

Research Article

A retrospective comparison of costs for the primary and revision total knee arthroplasty in Turkey

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ABSTRACT

Objective: This study aimed to compare the cost profiles of patients who underwent a primary or revision total knee arthroplasty (TKA) and to determine the effects of the length of hospital stay, comorbidities, and septic and aseptic revision rates on the treatment costs.

Methods: A total of 1,487 patients who underwent primary (n=1,328; 1,131 females, 197 males) or revision TKA (n=159; 137 females, 22 males) between 2010 and 2017 at our institution were retrospectively included in the current study. The patients' demographics (age and gender), the length of hospital stay, comorbidities, and septic and aseptic revision rates were collected from our hospital database. The total costs of revision and primary TKAs were calculated based on the prostheses and surgical equipment used, hospital stay, and other administrative costs in both the Turkish lira (TRY) and US dollar (USD) based on the parity of the 2 currencies from 2010 to 2017.

Results: The average cost per patient for primary TKAs was 7,985±2,927 TRY (5,265 USD) in 2010 and 7,070±1,775 TRY (1,852 USD) in 2017. The average cost for revision TKAs was 13,647±4,095 TRY (8,999 USD) in 2010 and 22,806±6,155 TRY (5,973 USD) in 2017. In terms of the total costs, significant differences existed over the years, with a significantly higher difference in 2015 compared with that from 2010 to 2013 (p<0.001); however, no difference was determined among the age groups (p=0.675). The difference between the total costs of the septic (n=34; 17,964±13,028 TRY) and aseptic revisions (n=125; 23,377±12,815 TRY) was significant (p=0.001), with a higher cost for patients with septic TKAs but with no significant difference between the total costs for the patients with and without comorbidities (p=0.254). Additionally, the length of hospital stay was 2 times higher in patients with revision TKAs than in those with primary TKAs (12.3 vs 6.2 days).

Conclusion: Revision TKAs cause higher costs than primary TKAs, with a prolonged hospital stay. The septic background seems to be an independent predictive factor for increased costs in revision TKAs.

Introduction

The number of individuals who undergo total knee arthroplasty (TKA) has increased with the increasing life span and high the elderly population (1). In recent years, the number of revision TKAs has increased owing to the increase in the number of patients undergoing primary TKA (2, 3). The causes that require revision are generally divided into aseptic and septic, which are important factors in cost-effectiveness (4).

Revision knee arthroplasties have higher complication rates and worse functional outcomes compared with primary arthroplasties (5). Although revision knee arthroplasty carries a relatively higher risk for the patient, it presents a higher cost profile, with significant consumption of the hospital resources in comparison with primary knee arthroplasty (6). Revision knee arthroplasties require a longer surgical time, more expensive implants, and longer hospital stays towing to high complication rates and increased morbidity. All these factors lead to increased costs and an increased burden on resources for revision knee arthroplasty (7).

In this study, we aimed to compare the cost profiles of the patients who underwent primary and revision

knee arthroplasties, and to evaluate the effect of the length of the hospital stay, additional diseases, and septic and aseptic revision rates on the cost. We asserted that the revision and primary TKAs are less costly in Turkey than in other countries.

Materials and Methods

Patients who were registered with the Social Security Institution code numbers, 612440 (revision knee arthroplasty) and 612420 (TKA), between 2010 and 2017, were identified from the database of our hospital and their bills were retrieved from the billing unit of the hospital. Consequently, 1,328 patients (1,131 females, 197 males) were found to have undergone primary TKA and 159 patients (137 females, 22 males) revision TKA. The demographic information (age, gender), comorbidities (diabetes, hypertension, chronic obstructive pulmonary disease, congestive heart failure, chronic kidney disease, and neurological disease), and the number of surgical operations and hospitalization of the patients were also retrieved from the hospital's database. The septic patients had been treated by two-stage reimplantation, whereas the aseptic and primary TKA patients had been treated by one-stage reimplantation. No patella resurfacing was

