovascular and respiratory diseases and/or other conditions that prevent surgical intervention), as well as severe dementia or other mental and physical impairments that prevented the patient from completing the questionnaire independently.

The median age of the patients was 67 years, body mass index was 34 kg/m2. Study participants included 34 men (26%) and 100 women (74%). Indications for revision TKA were aseptic loosening of the endoprosthesis in 55 cases (41%) and periprosthetic joint infection in 79 cases (59%). The study sample (134 patients) comprised of two groups based on the type of metaphyseal fixator, a sleeve (97 patients) or a cone (37 patients) (*Table 1*). Group I included patients with sleeves (e.g., manufactured by DePuy Synthes) to replace defects; Group II consisted of patients who underwent revision TKA using tantalum cones (e.g., manufactured by Zimmer Biomet) or a revision endoprosthesis (for example, by Stryker, with a Tritanium cone).

All patients underwent a standard preoperative clinical diagnostic examination, including physical examination, laboratory tests, radiography, CT, and MRI. Clinical examination was carried out using the Knee Society Scores (KSS) scale for assessing the function of the knee joint. Scores were calculated based on patient surveys. The KSS consists of two parts: clinical assessment and knee function assessment [10, 11]. X-rays were performed in a standing position; they encompassed the hip, knee and ankle joints. A number of studies were carried out in accordance with the KSTKARE scale (Knee Society Total Knee Arthroplasty Roentgenographic Evaluation) [12]: (a) disorders of the lower limb axes, (b) the location of the joint and patella line, (c) assessment of the endoprosthesis loosening with identification of osteolysis signs and determination of the position of endoprosthesis components. MRI and CT have higher sensitivity and specificity but are not recommended for routine practice due to high cost and elevated radiation exposure [13, 14]. In our practice, CT of the knee joint was performed according to indications to assess bone defects and spatial orientation of the endoprosthesis components. MRI of the knee joint was conducted if ligament damage was suspected.

Bone defects identified during surgery were assessed according to the AORI [15] and J. Insall [16] classifications. The type of defect was determined preoperatively using radiographs and during surgery after removal of all endoprosthesis components. Severe osteolysis of the tibia (T2B/T3) was observed in 81% of cases (108 out of 134). A pronounced defect in the femur (F2B/F3) was rarely detected (in 11%, or 15 cases out of 134). To assess the location and extent of the defect, we used the J. Insall classification [16], according to which bone defects are categorized into central (which do not extend onto the cortical plate) and peripheral (in which the cortical plate is damaged) lesions.

SMJ Saratov Medical Journal
ISSN 2712-8253, Saratov Medical Journal
2023. Volume 4. Issue 1 (March). Article CID e0104
DOI: 10.15275/sarmj.2023.0104

