International Orthopaedics (2019) 43:2503–2509
https://doi.org/10.1007/s00264-019-04296-z

ORIGINAL PAPER

Functional outcome of two-stage reimplantation in patients with periprosthetic joint infection after primary total knee arthroplasty

Petr Mikhailovich Preobrazhensky[1] · Svetlana Anatolievna Bozhkova[1] · Alexander Viktorovich Kazemirsky[1] · Rashid Murtazalievich Tikhilov[1] · Taras Andreevich Kulaba[1] · Nikolai Nikolaevich Kornilov[1]

Received: 24 September 2018 / Accepted: 8 January 2019 / Published online: 16 January 2019

Abstract

Introduction Two-stage reimplantation in patients with chronic periprosthetic joint infection (PJI) after total knee arthroplasty (TKA) with the use of either articulating or static antibiotic-loaded spacers during the first step is considered to be the golden standard in orthopaedics.

The aim of the study The aim of the study was to evaluate the correlation of spacer type with the infection elimination rate as well as functional outcomes after two-staged revision TKA in patients with PJI.

Materials and methods The cohort comprised 161 patients who were treated for PJI after TKA during a period from January 2007 to December 2015. After the exclusion of patients with severe bone defects (AORI 2B or 3), 104 were left for the analysis: 72 patients with articulating and 32 with static spacers. The overall patient mean age was 62 years old (95% CI, 30–84): 73 for females, 31 for males. The outcomes were evaluated after three, six and 12 months using the American Knee Society Score (KSS) and EQ-5D. Only 92 patients were available for observation: 25 with static and 67 with articulating spacers.

Results One year after the surgery, patients with articulating spacers demonstrated significantly higher mean KSS and function scores in comparison to patients with static spacers (90.4, 77.3 and 78.5, 67.8, respectively ($p < 0.05$)). The range of motion was also significantly better in patients with articulating spacers: 104.9° in comparison to 93.9° ($p < 0.0001$). The final EQ-5D score was comparable in both groups (0.82, 73.1 in articulating and 0.82, 72.6 in static spacers).

Conclusion The two-stage revision TKA for PJI using articulating spacers in comparison to the static ones provides better infection eradication rate as well as functional outcomes and improved quality of life.

Keywords Total knee arthroplasty · Periprosthetic joint infection · Two-stage revision · Spacer · Quality of life · Outcome

Introduction

Periprosthetic joint infection (PJI) is one of the most common early complications after primary total knee arthroplasty (TKA). According to different studies, up to 32.7% of all revisions were performed due to PJI [1, 2]. Other studies worldwide confirm this worrisome statistics. While just 15 years ago, polyethylene wear was the most common reason for revision after primary total knee arthroplasty; over the past five years, PJI has become one of the leading cause (38%) among other complications [3, 4]. Le DH et al. demonstrated similar results, where even among all the late complications after TKA, 25% of patients had PJI [5].

Diagnostic criteria of PJI are well defined [6]. The measurement of alpha defensin is a promising addition to a set of current methods for diagnosis of PJI which improves its accuracy [7]. Compliance with an up-to-date diagnostic algorithm allows surgeons to confirm PJI, identify pathogens, and select effective antibiotic therapy for the eradication of the infection [8].

Several treatment options are available for patients with PJI. Antibiotic suppressive therapy alone has inappropriate efficacy and might be only used in highly comorbid patients. Open debridement with the component retention has limited indications and demonstrates only moderate efficacy of the

✉ Petr Mikhailovich Preobrazhensky
p.preobrazhensky@gmail.com

[1] Russian Scientific Research Institute of Traumatology and Orthopedics named after R.R. Vreden, Akademika Baykova St., 8, St. Petersburg 195427, Russian Federation

infection eradication [9, 10]. Despite the growing interest in one-stage revision TKA for patients with PJI, two-stage reimplantation remains the "gold standart" approach worldwide due to the highest rate of infection elimination (up to 94%) [11–13].

In spite of the existing effective treatment algorithms, quality of life is substantially reduced after prosthetic infection [2]. During the first step of two-stage reimplantation, two types of antimicrobial cement spacers may be alternatively used: static and articulating. Both of them demonstrate a comparable infection control rate at around 90% [14, 15]. Articulating spacers support the extensor mechanism function and soft tissue elasticity facilitating the second surgery. This helps to reduce the need for the extended surgical approaches during the second stage and improves the quality of life in patients between the steps [16].

The aim of the study

To evaluate the correlation of the spacer type with the infection elimination rate as well as the functional outcomes after two-staged revision TKA in patients with PJI.