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observed. The patients who underwent primary TKAs were treated with the VANGUARD® Complete Knee System (Zimmer Biomet, Warsaw, IN, USA), GENESIS II Total Knee System (Smith & Nephew plc., London, UK) or SIGMA® Total Knee System DePuy Synthes, Raynham, MA, USA). Patients who underwent revision TKAs were treated with the LEGION™ Revision Knee System Smith & Nephew plc. 1450 Brooks Road Memphis, USA), (VANGUARD® 360 Revision Knee System Zimmer Biomet, Warsaw, Indiana 46581-0587 USA) or the (LINK® Endo-Model® knee prosthesis Waldemar LINK GmbH & Co. KG, Hamburg, Germany). The total cost of all hospitalizations and surgeries were calculated during the cost analysis. The costs of revision and primary TKAs were calculated based on the actual/observed surgical equipment used, costs of the hospital stay, and other administrative costs. The costs were measured both in Turkish Liras (TRY) and US dollars (USD) based on the parity of the 2 currencies from the year 2010 to 2017. All the surgeries were performed and followed up by a single surgeon (K.B.) who had over 15 years of experience.

Statistical analysis

The research data were uploaded and evaluated via the Statistical Package for Social Sciences for Windows, version 22.0 software (IBM SPSS Corp.; Armonk, NY, USA). The descriptive statistics have been presented as mean±standard deviation, median (minimum–maximum), frequency distribution, and percentages. The normality of the distribution of the variables was examined using the visual (histogram and probability graphs) and analytical methods (the Kolmogorov-Smirnov and Shapiro-Wilk tests). For the variables that did not exhibit normal distribution, the Mann-Whitney U and Kruskal-Wallis tests were used. When a significant difference was detected between 3 and more groups, Bonferroni correction was applied in post-hoc binary comparisons to find the source of the difference. The statistical significance level was accepted as $p < 0.05$.

Results

Of the 1,328 patients who underwent primary TKA, 93.91% were over 60 years of age, although this was the case for 81.3% of the 159 patients who underwent revision TKA.

Figures 1 and 2 show the age distribution of the patients who underwent revision and primary knee arthroplasties.

Both the patient groups, those who underwent primary TKA and those who underwent revision TKA, were mainly between the ages of 65 and 85. This finding confirms that the number of revisions TKAs increased with the increasing number of primary TKAs (Figure 1, 2).

The average cost for the patients who underwent primary TKA was $7,985 \pm 2,927$ TRY ($5,265 \pm 1,930$ USD) per case in 2010, whereas the cost was $7,070 \pm 1,775$ TRY ($1,852 \pm 485$ USD) in 2017. The decrease