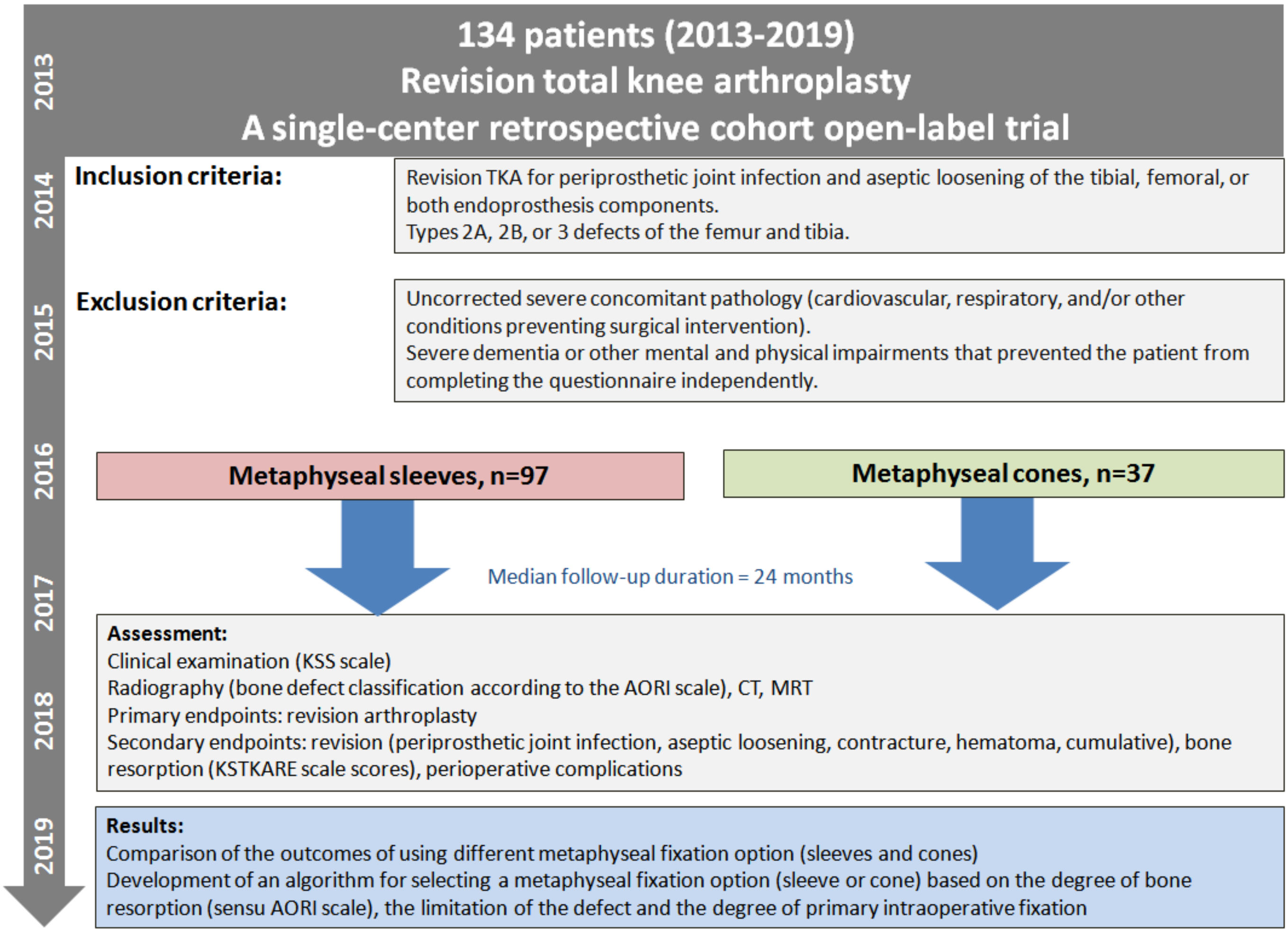

Figure 2. Design of the retrospective study

Based on the results of assessing the bone defects, we identified the necessity to use a metaphyseal sleeve or cone. If it was impossible to obtain stable fixation of the sleeve, a decision was made to use a cone [17].

Metaphyseal femoral sleeves and metaphyseal tibial sleeves were used in 10% of patients (10 out of 97) and 100% of patients (97/97), correspondingly. Reconstructive cones (e.g., manufactured by Zimmer Biomet) and cones (e.g., manufactured by Stryker) were employed in 57% of cases (21 out of 37) and 43% of cases (16/37), respectively.

Postoperative management of patients was carried out according to a standard protocol. The length of hospitalization was recorded as well as adverse treatment outcomes – such as aseptic loosening, periprosthetic joint infection, bone fractures during treatment and implantation of metaphyseal fixators, hematoma, contracture, and patella baja (low-riding patella). The outcomes of the surgery were assessed in 7-12 days after the intervention and then after 6, 12, and 24 months.

The obtained data from clinical and radiological examination of all groups were subjected to statistical analyses. Statistical processing of the data was carried out using SPSS 21.0 (USA). The normality of the distribution of quantitative characteristics was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk methods. Given the small sample size and non-normal distribution of most quantitative characteristics, nonparametric statistical methods were employed. To describe quantitative parameters, we used median and quartiles. Analysis of differences between different groups for quantitative characteristics was carried out using the Mann–Whitney U test. Friedman's two-way analysis of variance by ranks was used in related groups.

