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ORIGINAL ARTICLE / ARAŞTIRMA YAZISI

Orthopedics / Ortopedi

Tension Band Wiring of Patella Fractures: Mid-Term Radiological and Clinical Results

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ABSTRACT

Objective: To report our radiological and clinical results with a mid-term follow-up on patella fractures treated with tension band wiring (TBW).

Methods: Patients surgically treated with TBW for AO type 34-A1/C1/C2/C3 patella fractures between January 2013 and June 2021 at a level 1 trauma center were included. For radiological evaluation, radiographs obtained at the routine follow-up were analyzed for complications (such as nonunion, malunion, loss of reduction, malreduction, patella baja, elongated patella, implant failure), Insall-Salvati Index (ISI), and Patellar Morphology Ratio (PMR). The Knee Injury and Osteoarthritis Score (KOOS) was utilized for functional evaluation, which includes five subscales: pain, symptoms, activities of daily living (ADL), sports/recreation, and quality of life (QOL). The clinical assessment also included the range of motion (ROM), thigh circumference (TC), and complications such as implant irritation (II).

Results: This study reviewed 42 eligible patients (10 females, 32 males) with a mean age of 42.6 ± 16.1 years and a mean follow-up of 35.4 ± 24.1 months. There were 28 patients (66.7%) with at least one complication (II: 66.7%, flexion deficit: 61.9%, malunion: 40.5%, elongated patella/patella baja: 16.7%). The reoperation rate was high at 69.1% due to the high implant removal rate for II. There were statistically significant differences between injured (I) and uninjured contralateral healthy knees (UI) in terms of mean KOOS subscale scores (symptoms: I: 72.3, UI: 89.8; pain: I: 70.4, UI: 89.4; ADL : I: 72.1, UI: 90; sports: I: 61.4, UI: 84.8; QOL: I: 67.9, UI: 86.2), mean flexion degrees (I: 126.2°, UI: 135.4°), mean ISI (I: 0.9, UI: 1.0), and mean PMR (I: 1.5, UI: 1.4) (all $p < 0.01$). There was no difference in mean extension degrees and TC (all $p > 0.05$). All fractures achieved union.

Conclusion: The mid-term clinical results of patellar fractures treated with TBW were significantly worse than the contralateral healthy knee. Implant irritation, knee flexion deficit, malunion, and patella baja were the significant complications, and efforts should be made to manage these problems. Patellar fractures are susceptible to developing interesting cases of the elongated patella.

Keywords: Patella fracture, Tension band wiring, Radiological and clinical results, Complications, Implant irritation, Flexion deficit, Malunion, Patella baja, Elongated patella, Malreduction, Implant fail.

Patella Kırıklarında Gergi Bandı Tekniği: Orta Dönem Radyolojik ve Klinik Sonuçlar

ÖZET

Amaç: Gergi bandı tekniği (GBT) ile tedavi edilen patella kırıklarının orta dönem takibindeki radyolojik ve klinik sonuçlarımızı bildirmek.

Yöntem: Bu çalışmaya, bir birinci seviye travma merkezinde, Ocak 2013 ile Haziran 2021 arasında, AO tip 34-A1/C1/C2/C3 patella kırıkları nedeniyle GBT ile cerrahi olarak tedavi edilen hastalar dahil edildi. Radyolojik değerlendirme için rutin takipte alınan radyografiler komplikasyonlar (nonunion, malunion, redüksiyon kaybı, malredüksiyon, patella baja, uzamış patella, implant yetmezliği), Insall Salvati İndeksi (ISI) ve Patellar Morfoloji Oranı (PMO) açısından incelendi. Ağrı, semptomlar, günlük yaşam aktiviteleri (GYA), spor/rekreasyon ve yaşam kalitesi (YK) olmak üzere beş alt ölçek içeren Diz İncinme ve Osteoartrit Sonuç Skoru (KOOS) fonksiyonel değerlendirme için kullanıldı. Klinik değerlendirme ayrıca eklem hareket açıklığını (EHA), uyluk çevresi uzunluğunu (UÇU) ve implant irritasyonu (İİ) gibi komplikasyonları da içeriyordu.