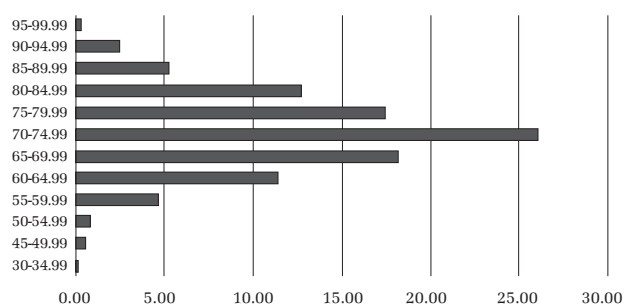


Figure 1. Age distribution of primary total knee arthroplasty patients

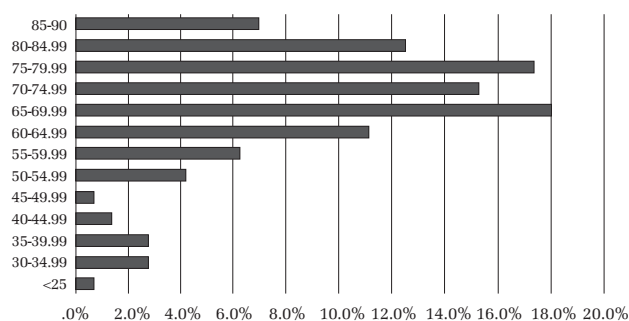


Figure 2. Age distribution of revision total knee arthroplasty patients

in the cost of primary TKA through years is related to the fact that the price of the prostheses used in our country has not changed and the prices of the other healthcare products have slightly decreased over these years. However, the average cost for the patients who underwent revision TKA was $13,647 \pm 4,093$ TRY ($8,999 \pm 2,699$ USD) per case in 2010, whereas the cost was $22,806 \pm 6,155$ TRY ($5,973 \pm 1,612$ USD) in 2017. The above numbers include the total cost of surgery, prostheses, medication, hospitalization, and other administrative services. The decrease in the average USD value of the total cost over the years was because of the USD/TRY parity (Table 1).

There was a statistically significant difference between the years in terms of the total cost ($p < 0.001$). The post-hoc binary comparisons demonstrated a significantly higher difference in the year 2015 as compared with the years 2010, 2011, 2012, and 2013 in terms of the total cost (Table 2).

The average cost was $22,370 \pm 22,368$ TRY for those under 60 years of age, $18,033 \pm 12,608$ TRY for the ages between 60 and 64, $17,471 \pm 5,359$ TRY for the ages between 65 and 69, $19,788 \pm 9,042$ TRY for the ages between 70 and 74, $19,023 \pm 7,538$ TRY for the ages between 75 and 79, and $16,198 \pm 8,082$ TRY for those 80 years and above. There was no statistically significant difference among the age groups in terms of the total cost ($p = 0.675$) (Table 3).

The direct comparison of the aseptic revision TKA ($n = 125$; $23,377 \pm 12,815$ TRY) with septic revisions ($n = 34$; $17,964 \pm 13,028$ TRY) confirms that the septic procedure is costlier than the aseptic one ($p < 0.01$). However, no statistically significant difference in terms of the total cost was observed between the external clinics ($n = 119$; $18,984 \pm 13,127$ TRY) and ours ($n = 40$; $19,530 \pm 13,306$ TRY), and between the patients who had no comorbidities ($n = 23$; $16,062 \pm 6,657$ TRY) or those who had comorbidities ($n = 136$; $19,639 \pm 13,884$ TRY) ($p = 0.874$ and $p = 0.254$, respectively) (Table 4).

HIGHLIGHTS

- This study offers an insight into the current status of the primary and revision total knee arthroplasty in Turkey, and its projection results can be useful for future planning of budget and resources.
- Clinicians may utilize this information to guide treatment recommendations and provide more accurate preoperative patient counseling and medical optimization.
- Similarly, administrators and payors may use this information to adjust reimbursement according to risk and costs.

Table 1. Average cost per patient for the primary and revision knee arthroplasties

Arthroplasty	Currency	2010	2011	2012	2013	2014	2015	2016	2017
Primary TKA	TRY	7.985	7.187	6.955	6.322	6.214	6.817	6.766	7.070
	USD	5.265	3.632	3.650	3.272	2.754	2.588	2.070	1.852
Revision TKA	TRY	13.647	15.982	16.738	18.030	19.091	21.037	20.385	22.806
	USD	8.999	8.077	8.784	9.332	8.461	7.986	6.235	5.973

TKA: total knee arthroplasty

Table 2. Distribution of the total cost of the primary and revision TKAs by years

Year	n	Total cost in TRY		p
		Mean±SD	Median (min-max)	
2010*	7	13.647±14.435	9.852 (2.335-44.856)	<0.001
2011*	19	15.982±11.577	11.230 (1.022-50.670)	
2012*	16	16.738±9.197	12.450 (9.585-44.629)	
2013*	21	18.030±23.003	13.072 (2.568-116.443)	
2014	26	19.091±14.007	13.845 (2.142-74.982)	
2015	24	21.037±6.110	21.652 (11.970-41.738)	
2016	23	20.385±6.100	21.109 (8.580-34.022)	
2017	23	22.806±13.820	21.604 (7.512-62.762)	
Total	159	19.121±13.132	15.329 (1.022-116.443)	