For qualitative characteristics, Pearson's χ^2 test was used. Logistic regression analysis was performed to identify risk factors for revision surgery. Variables included in the regression had $p<0.5$ on univariate analysis. A backward stepwise regression was used with an inclusion probability of 0.05 and an exclusion probability of 0.1 or greater. To identify the threshold of statistically significant values of quantitative characteristics, we constructed ROC curves with an assessment of the Youden's index. The survival rate of the prosthesis was analyzed using the Kaplan–Meier method. A revision with total replacement of the endoprosthesis or its components was considered a critical event. A curve of the prosthesis survival function was constructed. Pairwise comparisons of survival in two different groups were performed using the logrank test (Mantel–Cox). Results were considered statistically significant at $p < 0.05$, and two-tailed significance was assessed for all criteria.

Table 1. Clinical characteristics of patients before surgery

Parameter	All patients (*n*=134)	Group		p^*
		I (*n*=97)	II (*n*=37)	
Age, y/o	67 (61-73)	67 (62-73)	67 (60-73)	0.854
Height, m	1.6 (1.5-1.6)	1.6 (1.5-1.6)	1.5 (1.5-1.6)	**0.038**
Weight, kg	90 (76-102)	90 (79-102)	86 (75-101)	0.633
Body mass index, kg/m^2	34 (30-38)	34 (29-38)	36 (30-39)	0.344
Female gender, *n* (%)	100 (74%)	67 (69%)	33 (89%)	**0.025**
Time after initial surgery/revision, mos.	23 (11-40)	21 (11-42)	24 (10-38)	0.781
Indications for revision arthroplasty, *n* (%):				
Aseptic loosening	55 (41%)	37 (38%)	18 (49%)	0.269
Periprosthetic joint infection	79 (59%)	60 (62%)	19 (51%)	
Type of bone defect according to the AORI classification, *n* (%)				
F1	10 (7%)	7 (7%)	3 (8%)	0.992
F2A	59 (44%)	44 (46%)	15 (41%)	
F2B	60 (45%)	42 (43%)	18 (49%)	
F3	5 (4%)	4 (4%)	1 (2%)	
T1	2 (1%)	2 (2%)	0	**0.005**
T2A	24 (18%)	24 (25%)		
T2B	99 (74%)	66 (68%)	33 (89%)	
T3	9 (7%)	5 (5%)	4 (11%)	

For quantitative variables, the median and quartiles are calculated; *, calculation of the χ^2 (Fisher's exact test) and the Mann–Whitney U test; p-values suggesting statistical significance are presented in bold.

Results

The patients in groups organized based on different metaphyseal fixators (sleeves or cones) did not differ in their main preoperative parameters. In Group II (cones), there were more women, and a higher frequency of severe bone resorption was noted (T2B and T3 on AORI scale) (*Table 2*). The groups did not differ in the frequencies of one-stage or two-stage interventions. A longer time between stages of surgical treatment in case of a two-stage approach was revealed in Group I. The surgery duration in one-stage revision arthroplasty, or the duration of the second stage in a two-stage intervention (cement spacer replacement with an endoprosthesis), along with an intraoperative blood loss, exhibited higher values in Group II.

Group II patients had shorter follow-up periods after surgery as well. This was due to the fact that Scientific Research Institute of Traumatology, Orthopedics and Neurosurgery of Saratov State Medical University started actively using cones only in 2015 – 2017.

Patients were examined within a period of time between 4 and 50 months after operation. The median time of follow-up was 24 months (the quartiles: 11–42). In the long-term follow-up (beyond 24 months), it was possible to monitor the treatment outcomes in 90 out of 134 (67%) of patients. The rate of revision TKA, its causes (periprosthetic joint infection, aseptic loosening, contracture, hematoma), bone resorption (sensu KSTKARE scale), and perioperative complications were assessed. *Table 3* presents the outcomes of treatment with metaphyseal fixators in both groups of patients.