Materials and methods

The cohort comprised 161 patients who were treated for PJI after TKA during a period from January 2007 to December 2015. For further analysis of the functional outcome, patients with extensive bone defects (AORI type 2B and 3), extensor mechanism deficiency, and reinfection after the first stage were excluded. The final cohort consisted of 104 patients including 72 with articulating and 32 with static antibiotic-loaded spacers. The mean age of the patients was 62 years old (95% CI, 30–84): 73 for females, 31 for males. The outcomes were evaluated after three, six and 12 months using the American Knee Society Score (KSS) [17] and EQ-5D [17, 28]. Only 92 patients attended all follow-up visits to the hospital; thus, they were included in this study: 25 with static and 67 with articulating spacers.

The main indication for primary TKA was osteoarthritis. The percentages of post-traumatic cases and rheumatoid arthritis were equal in the compared groups (Table 1). The mean period between stages was comparable in patients of both groups. The type of infection was diagnosed in accordance with the Coventry–Fitzerald–Tsukayama classification.

PJI was diagnosed according to the international consensus on periprosthetic joint infection [6]. Pathogens were identified in all patients with PJI. Gram-positive bacteria were the main cause of PJI in both groups. The majority (68.1%) of patients with articulating spacers had an infection. The proportion of methicillin-resistant *Staphylococcus epidermidis* (MRSE) was comparable (15.1%) in both groups. Gram-negative pathogens and microbial associations were more frequent in patients with static spacers (Fig. 1).

Surgical technique The first step included arthrotomy with the excision of the old scar, removal of femoral and tibial components, and thorough debridement of all inflamed and necrotized soft and bone tissues with the jet lavage of more than 1500 ml of saline for the whole area. Articulating spacers were formed using resterilized femoral component and antibiotic-loaded PMMA bone cement (DePuy® CMW 3 Gentamicin, with 2 g of vancomycin per 40 g of the bone cement). In order to fill all cavities and balance the flexion and extension gaps after the implantation, the bone cement was molded into the tibia plateau and inserted in its doughy state. The static spacer was combined with the antibiotic-impregnated bone cement prepared in the same manner and formed with a rod implanted into the medullary canal of the femur and tibia.

During the post-operative period, every patient received a combination of antibiotics for six to eight weeks according to the sensitivity of the identified pathogens. All patients with static spacers were recommended to load the leg during

Table 1 Demographic data

	Articulating	Static	*p*
Age, years (95% CI)	61.9 (30–84)	60.7 (25–83)	0.55
Male, *n* (%)	17.3	35.1	> 0.05
Female, *n* (%)	82.7	64.9	> 0.05
Osteoarthritis, *n* (%)	50 (69.0)	24 (75)	> 0.05
Post-traumatic arthritis, *n* (%)	11 (15.5)	5 (15.5)	> 0.05
Rheumatoid arthritis, *n* (%)	11 (15.5)	3 (9.5)	> 0.05
PJI type I, *n* (%)	21 (29.2)	12 (37.5)	> 0.05
PJI type II, *n* (%)	25 (34.7)	9 (28.1)	> 0.05
PJI type III, *n* (%)	26 (36.1)	11 (34.4)	> 0.05
Period between stages, days (95% CI)	186.8 (59–499)	216.4 (105–793)	0.17

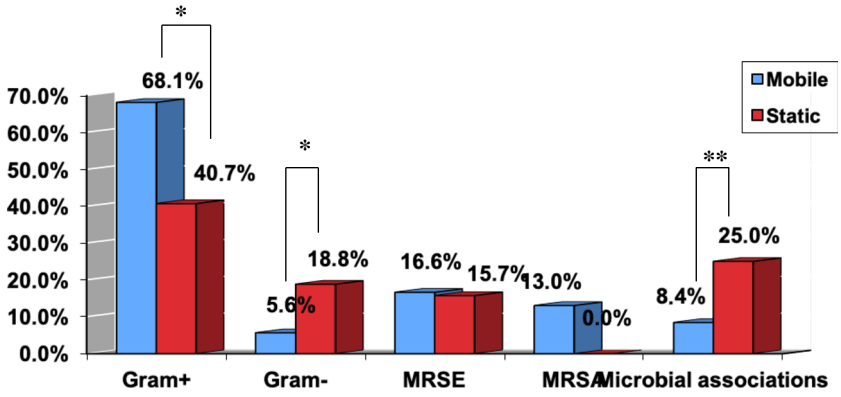

Fig. 1 Pathogens identified in patients of the compared groups. *$p < 0.05$, **$p < 0.01$

walking with a half weight using crutches. In order to reduce the mobility of the operated knee, patients with static spacers had to wear a brace until the second step of the surgery. One month after surgery, patients with articulating spacers were allowed to walk with full weight bearing without a brace and additional support.