*Post-hoc binary comparison showed a statistically significant difference in the year 2015
SD: standard deviation

Table 3. Distribution of the total cost of revision TKAs by age groups

Age group, years	n	Total cost in TRY		p*
		Mean±SD	Median (min-max)	
<60	35	22.370±22.368	13.467 (1.022-116.443)	
60-64	31	18.033±12.608	13.201 (2.335-74.982)	
65-69	31	17.471±5.359	18.229 (9.608-28.709)	0.675
70-74	22	19.788±9.042	19.765 (10.225-44.629)	
75-79	26	19.023±7.538	18.776 (10.214-37.543)	
≥80	14	16.198±8.082	14.047 (7.523-40.898)	
Total	159	19.121±13.132	15.329 (1.022-116.443)	

*Kruskal-Wallis test
SD: standard deviation

Table 4. Comparison of the total costs for the revision TKAs according to the septic/aseptic revision, primary surgery center, and additional diseases

Parameter	N	Total cost in TRY		p*
		Mean±SD	Median (min-max)	
Septic	34	23.377±12.815	22.490 (9.585-74.982)	0.001
Aseptic	125	17.964±13.028	13.494 (1.022-116.443)	
First operation at external clinic	119	18.984±13.127	15.076 (2.335-116.443)	0.874
First operation at our clinic	40	19.530±13.306	18.361 (1.022-74.982)	
No comorbidity	23	16.062±6.657	12.583 (2.335-29.045)	0.254
Have comorbidity	136	19.639±13.884	15.469 (1.022-116.443)	

*Mann-Whitney U Test
SD: standard deviation

According to its projections for the years 2013-2075, the Turkish Statistical Institute predicts a growth rate of 44.14% by 2025 and 261.6% by 2050 in the Turkish population (8). This suggests that the number of primary and revision TKAs will also increase with the increasing number of elderly individuals. According to this projection, it is estimated that 12,441,112 people (14.7% of the population) will be over the age of 60 years in 2025. According to year 2050 predictions, 26,551,288 people (28.4% of the population) will be over 60 (8).

In 2010, Ceyhan et al. reported the number of revision TKAs in Turkey as 1,079 (9). Since then, the cost of primary TKAs had increased by an average of about 8% every year until 2017. In Scenario 1, if we project that the trend will continue from 2017 to 2025 with an annual increase of 10%, the number of revision TKAs in Turkey will reach

13,421 by the year 2025 (Table 5). Accordingly, the average cost of 13,647 TRY per patient in 2010 is expected to be 48,888 TRY in 2025 (Table 5). In case we predict a 15% increase in the number of patients undergoing revision knee arthroplasty (Scenario 2), it is expected that the number of patients will be 19,153 and the average cost per patient will be 69,766 TRY in 2025. In Scenario 3, a 20% increase is projected annually until 2025; thus, the number of patients is expected to be 26,921, with an average cost of 98,064 TRY per patient.

In 2010, Ceyhan et al. reported the total number of primary TKAs in Turkey as 38,247 (9). Since then the number of primary TKAs had increased by an average of 14% every year until 2017. According to Scenario 4, if we project that the rate will continue from 2017 to 2025 with an annual increase of 10%, the number of primary TKAs in Turkey will reach 202,589 by the year 2025 (Table 6). Accordingly, the average cost of 7,985 TRY per patient in 2010 is expected to be 15.155 TRY in 2025 (Table 6). In case we predict a 15% increase in the number of patients undergoing primary knee arthroplasty (Scenario 5), it is expected that the number of patients will be 211,798 and the average cost per patient will be 21.627 TRY in 2025. In Scenario 6, a 20% increase is projected; thus, the number of patients is expected to be 406,373, with an average cost of 30.399 TRY per patient in 2025.

The above tables may give an idea about the burden of the revision and primary arthroplasty surgeries on the economy of Turkey.