The second revision was performed in 17 patients (18.8%), including 10 cases of recurrent infection (11.1%), two cases of aseptic instability (2.2%), three cases of contracture and pain syndrome (arthrofibrosis) (3.3%), and a case (1.6%) of the patient with a prolonged resolution of the hematoma (which required repeated intervention, irrigation and drainage). One observation revealed a periprosthetic fracture that required revision TKA. Another patient had a low-riding patella, which did not affect daily routine and, accordingly, did not require additional surgical intervention. Replacement or removal of the revision endoprosthesis components, which characterize its survival rate, was recorded in in 14 out of 90 followed patients (15.5%), including 10 patients of Group I and in 4 patients of Group II.

An analysis of the prosthesis survival rate after revision TKA using different metaphyseal fixators disclosed that the groups (sleeves vs. cones) did not differ statistically significantly, as implied by the logrank test (Mantel–Cox) p=0.108. However, annual survival rate of the prosthesis during the first year of the follow-up was significantly higher in Group I than in Group II, 96% vs. 74%, respectively. At a two-year point of the postoperative follow-up, survival rates for sleeves and cones were 86 and 74%, correspondingly. The median follow-up in Group II was only 12 months (the quartiles: 6–16). Consequently, we were able to estimate the four-year cumulative survival rate of the prosthesis only for Group I (64%). Such values were due to the small number of monitored patients (12 out of 134, 8.9%) in the long term (more than 48 months).

Functional and radiography-based treatment outcomes were assessed using the KSS and KSTKARE scales in 12–24 months after revision TKA, respectively. According to the KSS scale, final score as a sum of the function score and knee score (clinical assessment) was excellent (80-100 points) in 47 of 134 patients (35%), good (70-79 points) in 42 study subjects (31%), fair (60-69 points) 28 participants (21%) and poor (less than 60 points) in 17 individuals (13%). The overall median KSS for all patients was 75 points (the quartiles 65–80), which was regarded as a good result. Therefore, the groups did not differ on the KSS scale.

Table 2. Clinical characteristics of patients in the postoperative period

Parameter	All patients (*n*=134)	Group		*p**
		I (*n*=97)	II (*n*=37)	
One-stage revision arthroplasty, *n* (%)	46 (35%)	31 (32%)	15 (40%)	0.417
Two-stage intervention, *n* (%)	88 (65%)	66 (68%)	22 (60%)	
Time between stages, mos.	6 (3-9.5)	7 (4.5-11.5)	4 (2.2-6)	0.003
Surgery duration, min	120 (110-135)	120 (105-130)	130 (120-140)	0.008
Intraoperative blood loss, mL	300 (200-300)	200 (200-300)	300 (200-300)	0.027
Blood loss through drainage, mL	350 (225-550)	350 (212-500)	350 (225-600)	0.854
Length of hospitalization, days	8 (7-10)	7 (7-10)	8 (7-11)	0.818
Follow-up duration, mos.	24 (11-42)	32 (22-46)	12 (6-16)	<0.001

For quantitative variables, the median and quartiles are calculated; *, calculation of the χ^2 (Fisher's exact test) and the Mann–Whitney U test; p-values suggesting statistical significance are presented in bold.

Table 3. Outcomes of revision total knee arthroplasty using metaphyseal fixators

Parameter	All followed up patients (*n*=90)	Group		*p**
		I (*n*=60)	II (*n*=30)	
Revision (total), *n* (%)	17 (19%)	12 (20%)	5 (16.6%)	0.513
Revision for recurrent infection	10 (12%)	7 (11.6%)	3 (10%)	0.726
Revision for aseptic loosening	2 (2%)	1 (1.6%)	1 (3.3%)	0.477
Revision for contracture	3 (3%)	2 (3.3%)		0.305
Irrigation and drainage for hematoma, *n* (%)	1 (1%)	1 (1.6%)	0	0.724
Periprosthetic fracture, *n* (%)				
Revision with replacement/removal of endoprosthesis components, *n* (%)	14 (15.5%)	10 (16.6%)	4 (13.3%)	0.767

For quantitative variables, the median and quartiles are calculated;
*, calculation of the χ^2 (Fisher's exact test) and the Mann–Whitney U test

After the surgery, the groups differed statistically significantly only in the function score sensu KSS, but because this parameter was higher in Group I even before it, it was impossible to unambiguously prove the advantage of metaphyseal sleeves.