The second step was only performed in the absence of any signs of infection (local and general) with negative microbiological cultures and a normal blood cell count.

Statistical methods

Statistical analysis of the results was performed with STATISTICA 9.0 software (StatSoft, USA). The following statistical methods were employed in the analysis: chi-square test with Yates's correction, Fisher's exact test, ANOVA, the Mann–Whitney *U* test, and the Wald test.

Results

The cohort in the study comprised 161 cases with PJI including 80 patients with dynamic and 81 with static spacers. After the first stage, PJI was eliminated in 118 (73.3%) patients. In 43 (26.7%) patients with recurring infection, 34 (79.1%) were with static and six (20.9%) with articulating spacers. Sixteen (37.2%) of 43 patients underwent further successful reimplantation of the second spacer; while in 27 (62.8%) patients, after several episodes of reinfection, arthrodesis was performed as a limb-salvaging procedure which also helped to achieve the infection eradication.

The efficacy of the first stage was 74.3%, including 88.8% with dynamic and 59.1% with static spacers ($p < 0.01$).

KSS

After the first examination prior to spacer implantation, the mean KSS values in patients of both groups were unsatisfactory. Despite the fact that the same values were still «unsatisfactory» prior to the second step, patients with articulating spacers demonstrated greater improvement of the operated knee score than patients with static spacers ($p < 0.05$). This tendency remained after the second step, three, six and 12 months after revision TKA. While patients with static spacers after the second step had the mean number of points corresponding to the «satisfactory» outcome, patients with articulating spacers three months after revision TKA had the «good» outcome which lasted until the final follow-up. The mean «excellent» score was observed in patients with articulating spacers one year after surgery ($p < 0.003$) (Fig. 2).

KSS function score

The presence of PJI reflected on the «unsatisfactory» points after the first examination for articulating and static spacers. Three further examinations after the two-stage treatment protocol showed rapid improvement to the «good» outcome in patients with articulating spacers ($p < 0.05$). In contrast, the final examination showed no significant difference ($p = 0.174$) between articulating and static spacer groups (Fig. 3).

EQ-5D

Patients with articulating and static spacers had similar results before the first and second stages of treatment: 0.18 (95% CI, −0.51–0.64) and 0.21 (95% CI, 0.16–0.63); 0.57 (95% CI, 0.16–0.8) and 0.53 (95% CI, −0.01–0.74), respectively. At the same time, mean scores three and six months after revision TKA in patients with articulating spacers were significantly higher ($p < 0.01$): 0.71 (95% CI, 0.53–1.0) and 0.59 (95% CI, −0.08–0.83); 0.8 (95% CI, 0.54–1.0) and 0.74 (95% CI, 0.43–1.0), respectively. Eventually, the final scores in both groups at one year after two-stage reimplantation were equal—0.82.

Visual analogue scale of EQ-5D was assessed at the same period of time. The feasibility of using articulating spacers was confirmed by better QOL improvement between stages of treatment (60.0 (95% CI, 40–85) and 51.6 (95% CI, 20–80), respectively) and three months after revision surgery (63.5 (95% CI, 40–90) and 54.2 (95% CI, 20–95),

