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The economic impact of two-stage knee arthroplasty revisions: a projection for a specialized health center in Türkiye

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ABSTRACT

Objectives: The increase in the number of arthroplasty surgeries worldwide also leads to an increase in revision surgeries. This study examines the costs of primary and revision arthroplasty treatments in a tertiary university hospital's orthopedics and traumatology clinic. It also explores the impact of revision surgeries on the healthcare system.

Methods: Seventy-six patients who had total knee arthroplasty at a university hospital between 01.01.2017 and 30.09.2022 were included in the study. The patients were divided into three groups: primary (n=25), aseptic reasons one-stage revision (n=27), and septic reasons two-stage revisions (n=24). For each patient included in the study, detailed documents regarding medical supplies, anesthesia, operating room, intensive care, consultation, medicine/serum, medical treatment, laboratory, blood and blood products, microbiology, radiology, food, bed, and attendant fees were provided separately by the hospital purchasing and statistics departments.

Results: When comparing the costs of primary, one-stage revision, and two-stage revision surgeries, the average costs were 5689 Turkish Lira (₺), 8294.97 ₺, and 40919.67 ₺, respectively. In patients with septic reasons, the group that underwent two-stage revisions had significantly higher costs than the aseptic group in terms of surgery time, hospital stay duration, medication, treatment, surgery, anesthesia, intensive care, laboratory tests, imaging, blood center services, consultations, visits, meal expenses, and invoiced amount (P<0.001).

Conclusion: Preventing and treating periprosthetic infections is costly and challenging. We need more research to develop effective protocols and reduce costs. As the number of patients undergoing knee arthroplasty is expected to rise, healthcare systems must ensure the sustainability of public financial resources, especially in public university hospitals.

Keywords: Arthroplasty, knee replacement, revision, cost analysis, hospital economics

Osteoarthritis continues to be an essential public health problem worldwide [1]. Due to the population's increasing age and expectations from daily life, the number of prosthetic joint replacement operations is increasing daily. Since the demand for joint arthroplasty is expected to increase significantly

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in the coming years, it is natural to expect that the number of knee revisions and the economic burden of prosthetic infections will increase over the years [2]. In a study conducted in Germany, the number of geriatric patients is expected to increase in the coming years, and the use of orthopedic implants will increase rapidly. The same study predicted that the incidence of total knee arthroplasty (TKA) operations would increase by 43%, and a total of 225,957 TKA procedures will be applied in 2050. In addition, it is predicted that annual TKA revision operations will increase rapidly by 90% [3].

The increase in the elderly group and the number of applied prostheses increase the number of implant failures. The most common causes of implant failure and need for revision are instability, mechanical loosening, incorrect prosthesis positioning, dislocation, polyethylene wear, periprosthetic fractures, and infection [4]. Periprosthetic infection is a very devastating complication that increases the time and cost of treatment. The infection rate in knee arthroplasty ranges from 0,4% to 2% in primary total knee replacement and 5,6% in revisions [5]. Prosthetic joint infections (PJIs) have increased, as is obvious, and we anticipate that this trend will continue as more primary joints are replaced.

Two-stage revision is the most commonly used treatment method worldwide in treating infected hip and knee arthroplasty [6]. In the first stage, the infected prosthesis is removed. The local antibiotic release aims to fill the formed space with antibiotic bone cement (spacer). At the same time, systemic infection control is tried to be achieved with intravenous (IV) antibiotics. After infection control is ensured with antibiotics lasting an average of 4 months (2-6 months), the spacer is removed, and the final treatment is implant placement. During all this time, patients undergo a very costly treatment process, considering prolonged hospitalizations, long-term drug treatments, and at least two operations.

Parallel to the increasing number of arthroplasty cases, revision due to aseptic loosening and two-stage revision cases due to periprosthetic infection are also increasing. The cost of managing knee revisions is expected to increase as an issue for patients, physicians, and healthcare institutions [7]. Recent research on this subject is limited because the stated costs are estimated costs. Readmissions, prolonged hospital stays, long-term medication use, and prolonged post-operative rehabilitation times account for many of these high costs. However, more evidence-based information is needed to support these measurements [8]. Existing studies have limitations because they either report estimates rather than actual costs, provide no comparison group (such as cases of non-infected primary total knee arthroplasty), or sum up all orthopedic surgery cases rather than report on specific procedures [9-11]. Furthermore, many of these studies needed to analyze the factors contributing to higher costs beyond repeated operations.