The main indicator of the radiographic assessment on the KSTKARE scale was the presence of a boundary of bone resorption under the endoprosthesis components.

According to the KSTKARE scale, resorption was categorized as nonprogressive (0-4 points); stable (requiring observation: 5-9 points); significant (manifested by symptoms of aseptic loosening (>10 points). After 12–24 months following revision TKA, of 134 patients, 3 exhibited significant bone resorption (2.2%), 18 showed stable resorption (13.4%), while 113 monitored subjects had no resorption whatsoever or nonprogressive resorption (84.3%). None of the patients showed progressive bone resorption in the area of the femoral component. We observed no differences between Groups I and II did in terms of the radiography-based bone resorption scale.

To evaluate predictors of revision TKA with metaphyseal fixators, we carried out a regression analysis, which included parameters previously identified in univariate analysis with statistical significance of p<0.5. In a multivariate analysis, significant predictors of revision TKA were pronounced defects of the femur and tibia requiring simultaneous use of two sleeves (femoral and tibial) in the same patient (p=0.007, OR 15.2, 95%CI: 1.2-180). With a two-stage intervention, the duration of the time interval between the 1st and 2nd stages was over 16 months (p=0.005, OR 19.7, 95%CI: 2.5-155), metaphyseal bone loss in the tibia was assessed as severe on AORI T3 scale (p=0.048, OR 13.8, 95%CI: 1.0-185), and final KSS before surgery was less than 74 points (p=0.001, OR 18.6, 95%CI: 2.6-140).

Discussion

The outcomes of using various metaphyseal fixators are presented in many publications. The general trend indicates good and excellent survival of sleeves and cones in the early and midterm follow-up periods for types 2A, 2B and 3 defects sensu AORI. Over the past three decades, the quality of the studies covering this issue increased substantially, sample sizes have become greater, and study designs have improved. However, studies comparing different metaphyseal fixators are still rare. The conducted systematic reviews and meta-analyses did not allow confirming the advantage of one or another metaphyseal fixator [7].

In our retrospective study performed on a large cohort of patients, the early and midterm follow-up survival rate of prostheses used for TKA (median: 24 months; the quartiles: 11-42 months) was 89.6% (120/134). When analyzing the survival rate of the prosthesis after revision TKA using various metaphyseal fixators, the groups of sleeves and cones did not differ statistically significantly: logrank test (Mantel – Cox) yielded p=0.108). At the same time, the first-year survival rate of the prosthesis in Group I was significantly higher vs. Group II: 96% vs. 74%, respectively. The two-year survival rate was 86 and 74%, correspondingly. The median duration of the follow-up in Group II was only 12 months. (the quartiles: 6-16). Consequently, the four-year cumulative survival rate was estimated solely for Group I (64%). Such low value is associated with a small number of patients followed in the long-term (longer than 48 months): 12 out of 134, or 8.9%). The necessity of revision TKA was mainly due to recurrent periprosthetic joint infection (10/134, or 11.1). Aseptic loosening was the cause in only 2 out of 134 patients (2.2%). The groups did not differ in causes of revision TKA.

During our study, we noticed that the replacement of minor bone defects with the a metaphyseal sleeve was much simpler when using the technique of cementing the remaining space. We thought that this technique was acceptable since the primary fixation of the metaphyseal sleeve occurs by pressing the implant into the bone, and then good secondary fixation is ensured due to osseointegration into the porous coating of the sleeve. In this case, axial and torsional loadings are spread onto the metaphyseal area, which makes it possible to perform grafting of the remaining epiphysis defect with cement. When choosing between bone cementing and autograft, preference was given to cementing, since when performing revision TKA, autografts were barely available and were employed mainly to replace central bone defects in order to create support for the sleeve. Bone allografts were not used due to the risk of developing infectious and inflammatory complications [18]. It should be noted that cement can act as a depot of antibacterial chemotherapy, which, in turn, reduces the risk of recurrence of the infectious process.