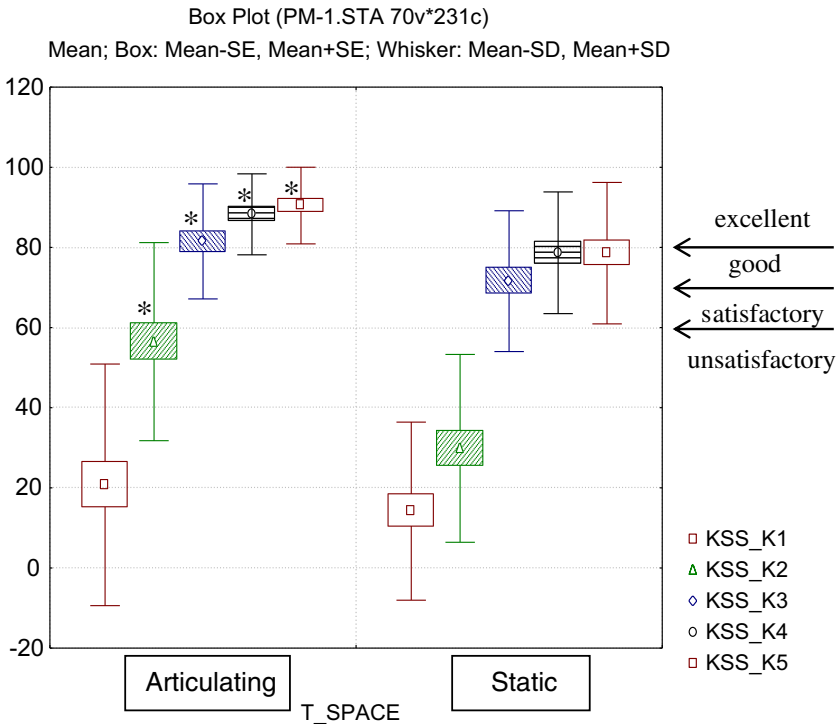

Fig. 2 KSS in patients of the compared groups. *$p < 0.05$ articulating vs. static spacer

respectively). The results in one year after surgery in both groups were comparable: 69.6 (95% CI, 35–100) in articulating and 65.9 (95% CI, 30–100) in static spacers.

The mean range of motion (ROM) of the operated knee in patients treated with articulating spacers during the first step at the final follow up was 104.9°, (95% CI, 80–130), and significantly exceeded ($p < 0.0001$) the same level in the compared group—93.9°, (95% CI, 80–110) (Fig. 4).

One of the main conditions to achieve the effective elimination of the infection and normal range of movement in the operated knee after two-stage reimplantation is providing an adequate interval between spacer implantation and revision

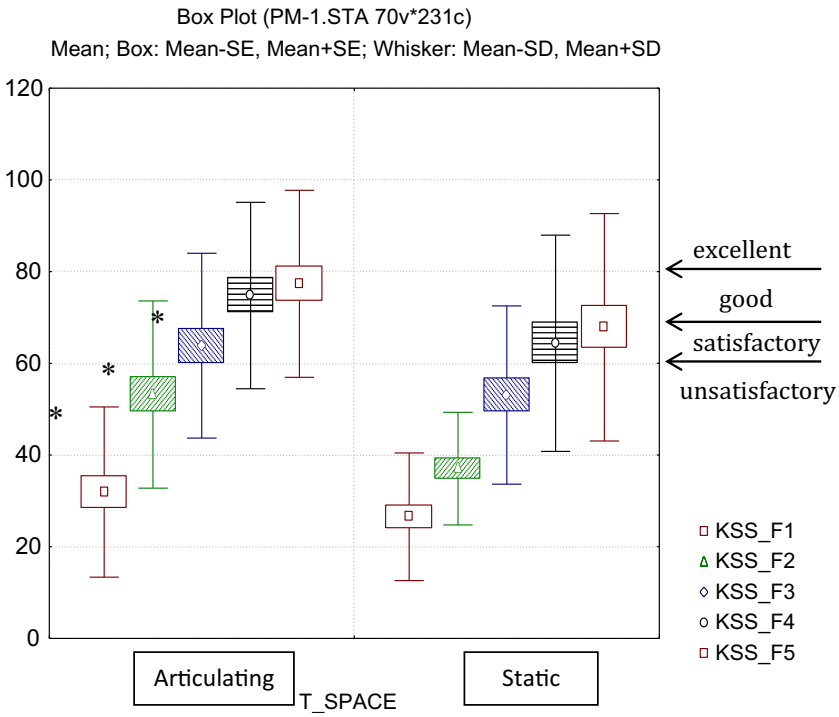

Fig. 3 KSS function score in patients of the compared groups. *$p < 0.05$ articulating vs. static spacer

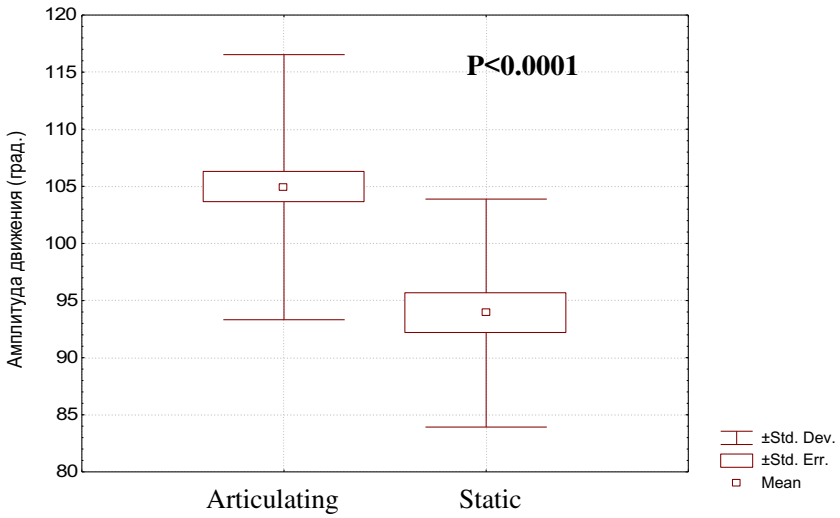

Fig. 4 ROM in patients of the compared groups

TKA. In the present study, the interval was higher than recommended in the compared groups. Those who underwent the second step during a period of fewer than 90 days (4 patients with static and 14 patients with articulating spacers) had the same range of motion (105°) compared to all cohort: 93.9° with static and 104.9° with dynamic spacers. The interval of more than 90 days after static spacer implantation could have had a possible negative impact on the final range of motion. Statistical analysis showed correlation between these two factors.