This study compared primary arthroplasty operations, revision operations due to aseptic loosening, and two-stage revision procedures due to periprosthetic infection. Our main aim is to determine the costs of certain services such as pharmaceutical services (inpatient and outpatient treatment), medical and surgical supplies, anesthesia services, diagnostic and radiographic evaluations, operating room services, laboratory costs, blood products, and consultation services in these groups.

METHODS

This study was conducted at a single specialized tertiary care center between January 1, 2017, and December 31, 2022. Patient medical records and infection monitoring database were reviewed for 524 patients who underwent total knee arthroplasty in our institution. The patients were followed for one year from the first surgery date. Institutional review board approval was obtained to analyze patient records and data from the current study (approval number: E-15374210-010.06.99-349814).

A total of 76 patients were included in the study and were divided into three separate groups. In the first group, with the help of a computer-generated program, a study group of 25 primary total knee arthroplasty with no infection matched in terms of type of surgical procedure, date of surgery, age, and gender parameters was formed. In the second group, 27 patients who underwent revision surgery due to radiological aseptic loosening in Ewald and did not develop complications in their follow-up were included. Aseptic loosening criteria, as stated in Ewald, 1) radiolucent lines <2 mm regardless of their localization and progression, 2) the

presence of radiolucent lines reaching the tibial plateau surface, 3) radiolucent lines in the tibial zone 5-6-7, 4) progressive radiolucent lines are has been accepted [12]. The third group consisted of 24 patients who had only deep or joint cavity infections and needed a two-stage revision following their primary procedure. A new definition of PJI has recently been proposed by the European Bone and Joint Infection Society (EBJIS) [13]. Based on this definition, only deep infections characterized by extension into the joint space or deep fascial layers were included in the study. This group did not include patients who underwent debridement and washing due to early postoperative infection and superficial infections. There were no deaths for all three cohorts in our study.

Post-operative care is standard for all patients and includes post-operative dressing with iodine solution at intervals of 48 hours, pain control, empirical antibiotic therapy, use of pharmaceutical agents for anti-embolic prosody, and physical therapy and rehabilitation studies.

The detailed documents of the operation costs, anesthesia, and operating room costs, consultation costs, pharmaceutical agents costs, laboratory costs, blood center expenses, microbiology expenses, radiology expenses, and bed and attendant fees of the patients included in the study were obtained from the purchasing and statistics department of our hospital. Operating room costs include implants, intravenous solutions, surgical supplies, and post-operative recovery. Fees are charged to the laboratory for biochemistry, hematology, urology, immunology, microbiology, and histological specimen processing. Radiology costs include x-rays, ultrasound, computed tomography, and magnetic resonance imaging scans. The consultation fees obtained in this study include those from pulmonology, cardiology, and other internal branches in inpatient and outpatient settings.

Statistical Analysis

Microsoft Excel spreadsheet program (Version 2013, Microsoft Corporation) was used for data collection, comparison, and calculations. Statistical analysis of the study's data was performed using the SPSS for Windows 23.0 program (SPSS Inc). The mean, standard deviation, median lowest, highest, frequency, and ratio values were used in the descriptive statistics. The distribution of the variables was measured using the Kolmogorov-Smirnov test. In the comparison of two independent groups showing normal distribution, two Independent t-tests were performed, and One-way Analysis of Variance (One-Way ANOVA) was used to compare more than two groups. The Kruskal–Wallis H test was performed to investigate differences between more than two independent groups that did not conform to normal distribution. When there was a difference between the groups, to determine from which group or groups this difference originated, the Mann–Whitney U test was used to compare the two groups. The chi-squared test was used for categorical variables. Statistical significance was set at a P-value of less than 0.05.

RESULTS

Out of the 76 patients, 60.5% were female and 39.5% were men. The mean age was 65.5±16 years. While 7 (28%) of 25 patients who underwent primary arthroplasty were smoking, 6 (22.2%) of 27 patients who underwent one-stage revision were smokers. Of the 24 patients who underwent two-stage revision, 8 (33.3%) were smokers. There was no statistical difference between the groups (P=0.78).

The age and sex distribution did not differ significantly in the aseptic and septic groups (P>0.05) (Table 1). In the septic group, length of stay, surgery time, service expenses, drug, laboratory, radiology, operation-anesthesia, blood and blood product, consulting, intensive care, and policlinic expenses were significantly higher than the aseptic group (P<0.001) (Table 2).