Essentially, the metaphyseal sleeve provides hybrid fixation of the endoprosthesis component. In the area of the intact epiphysis, cement fixation is performed, in the metaphyseal area, primary press-fit fixation and secondary fixation with a sleeve are ensured, and diaphyseal fixation is provided by a cementless rod. According to the concept of three-point fixation, metaphyseal fixation of prostheses is optimal [5], because loads are distributed evenly across all parts of the tibia, thereby contributing to an increase in the service life of the endoprosthesis. We believe that in the future, the use of metaphyseal sleeves may help abandoning metal augments (blocks and wedges) entirely for types 2A and 3 tibial bone defects. On the contrary, sleeves are required much less frequently in femoral reconstruction, since metal augments are indispensable for accurately restoring the joint line and femoral posterior condylar offset.

Another option for replacing bone defects during revision TKA is the use of porous tantalum cones, which have also demonstrated good results. For instance, W. Long et al. [19] confirmed good immediate results from the use of cones for types 2 and 3 defects. R. Meneghini et al. [20] observed complete osseointegration when using tibial cones, which implied their survival at the level of 100%; however, the authors stated that the indications and methods of using tantalum cones differ from those of sleeves. The tantalum cone, unlike the metaphyseal sleeve, is not part of the endoprosthesis: it is intended to replace the existing defect and create support for the endoprosthesis. The absence of rigid fixation between the cone and the endoprosthesis contributes to better fixation of the cone to the bone. Despite the fact that sleeves and cones demonstrated excellent and good results when replacing types 2 and 3 defects, there are fundamental differences in the indications and methods of their use; and in our opinion, each of these aspects requires a detailed investigation.

In our study, the clinical and radiography-based outcomes of using sleeves and cones were similar. Clinical examination was carried out using the clinical and functional assessment scale (KSS) [10, 11], since it was habitually used in most studies of revision TKA [7]. The median KSS in all patients was 75 points (the quartiles: 65-80), which was regarded as a good result. Our results are consistent with other studies. In a systematic review by P. Byttebier et al., KSS values for the group with cones and group with sleeves were 77.2 (20 studies) and 78.6 (12 studies), respectively [7]. In our study, differences between groups in postoperative functional assessment according to KSS are explained by baseline differences prior to the surgery.

The radiography-based outcome was assessed using the KSTKARE scale [12]. Significant bone resorption in our study was detected in 3 of 134 patients (2.2%), while stable grade was noted in 18 of 134 patients (13.4%). Absence of bone resorption or nonprogressive grade 12-24 months after revision TKA were observed in 113 of 134 patients (84.3%). None of our study subjects exhibited progressive bone resorption in the area of the femoral component. Groups I and II were similar in this respect in terms of the grade of the KSTKARE scale.

Each revision TKA operation is unique. The surgeon needs to assess the degree of complexity of each case and employ the entire available pool of resources. To properly manage bone mass defects, it is necessary to consider the size and location of the bone defect, as well as patient demographics (body mass index, activity level, age, and life expectancy). All of these factors influence the functional outcome of treatment and the survival of the endoprosthesis. We carried out multivariate regression analysis to identify possible predictors after revision TKA with metaphyseal anchoring. Statistically significant predictors included the need to use a two-component sleeve (both tibial and femoral in the same patient), an interval of more than 16 months between the 1st and 2nd stages in two-stage treatment of periprosthetic joint infection, a pronounced grade of bone resorption in the tibia on AORI T3 scale, and final KSS (a function score and clinical assessment score combined) before surgery less than 74 points. The limitation of our study is indisputably its retrospective nature and small sample size. Further research may allow clarifying the significance of the identified risk factors for the revision TKA failure.