Bulgular: Bu çalışmada, ortalama yaşı 42.6 ± 16.1 yıl ve ortalama takip süresi 35.4 ± 24.1 ay olan 42 uygun hasta (10 kadın, 32 erkek) incelendi. En az bir komplikasyonu olan 28 hasta (%66,7) vardı (İİ: %66.7, fleksiyon defisiti: %61.9, malunion: %40.5, uzamış patella/patella baja: %16.7). İİ kaynaklı yüksek implant çıkarım oranı nedeniyle yeniden ameliyat oranı (%69.1) yüksekti. Opere edilen (O) ve opere edilmeyen kontralateral sağlıklı dizler (S) arasında, ortalama fleksiyon dereceleri (O: 126.2°, S: 135.4°), ortalama ISI (O: 0.9, S: 1.0) ve ortalama PMO (O: 1.5, S: 1.4) ve KOOS alt ölçek puanları (Semptomlar: O: 72.3, S: 89.8; Ağrı: O: 70,4, S: 89.4; GYA: O: 72.1, S: 90; Spor: O: 61.4, S: 84.8; YK: O: 67.9, S: 86.2) açısından istatistiksel olarak anlamlı farklılıklar vardı (tümü $p < 0.01$). Ortalama ekstansiyon dereceleri ve UÇU açısından fark yoktu (tümü $p > 0.05$). Tüm kırıklarda kaynama sağlandı.

Sonuç: GBT ile tedavi edilen patella kırıklarının orta dönem klinik sonuçları, karşı taraf sağlıklı dizden belirgin ölçüde daha kötüydü. İmplant irritasyonu, diz fleksiyon defisiti, malunion ve patella baja belirgin komplikasyonlardı ve bu sorunları yönetmek için çaba sarf edilmelidir. Patella kırıkları, uzamış patella kaynaklı ilginç vakaların gelişmesine yatkındır.

Anahtar Kelimeler: Patella kırıkları, Gergi Bandı Tekniği, Radyolojik ve Klinik Sonuçlar, Komplikasyonlar, İmplant İrritasyonu, Fleksiyon defisiti, Malunion, Patella Baja, Uzamış Patella, Malredüksiyon, İmplant Yetmezliği.

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The patella is the largest sesamoid bone in the body and has the thickest articular cartilage, with an average cartilage thickness of 5.5 mm (1). Its functions are to be the pivot point for the knee's extensor mechanism (quadriceps muscle/tendon, patella, patellar tendon) and protect the distal anterior cartilage of the femur against impacts from the knee from the front. It acts as a lever arm by elevating the extensor mechanism from the knee's rotation center and increasing the extensor mechanism's efficiency by 30% (2).

Patella fractures account for 1% of all fractures in adults and occur predominantly in patients between 20 and 50 years, and the incidence has been estimated to be 13.1 per 100,000 person-years (3, 4).

The fractures of the patella cause extensor strength weakness, range of motion restriction, patellofemoral and tibiofemoral arthritis, thus reducing the quality of life (5). The treatment aims to restore the extensor mechanism function, minimize bone loss, ensure the integrity of the articular cartilage, and enable early mobilization (1). Therefore, patella fractures with articular step-off > 2 mm, displacement > 3mm, extensor mechanism disruption, and open fractures are treated by surgical means (6).

The most widely accepted surgical treatment method for displaced patella fractures is tension band wiring (TBW) which converts tension forces into compressive forces across the patella (7). In the classical TBW technique, two K wires are bent proximally and parallel to each other, and a figure of eight bent cerclage wire around them is used (8). For comminuted fractures and distal pole fractures, additional circular cerclage or de-tensioning cerclage (Mclaughlin) may be used, respectively (9).

Although union rates of patella fractures are high and favorable radiological outcomes have been reported, the information on the knee range of motion, pain, other symptoms, daily living function, sports/recreation, and knee-related quality of life is limited in the literature (10). Therefore, we aimed to share our relevant radiological and clinical results with a mid-term follow-up on patella fractures treated with TBW.

PATIENTS AND METHODS

Patient Selection

An ethical review board approved this retrospective study (02.06.2022-5-26) which was performed in compliance with the Declaration of Helsinki. Written informed consent was obtained from all patients enrolled in this study. Patients surgically treated with TBW for AO type 34-A1 (avulsion) and 34-C1 (transverse), C2 (transverse plus second fragment), and C3 (comminuted) patella fractures between January 2013 and June 2021 at our level 1 trauma center were included in this study. Patients had to have had a surgically treated patella fracture, be at least 18 years old, and have had at least a 12-month follow-up period after surgery for the inclusion criteria. Patients with an age under 18 years old (n=1), a conservatively treated patella fracture (n=1), a prior medical condition limiting physical or mental health (n=1), a concomitant brain or spinal cord injury (n=1), ipsilateral/contralateral lower limb fracture, or dislocation (n=1) were excluded. Two patients were lost to follow-up. Hence, the results of forty-two eligible patients were demonstrated in the study.