Discussion

Over the past ten years, the two-stage reimplantation due to PJI after TKA has become the preferred treatment algorithm which demonstrates convincing results both with respect to the efficacy of the infection eradication and with better functional outcomes [18, 19]. It is especially evident in patients with a sinus tract, late infection, and Gram-negative bacteria or polymicrobial associations [20]. In case of multiresistant microorganisms, such as *Klebsiella*, three-stage reimplantation with double exchange of the antimicrobial spacer could be applied for an effective infection control [21]. In our study, the comparison of the infection eradication efficacy during the first step showed the superiority of articulating spacers (88.8%) over static ones (59.1%) ($p < 0.01$). This finding could be explained by the fact that static spacers were more likely to be implanted in complicated cases: microbial associations, multiresistant pathogens, post-traumatic cases, multiple debridements without endoprosthesis removal. Moreover, risk factors such as a positive culture during the reimplantation stage, female gender, psychiatric disorders, and heart diseases increase the risk of infection recurrence and must be analyzed during pre-operative planning [22, 23].

One-stage reimplantation is an effective surgical strategy, demonstrating a high rate of infection control (93%) even in case of chronic infection and is associated with the less comorbidity, low costs, and an improved function. Strict indications such as minimal or moderate bone loss, healthy soft tissues, non-immunocompromised state, and known organisms with established sensitivity should be accounted for [24].

In our practice, we often deal with complicated cases of PJI: the presence of DTT pathogens, high comorbidity, insufficiency of soft tissues, and two-stage reimplantation as a preferable treatment algorithm for these patients. Along with the infection eradication, every surgeon has to aim for the best possible functional outcome in patients after two-stage reimplantation. Our findings are in accord with the results of independent studies from other medical centres. Their conclusions were unanimous regarding the main reason for the advantage of articulating spacers over static ones which was due to the preserved mobility in the operated knee between the steps of surgery. This benefit makes revision TKA more comfortable for a surgeon and leads to a better functional outcome, which in turn increases the satisfaction of the patients with the treatment [14, 15, 25, 26]. Shakih A. in his study made a conclusion that the dynamic spacer allows to achieve a good function in operated knee (87°) between stages of treatment, this resulted in better final KSS compared to patients with static spacers [27].

Furthermore, some studies report a good functional outcome and improved QOL after two-stage reimplantation with the use of static spacers when the condition of an optimal interval between the infection eradication and revision TKA was fulfilled [13, 18]. The main benefit in these studies was a better infection control in case of the knee immobilization.

In general, the comparison of two spacer types could sometimes be incorrect. Due to the reinfection after the first step with the massive bone loss, poor soft tissue condition, and extensor mechanism insufficiency, surgeons prefer to implant static spacers in order to immobilize the knee and support the

effective local antibiotic delivery to the site of infection [13]. For this reason, our inclusion criteria were two-stage reimplantation without reinfection, good condition of the soft tissue, and the absence of large bone defects (only AORI type 1 and 2A). The adherence of our study to these criteria allowed performing an objective comparative analysis of the functional outcomes.

The mobility of the operated knee between the steps allowed preservation of the soft tissue envelope elasticity. In three and six months after revision TKA, this results in rapid recovery of the knee function which reflects on the KSS and EQ-5D scores.

The main limitation of our study was the inability to comply the optimal interval between stages of surgical treatment.

Conclusion

The main advantage of using articulating spacers for the first step of two-stage reimplantation in patients with PJI is the effective eradication of the infection. In addition, their ability to maintain mobility and support of the operated limb between the steps of the surgery improves the outcome of the revision TKA. This greatly benefits the QOL shortly after the spacer implantation with its further improvement during the first six months after the second step. A year after surgery, a less traumatic revision TKA with the use of articulating spacer leads to a better range of motion in the operated knee. These advantages far outweigh the negatives of the common inability to comply with the recommended intervals between the steps which are associated with the high medical care costs.

Compliance with ethical standards

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

Ethical approval All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

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