As previously stated, the choice between a metaphyseal cone and a sleeve is currently controversial and is largely determined by a surgeon's preference and possibly the shape and size of the bone defect. The conventional indication for polymethyl methacrylate (PMMA) cementation is bone deficit of less than 5 mm. If it is 5-10 mm and affects less than 50% of the femoral condyle or tibial surface, then the use of polymethyl methacrylate with reinforcement screws is recommended. If there is a deficit of over 5 mm, bone grafting with crushed cancellous bone allograft is strongly advised. For a deficit of 5-15 mm affecting more than 50% of the femoral condyle and the surface of the tibia, modular systems with legs and augments are suggested. Finally, in case of a deficit of over 15 mm, structural allografts, megaprostheses, and porous metal augments need to be employed.

A similar algorithm is proposed based on the AORI classification. For small and limited defects (type 1 sensu AORI), cementation with or without reinforcement screws and the use of auto- or allografts of bone tissue are recommended. For average defects (type 2A sensu AORI), metal augments should be used. For large defects (types 2B and 3 sensu AORI), structural allografts or porous metaphyseal fixators (cones and sleeves) should be recommended.

Figure 3 presents a summary matrix for selecting a fixation method for revision TKA depending on the size and type of defect (on AORI scale), albeit long-term clinical outcomes and prosthesis survival after revision TKA remain suboptimal and depend on multiple factors, such as the reason for revision, employed surgical approach, and type of the implant. Hence, more scientific evidence is needed to help determining the optimal method for each particular patient.

Conclusion

Favorable clinical and radiological results of using metaphyseal sleeves and cones during revision TKA in our study allow recommending their use for tibial defects (types 2A, 2B and 3 sensu the AORI classification). Both methods provided reliable reconstruction of bone defects with similar clinical and radiological outcomes and endoprosthesis survival.

However, further study and analysis of the long-term outcomes of using these structures is necessary. The primary task that needs to be solved is the introduction of new algorithms for choosing one or another fixation method, taking into account not only the size of bone defects, but also predictors of endoprosthesis failure in the course of the treatment of this complex group of patients.

Conflict of interest. None declared. The study was carried out within the framework of the R&D plan of Scientific Research Institute of Traumatology, Orthopedics and Neurosurgery of V.I. Razumovsky State Medical University of Saratov, Optimization of Revision Total Knee Arthroplasty, State R&D Registration Number AAAA-A18-118050890023-7.

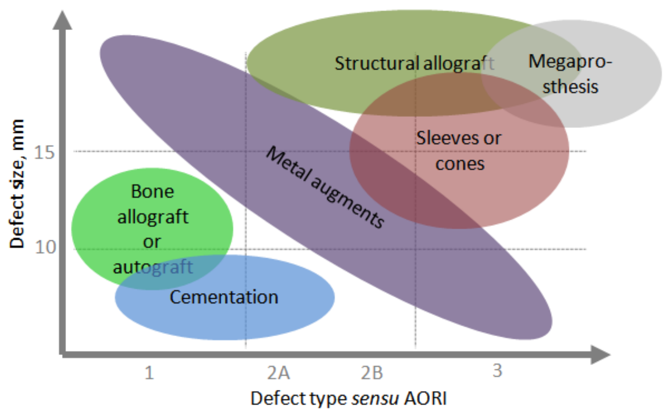

Figure 3. Matrix for choosing a fixation option for revision total knee arthroplasty depending on the size and type of defect (sensu AORI)

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Authors:
Mikhail V. Girkalo – PhD in Medicine, Deputy Director of Medical Services, Scientific Research Institute of Traumatology, Orthopedics and Neurosurgery of V.I. Razumovsky State Medical University of Saratov, Saratov, Russia;
Ivan N. Shchanitsyn – PhD in Medicine, Senior Research Scientist, Division of Innovative Projects in Neurosurgery and Vertebrology, Scientific Research Institute of Traumatology, Orthopedics and Neurosurgery of V.I. Razumovsky State Medical University of Saratov, Saratov, Russia;
Vladimir V. Ostrovskiy – Director, DSc (Medicine), Director, Scientific Research Institute of Traumatology, Orthopedics and Neurosurgery of V.I. Razumovsky State Medical University of Saratov, Saratov, Russia;
Maxim N. Kozadaev – PhD in Medicine, Orthopedic Traumatologist, Saratov, Russia;
Alexander V. Derevyanov – Orthopedic Traumatologist, Saratov, Russia.