Surgical Technique

In this level 1 trauma center setting, senior orthopedic surgeons performed more than half of the operations and supervised the senior residents during less than half of the operations. Following a longitudinal midline incision over the patella, the fracture was reduced using reduction clamps. Then, two parallel K wires were inserted longitudinally into the patella, a cerclage was bent in a figure of eight around the K wires, and the cerclage's two ends were curled to secure and tighten the construct (Figure 1). For most of the operations, the K wires were bent proximally and distally. For three cases, the K wires were bent only proximally. The decision regarding where to bend the K wires was up to the surgeon's preference. No objective criteria were used for this process. For comminuted fractures (AO type 34-C3), especially if the fracture was as a "bag of bones", to improve stability, an additional circular cerclage around the patella or additional K wires were used. Surgeons knew that this situation meant sacrificing implant irritation to gain more stability for achieving union, and these patients were acknowledged about this situation after the surgery. Fluoroscopy was used to inspect the reduction, the K wires' position, and the cerclage. Also, if the eventful rupture of the retinaculum was present, it was used to check the intra-articular step-offs.

Follow-up and Rehabilitation

A long leg splint with a full knee extension was applied for two weeks after the operation to allow the wound to heal. On the 15th day, sutures and the splint were removed, and the patient was allowed to bear weight with a hinged knee brace locked at full extension. On the 30th day, the hinged brace was adjusted to allow 90 degrees of flexion. The flexion range was increased by 10 degrees weekly. The hinged knee brace was removed at the end of the second month. Patients were admonished to abide by a home exercise program focused on quadriceps strengthening and knee range of motion (ROM).

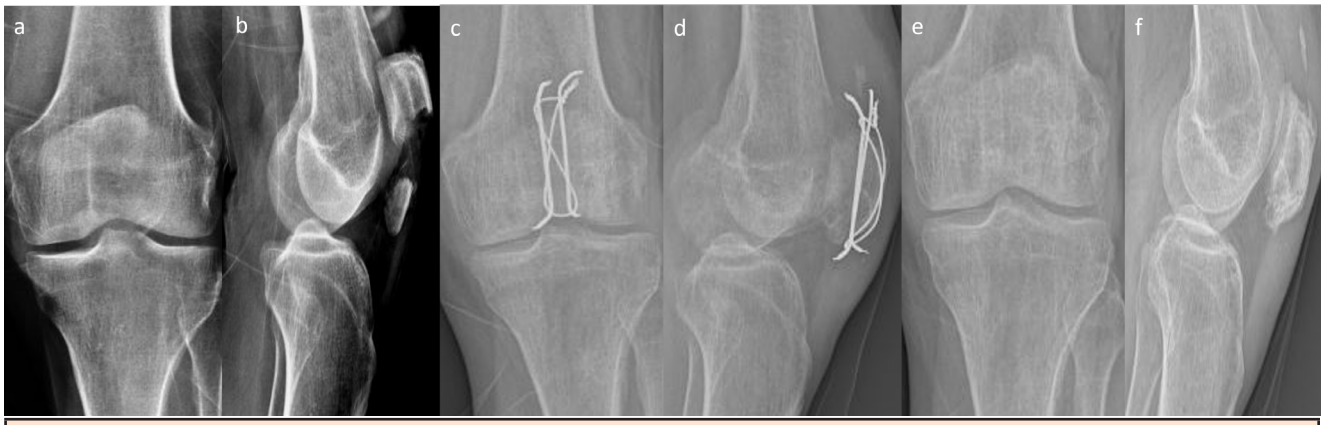

Figure 1. *Preoperative anteroposterior (AP) and lateral (L) knee radiographs of a fifty-seven-year-old male patient who sustained an AO-34C1 patella fracture are demonstrated in a and b. Early postoperative and latest (after implant removal) AP and L knee radiographs are shown in c, d, e, and f, respectively.*

For follow-up, patients were evaluated postoperatively on the 2nd, 4th, 8th, and 12th weeks and at the 6th and 12th months and then if needed. Implant removal was performed between the 6th and 12th months if the patient demanded it after the bony union. Also, implant removal was advised for some patients if the clinical results were worse than expected by the operating surgeon, who knew the natural course of the recovery period of the fracture with their experience. But even in this situation, the patient made the final decision of the implant removal.