Discussion

The incidence of TKA is increasing in the United States and is expected to reach 3.48 million in 2030 from 500,000 in 2005 (10). The US Census, National Health Expenditures, and National Inpatient Sample data show that the need for surgery increased by 6.1% in 2009 and 13.5% in 2010, independent of the economic crisis (11). Despite the advances in the surgical techniques and component designs, the number of revision TKAs in the United States continues to increase and imposes a current burden of \$2.7 billion on the healthcare system (12). The increase in the cost of primary and revision TKAs is expected to exceed \$13 billion per year by 2030 (12, 13). In Turkey, the number of primary TKAs was 38,000 and the number of revision TKAs was 1,079 in 2010 (9), and the projected numbers for the year 2030 are 326,000 and 21,000, respectively. This projected cost will pose a great economic burden for our country.

The treatment costs per patient vary considerably according to different studies, countries, and success dates (14). Delanois et al. noted that revision knee arthroplasty had the highest cost with the femoral component revision (90.065 USD) and the lowest cost with the patellar component revision (42.916 USD), bringing the total average to \$75.028 (15). Bozic et al. showed that the average hospital cost for revision knee arthroplasty in 2005-2006 was 49.360 USD with the National Inpatient Sample database (16). In the 90s, the average total direct cost at the Durham Regional Hospital (North Carolina, USA) was 8.206 USD for infected TKAs and 5,492 for uninfected TKAs (17). In 2005, the direct hospital cost at the Jagiellonian University (Krakow, Poland) for infected TKAs reached 37.903 USD and the cost of anti-

Table 5. Scenario 1 projecting the number of revision TKAs and costs per patient in the coming years.

Scenario 1: Between the years 2010 and 2017, the cost of revision arthroplasties in Turkey had increased by an average of about 8% annually. In this scenario, we expect that the increase rate will be 10% until the year 2025

Year	Number of revision arthroplasties	Average cost per patient in TRY
2010	1.079	13.647
2011	1.421	15.982
2012	2.091	16.738
2013	2.455	18.030
2014	2.972	19.091
2015	3.208	21.037
2016	5.478	20.385
2017	6.261	22.806
2018	6.887	25.087
2019	7.576	27.596
2020	8.333	30.355
2021	9.167	33.391
2022	10.083	36.730
2023	11.092	40.403
2024	12.201	44.443
2025	13.421	48.888

Table 6. Scenario 4 projecting the number of primary TKAs and costs per patient in the coming years.

Scenario 4: Between the years 2010 and 2017, the cost of revision arthroplasties in Turkey had increased by an average of 14% annually. In this scenario, we expect that the increase in rate will be 10% until the year 2025.

Year	Number of primary arthroplasties	Average cost per patient in TRY
2010	38.247	7.985
2011	50.018	7.187
2012	59.471	6.955
2013	64.523	6.322
2014	70.991	6.214
2015	78.107	6.817
2016	85.918	6.766
2017	94.509	7.070
2018	103.960	7.777
2019	114.356	8.555
2020	125.792	9.410
2021	138.371	10.351
2022	152.208	11.386
2023	167.429	12.525
2024	184.172	13.777
2025	202.589	15.155

otic treatment was 11,067 USD (18). In the study by Elbuluk et al., the average cost for the two-component revision TKA was 11,142 USD and the cost for three-component revision TKA was 13,640 USD (19). Kallala et al. found that the average duration of hospital stay in case of infected revision TKA was twice that of the aseptic cases (21.5 vs 9.5 days) and the average cost was more than 3 times of an aseptic revision (30.011 vs 9.655 GBP) (20). In their study, Musil et al. found that the average cost of managing infection as a complication of TKA amounted to CZK 405.864 (21). The average cost of a two-stage revision was 497.487 CZK and the cost of a revision surgery with the original implant retention was 175.312 CZK (21). In another study from Norway, Bolognesi and Hofman showed that the cost per operation for the primary prostheses was 146,135 NOK based on the DRG rate 209A and 192,418 NOK for the revision prostheses based on the DRG rate 209B in 2011 (22). In our study, the average cost of the revision knee arthroplasty was 13,647 TRY (8.999 USD) in 2010 and 22,806

TRY (5,973 USD) in 2017. The mean cost of infected revision was significantly higher than that of aseptic revision. The duration of the hospital stay was approximately twice as high (11.4 vs 7.2 days) in the septic revision as compared with that in the aseptic revision.