The median hospital stay was 21 (min 2 and max 42) days in the group that underwent two-stage revision surgery due to periprosthetic knee infection, and this duration was significantly higher than 3.5 days (between 2-8 days) in the group that underwent primary total knee arthroplasty (P<0.001).

The mean number of readmissions in the two-stage knee revision group was 5.6 (range, 2 to 9), the mean was 2.4 in the single-stage knee revision group (range, 2 to 4), and the mean in the primary total knee arthroplasty group was 0.12 (range, 0 to 2) (P<0.001).

When the hospitalization and service fees of the patients in the groups were compared, it was found that the average of 112.39 Turkish Lira (₺) in the primary arthroplasty group, 222.15 ₺ in the patients who

Table 1. Descriptive characteristics of the data

Characteristisc	Data	
Age (years)	65±16	58 (40-81)
Gender		
Female	46 (60%)	
Male	30 (40%)	
Cigarette		
Use	16 (21%)	
Not Use	60 (79%)	
Length of stay (days)	23±19	21 (3-42)
Surgery time (min)	209.34±86.42	150 (90-300)
Service expenses	1889±1258	350 (78-12150)
Drug expenditures	1841±313	1370 (88.9-2876)
Laboratory expenses	258.54±205	124 (32-530)
Radiology expenses	90.2±45.4	98 (39.99-156)
Operation, anesthesia expenses	19045.74±12012	18622 (3650-32678.88)
Blood and blood product expenses	1653.54±1664	461 (14-3745.8)
Consulting expenses	261.75±260	42 (0-580.99)
Intensive care	414.78±367	420 (0-780)
Policlinic	148.88±93.14	111 (30-286)
Total	23452±16154	20008 (4799-43308.73)

Data are shown as mean±standard deviation or median (minimum-maximum). Expenditure amounts are stated in **TL(₺)**.

underwent one-stage revision, and 1027.04 ₺ in the patients who underwent two-stage revision (Fig. 1). In the statistical study, it was found to be significant between the groups (P<0.001). The cost difference is thought to be high due to the extended stay in the service and the large number of medical supplies used in patients who underwent two-stage revision.

When the operation and operating room expenses of the patients were compared, it was found that the average of the patients who underwent primary arthroplasty was 5583.21 ₺, and the patients who underwent one-stage revision were 13301.30 ₺. In comparison, the average of the patients who underwent two-stage revision was 31592.44 ₺ (Fig. 1). A statistically sig-

Table 2. Comparison of primary, aseptic reasons, one-stage revision and septic reasons, two-stage revisions knee arthroplasty data