Radiological Evaluation

For radiological evaluation, radiographs obtained at the routine follow-up were analyzed for complications such as nonunion, malunion, loss of reduction, malreduction, patella baja, and implant failure (K wire migration and cerclage stripping off from K wires). A complication was defined as a significant deviation from the normal course of events during surgery or post-operatively by the European Society of Sports Traumatology, Knee Surgery & Arthroscopy (ESSKA) (11).

To be more precise, in our institution, we define an orthopedic complication as any clinical or radiological condition that develops during or after a surgical/non-surgical intervention that adversely affects the patient. Nonunion was defined as less than 80% bridging of the fracture line observed on the lateral knee radiograph (12, 13). Malunion of the patella was defined as a non-anatomical union of the patella with either an elongated patella or an articular step-off of more than 2 mm (Figure 2) or displacement of fragments more than 3 mm. These three malunion conditions were caused by gradual reduction loss or initial malreduction. Insall-Salvati Index (ISI) (patellar tendon length/patellar length) and Patellar Morphology Ratio (PMR) (patellar length/patellar articular surface length) were calculated on lateral knee radiographs with knees at 45° of flexion and superimposed femoral condyles (Figure 3) (14). Patella Baja is defined as an ISI measurement below 0.8 (15). An elongated patella was defined as a PMR measurement above 1.5 according to the Grelsamer classification (Figure 4) (16).

Figure 2. *Preoperative (a), early postoperative (b), latest (c) lateral radiographs, and a sagittal CT view (d) of a fifty-nine-year-old patient who sustained an AO-34C3 patella fracture are demonstrated. Note that an articular step-off caused by initial malreduction leading to malunion is presented.*

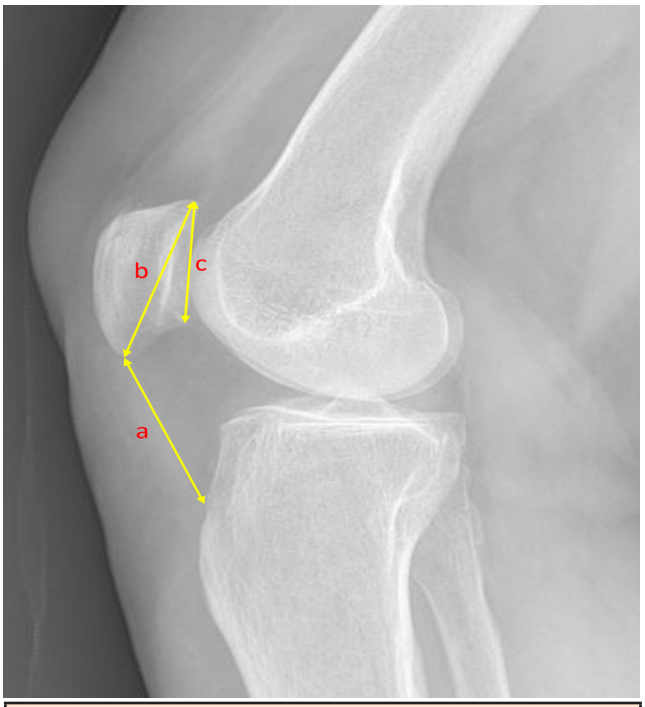

Figure 3. *The demonstration of the Insall-Salvati Index (ISI) and the Patellar Morphology Ratio (PMR). For ISI, the length of the patellar tendon (a) is divided by the length of the patella (b). For PMR, the length of the patella (b) is divided by the articular surface length (c).*

Clinical Evaluation

The Knee Injury and Osteoarthritis Score (KOOS), a knee-related, self-administered, validated, and widely recognized questionnaire, was used to assess functional status (17). The KOOS includes five subscales: pain, symptoms, daily living activity, sports/recreation, and quality of life. Each subscale was computed as a normalized score ranging from 100 (no symptoms) to 0 (extreme symptoms). Injured and uninjured sides were compared regarding the functional outcomes. A goniometer was used to determine the range of motion of the injured and uninjured knees during active flexion and extension. The flexion and extension deficits were calculated by subtracting the injured side's flexion/extension degrees from the uninjured side. Thigh circumference (TC) was measured from 15 cm above the patella, and the difference of more than 2 cm between injured and uninjured sides was thought to be an indicator of quadriceps muscle atrophy. Complications such as wound complications, infection, implant irritation, TC difference > 2 cm (compared with the contralateral healthy knee), and flexion/extension deficit (compared with the contralateral healthy knee) were evaluated using clinical data. Implant irritation was defined when the patient complained about the skin irritation by prominent hardware during regular follow-up. KOOS, ROM, TC, ISI, and PMR values recorded on the last follow-up visit were demonstrated in this study.