Hustedt et al. showed that the average hospital cost for each surgical procedure was 17,464 USD for primary TKAs in 2.7 million cases (23). This study determined that the average cost in patients undergoing primary TKA was 7,985 TRY (5,265 USD) per case in 2010 and 7,070 TRY (1,852 USD) in 2017.

In another study, Kasch et al. compared the costs of aseptic revision TKA (n=71; 6,749 USD) with septic revisions (n=35; 12,224 USD) (24). Oduwole et al. reported a cost of 13,666 USD for aseptic and 20,816 USD for septic TKA revisions performed between 2002 and 2006 (6). In our study, the average cost of aseptic revision TKA was 23,377 TRY (6,136 USD) and 17,964 TRY (4,715 USD) for septic revision TKA (p<0.01).

Kilgus et al. showed that implant revisions were performed more often on younger patients than on the older patients (25). In our study, the rate of revision was higher at a younger age. We associated this with the activity level and the duration of implant use in young patients.

Lavernia et al. performed a cost analysis of 100 revision knee arthroplasty cases (26). Of them, 67 were revised because of aseptic loosening and 33 were revised because of infection. Approximately 75% of the 67 patients who underwent aseptic revision knee prosthesis were females with a mean age of 63.5 years and an average hospital stay of 6.6 days. The duration of the hospital stay was also higher in all cases with component changes. In our study, 34 of the 159 patients underwent revision TKA because of septic loosening and 125 because of aseptic loosening. The mean duration of hospital stay in those who underwent revision TKA was 2 times higher than the primary TKA patients (12.3 vs 6.2 days). We found that although diabetes mellitus, hypertension, and other comorbidities increased the cost, the difference was statistically insignificant.

Conducting the study at a single university hospital and the fact that our study population might not be representative of the other hospitals or centers performing the aseptic and septic knee revision surgeries because the prices for the materials (e.g., implants) and salary structures differ a lot between countries and healthcare systems, may be a limitation for our study. In addition, our cohort for revision TKAs was small. Another limitation was not including the cost of the antibiotics used after discharge in the septic patients to the cost as we only analyzed the direct costs that arose from performing the surgeries. For a comprehensive assessment related to the revision TKAs, future studies should analyze the cost of the outpatient clinics, postoperative care, and rehabilitation. However, the treatment and follow-up of all patients by the same surgeon is a strength of our study. In addition, we were able to perform a detailed cost analysis of the patient data retrieved from the hospital database.

In conclusion, the septic background is an independent predictive factor of the cost. Although the rate of revision TKA in young patients is higher than that in the elderly population, the increased number of primary TKAs in the elderly population is associated with the increased number of revision TKAs. The female patients were more prevalent in both the primary and revision TKAs. Revision arthroplasty requires twice the duration of stay than primary TKA. The average cost of revision TKA was found to be 3 times higher than the cost of primary TKA.

The increase in the elderly population as well as the increase in the number of primary and revision knee arthroplasties may pose significant cost to the national economy.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Ankara University.

Informed Consent: Informed consent was obtained from all the individual participants included in the study.

Author Contributions: Concept - E.G, M.S.B; Design - E.G, M.S.B; Supervision - E.G, M.S.B; Materials - E.G, K.B; Data Collection and/or Processing - E.G, M.S.B, K.B; Analysis and/or Interpretation - E.G, M.S.B; Literature Search - E.G, M.S.B; Writing Manuscript - E.G; Critical Review - E.G, M.S.B, K.B

Conflict of Interest: The authors have no conflicts of interest to declare.

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