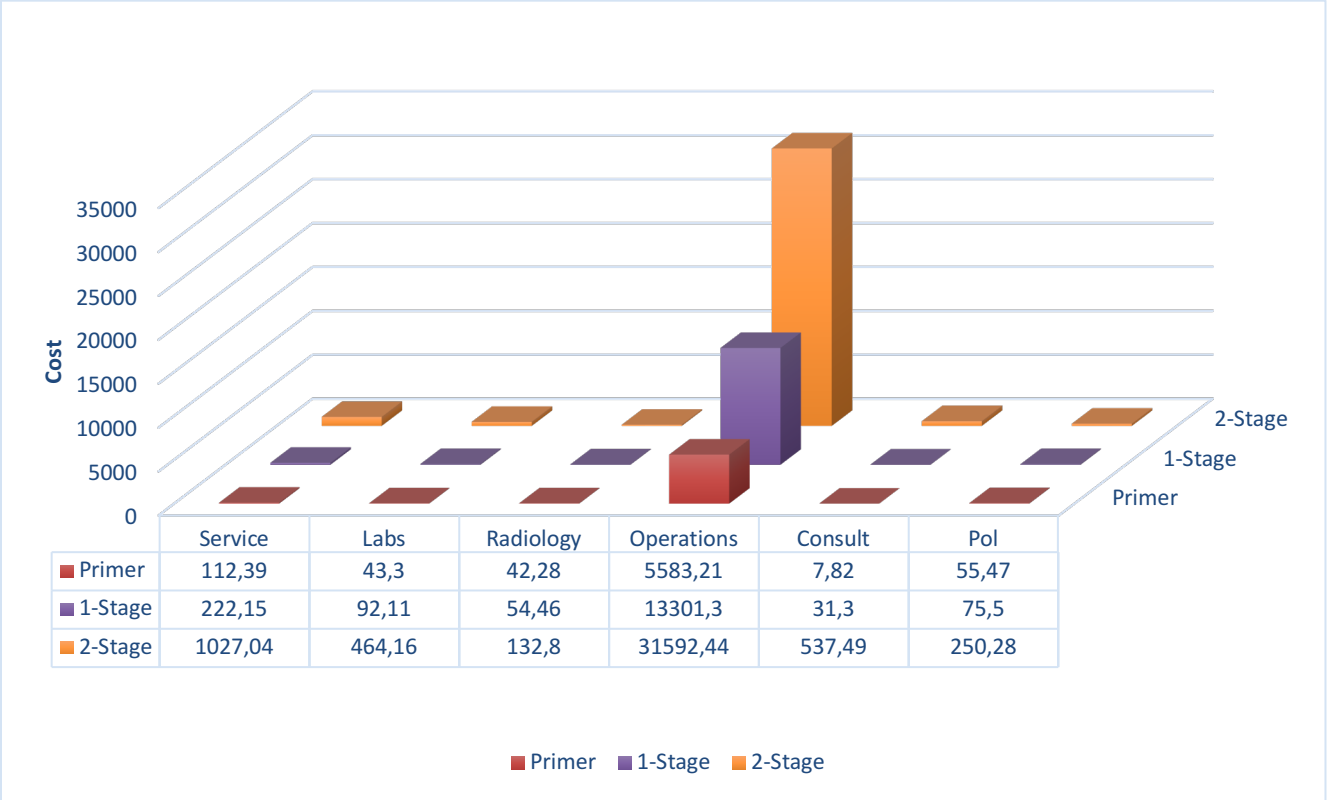
	Primary	Aseptic reasons, one-stage revision	Septic reasons, two-stage revisions	P value
Length of stay (days)	3 (2-4)	6 (3-7)	27 (18-49)	**<0.001**
Surgery time (min)	90 (75-120)	150 (120-180)	270 (180-320)	**<0.001**
Service expenses	98.98 (78-176)	135.56 (78-350)	1051.31 (467-1210)	**<0.001**
Drug expenditures	168 (88.9-189)	189 (88.9-3410)	2987.33 (1987-3865)	**<0.001**
Laboratory expenses	42 (32-56)	46 (32-245)	496 (126-530.79)	**<0.001**
Radiology expenses	38 (32-46)	40.12 (39.99-150)	135 (110-156)	**<0.001**
Operation, anesthesia expenses	3890 (3650-4980)	6120 (3650-19769)	31864 (18111-32678)	**<0.001**
Blood and blood product expenses	14 (14-28)	103 (14-464)	3354.78 (230-3745)	**<0.001**
Consulting expenses	12 (0-48)	19.37 (0-68)	510 (42-580.99)	**<0.001**
Intensive care expenses	0	89.36 (0-420)	780 (0-780)	**<0.001**
Policlinic expenses	49 (30-67)	66.82 (30-131)	216 (49-286)	**<0.001**
Total	5689 (4799-8294)	8294.97 (4799-21174)	40919.67 (19362-43308)	**<0.001**

Data are shown as median (minimum-maximum). Expenditure amounts are stated in **TL(₺)**.

nificant difference exists between the groups (P<0.001). The fact that patients who underwent two-stage revision underwent multiple operations and the cost of the revision implants used confirms this difference.

When the pharmacological costs were compared, the mean of the primary arthroplasty group was 141.66 ₺, and the mean of the patients who underwent one-stage revision was 389.17 ₺. The mean of the patients who underwent two-stage revision was 2964.79 ₺ (Fig. 2). These data were found significant when compared (P<0.001). The high cost of pharmacological agents in two-stage revisions can be attributed to the fact that they received both prophylactic and agent-specific antibiotics during the hospitalization, the lengthening of the hospitalization period, and the increase in the agents used due to additional patients.

When the blood products of the patients were added up, it was found that the average of patients who underwent primary arthroplasty was 34.17 ₺. In comparison, it was 182.96 ₺ for the patients who underwent one-stage revision and 3430.19 ₺ for those who underwent two-stage revision (Fig. 2). A significant statistical difference was found between the groups (P<0.001). The fact that the cost of blood products of patients who underwent two-stage revision is relatively high indicates that the need for blood product transfusion is high in preparation for the operation, during and after the operation.



	Service	Labs	Radiology	Operations	Consult	Pol
Primer	112,39	43,3	42,28	5583,21	7,82	55,47
1-Stage	222,15	92,11	54,46	13301,3	31,3	75,5
2-Stage	1027,04	464,16	132,8	31592,44	537,49	250,28

Fig. 1. **Distribution of significant expenditure items among groups. Expenditure amounts are stated in TL(₺).**

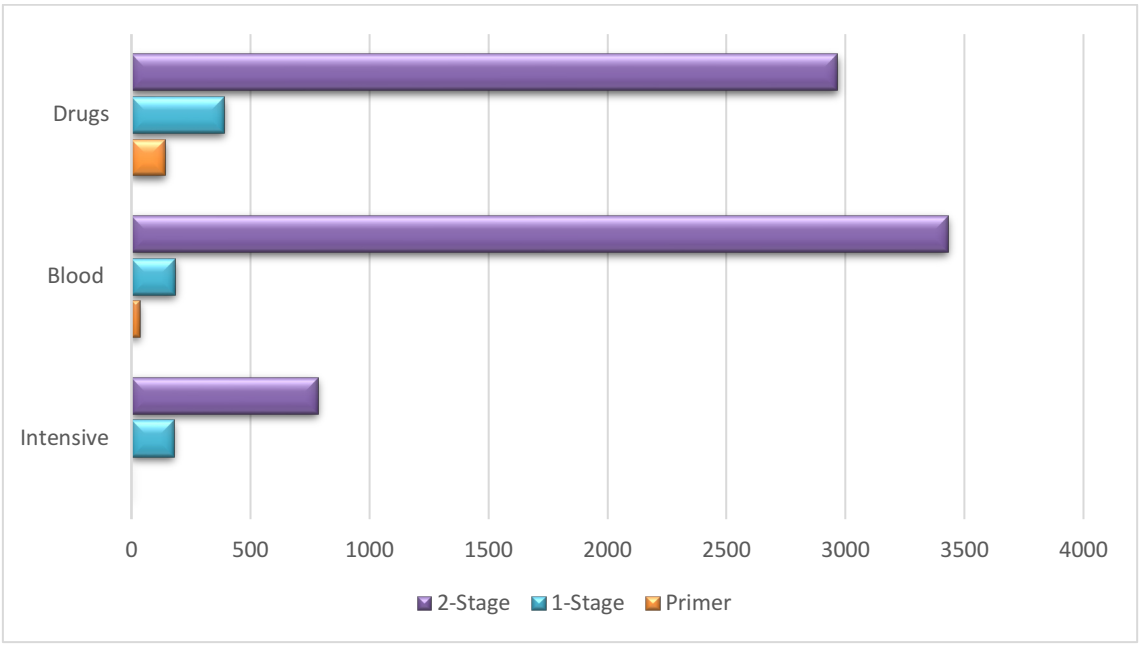


Fig. 2. **Comparison of intensive care-blood products-drug cost between groups.**

When the intensive care unit expenses of the patients were added up, it was seen that the patients who underwent primary arthroplasty did not need intensive care. While the mean of patients who underwent one-stage revision was 177.69 ₺, it was found to be 780.00 ₺ for patients who underwent two-stage revision (Fig. 2). When the data were compared, it was found to be statistically significant, and it was found that the cost of intensive care increased due to the increase in the number of operations and revision operations being more complex and taking longer (P<0.001).

DISCUSSION

As a result of advancing technological opportunities and increasing comfort expectations, the number of hospital applications and operations is rising daily. As a result of the increase in the elderly population, orthopedic prosthesis operations are increasing not only in our country but also worldwide. As a result of the increase in primary arthroplasty operations, revision operations are also increasing in parallel [14-16]. At the same time, the incidence of periprosthetic knee infections is increasing [10]. Managing these infections often requires two-stage revision procedures, which can cost more than mechanical failure and/or aseptic loosening revisions [17].

In our study, we aimed to reveal the cost items of primary arthroplasty and revision operations and to draw attention to the burden on the health system. Two-stage revision costs due to periprosthetic infection were observed to triple the costs of revision procedures due to aseptic loosening. In these infections, the increasing resistance of microorganisms and the ineffectiveness of antibiotic treatments are blamed. For this reason, the doses of antibiotics are increased, and the duration of use is prolonged. Patients require long-term hospitalization, and in some cases, additional operations may be necessary. Therefore, the prevention of periprosthetic infections is essential for reducing health expenditures.

The results of our study were similar to previous studies evaluating the economic impact of surgical site infections following total knee joint arthroplasty [17-20]. Kapadia *et al*., mean episode cost, length of hospital stay, and median readmissions were significantly higher in the infected group compared to the matched cohort: $88,623 to $25,659, 7.6 to 3.29 days, and 2 to 0. Periprosthetic care after TKA was approximately the cost of the episode. It was caused by a 3-fold, 2-fold increase in the average length of hospital stay and an increase in the median readmission time [20]. Periprosthetic infections following TKA represent a tremendous economic burden for tertiary-care centers and patients [19].

It has been observed in the literature that when it comes to septic-based revision surgery, the cost of blood products and drugs is significantly higher during inpatient treatment [21]. A cost analysis of septic total knee revision surgeries should include all costs covered by the hospital, including two separate hospitalizations for the two-stage revision and personnel costs [22]. This study is important because it takes into account all costs incurred during inpatient treatment covered by the hospital, including hospitalization duration, medication, treatment, surgery, anesthesia, laboratory tests, imaging, blood center services, consultation, visits, meal costs, total costs, and billing expenses. The study found that the costs incurred in the septic group were significantly higher than the aseptic group (P<0.001).

Minimizing the number of revisions per patient is crucial in reducing the overall cost burden of revision. This can be achieved by adopting a comprehensive approach that includes optimal patient selection, prosthesis selection, and procedure selection for primary TKA [23, 24]. Careful evaluation of patient characteristics, such as age, weight, and comorbidities, is necessary to select the most appropriate prosthesis and procedure. In addition to these measures, reducing the number of primary TKA surgeries can be achieved through effective non-operative knee osteoarthritis management. This may include weight management programs to combat obesity, exercise programs to improve joint flexibility and strength, and lifestyle changes to reduce the risk of joint injury. By implementing these strategies, the incidence of revision surgeries can be reduced, and the overall cost burden of TKA can be minimized.

The financial burden of septic revision TKA with re-revision can be significantly higher, up to 2.5 times, compared to septic revision alone. Similarly, it can be up to 4 times higher than aseptic revision when re-revision is not required. However, cost savings can be realized by minimizing the occurrence of primary

TKA that develop PJI, avoiding re-revisions for PJI, and shortening the length of hospitalization following revision surgery [25].

Limitations

This study has some limitations. Differences in patients' socioeconomic status may have introduced confounding factors among cohorts, leading to an over- or underestimation of inconsistencies in costs, number of readmissions, and length of hospitalization. However, to minimize any potential bias, patients were selected into groups and matched with the help of a computer-aided program according to the type of surgical procedure, date of surgery, age, and gender parameters. Other limitations are the short follow-up period, the small number of subjects, and the study's retrospective nature. Longer follow-up, larger sample sizes, and prospective multicenter studies are needed to analyze this patient population better. In light of the COVID pandemic, many countries, including Turkey, have been experiencing economic difficulties. It has been observed that the costs of many healthcare practices, materials and revision knee arthroplasty have increased over the years [26, 27]. However, it is important to note that the study conducted had a limitation in terms of fair cost distribution between groups based on the number of years, as it was a direct cost comparison study. Due to these limitations, the real economic and personal impact seen in the cohort undergoing two-stage revision surgery may be more significant than it is.

CONCLUSION

Preventing and treating periprosthetic infections is costly and challenging. We need more research to develop effective protocols and reduce costs. As the number of patients undergoing knee arthroplasty is expected to rise, healthcare systems must ensure the sustainability of public financial resources, especially in public university hospitals.

Ethics approval

This retrospective study was conducted with the approval of the Ondokuz Mayıs University clinical research ethics committee (approval number: E-15374210-010.06.99-349814). Institutional Review Board approval and informed consent of the patients were obtained.

The institution where the study was carried out

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Authors' Contribution

Study Conception: AY, FS; Study Design: AY; Supervision: FS; Funding: N/A; Materials: AE, CŞŞ; Data Collection and/or Processing: AY, AE, CŞŞ; Statistical Analysis and/or Data Interpretation: AY, AE, CŞŞ; Literature Review: AY, AE; Manuscript Preparation: AY, AE, CŞŞ and Critical Review: AY, AE, FS.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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