Figure 4. *Preoperative coronal and sagittal CT views (a and b), early postoperative AP and Lateral knee radiographs (c and d), lateral knee radiograph before implant removal (e), latest AP and lateral knee radiographs (f and g), and contralateral healthy knee lateral radiograph of a patient with an AO-34C3 patella fracture are demonstrated. Note that there is an elongated patella with patella baja (g) compared to the contralateral healthy knee (h). The reason for this malunion case was initial malreduction.*

Statistical Analysis

Descriptive statistical analysis was performed using SPSS 25.0 (SPSS Inc., IBM, NY, USA). Numerical variables were given as means and standard deviations, and categorical variables were provided as frequencies and percentages. Means were compared by using either Student t-test (under the parametric assumption) or Mann-Whitney U test (under violation of the parametric assumption), or Kruskal-Wallis test (under violation of the parametric assumption for more than two groups) in accordance with the Shapiro-Wilk normality test. The P-value was set at a significance level of 0.05.

RESULTS

This study reviewed 42 eligible patients (10 females and 32 males) with a mean age of 42.6 ± 16.1 years and a mean follow-up of 35.4 ± 24.1 months. The main clinical characteristics of the patients were demonstrated in Table 1.

Table 1. Main clinical characteristics of the patients.	
Number of patients	42
Mean age (years)	42.6 ± 16.1
Mean follow-up (months)	35.4 ± 24.1
Gender	
Male	32 (76.2%)
Female	10 (23.8%)
BMI (kg/m2)	25.3 ± 2.1
Side	
Left	20 (47.6%)
Right	22 (52.4%)
Mechanism of injury	
Fall	37 (88.1%)
Traffic accident	3 (7.1%)
Other	2 (4.8%)
Fracture type (AO classification)	
34-A1	9 (21.4%)
34-C1	16 (38.1%)
34-C2	5 (11.9%)
34-C3	12 (28.6%)
Wound type (Gustillo Anderson)	
Type 1 open	1 (2.4%)
Type 2 open	1 (2.4%)
Closed	40 (95.2%)
ASA classification	
ASA 1	35 (83.3%)
ASA 2	6 (14.3%)
ASA 3	1 (2.4%)
ASA 4	0 (0%)
Hospitalization time (days)	1.7 ± 1.2
Type of anesthesia	
Spinal	39 (92.9%)
General	3 (7.1%)
Mean operation time (min)	40.1 ± 10.4
Mean Union time (weeks)	15.4 ± 5.5
BMI: body mass index, ASA: American Society of Anesthesiologists, AO: Arbeitsgemeinschaft für osteosynthesefragen	

There were statistically significant differences in all KOOS subscales between injured and uninjured knees, especially prominent in the sports/recreation and quality of life scores (all $p < 0.01$). Also, there were statistically significant differences in ROM (flexion), ISI, and PMR results between injured and uninjured knees (all $p < 0.01$). All patients achieved full extension after the TBW surgery. All patients but one had no TC difference between injured and uninjured knees. KOOS, ROM, TC, PMR, and ISI results compared to the uninjured knee were shown in Table 2.

Table 2. KOOS, range of motion, thigh circumference, patellar morphology ratio, and Insall-Salvati Index results in comparison with uninjured knee			
	Injured (n = 42) (mean, SD)	Uninjured (n = 42) (mean, SD)	p
KOOS functional results (points)			
Symptoms	72.3 ± 18.8	89.8 ± 13.5	< 0.01
Pain	70.4 ± 20.0	89.4 ± 13.9	< 0.01
ADL	72.1 ± 18.6	90 ± 13.1	< 0.01
Sports/recreation	61.4 ± 24	84.8 ± 19.3	< 0.01
QOL	67.9 ± 19.9	86.2 ± 17.3	< 0.01
Range of motion (°)			
Flexion°	126.2° ± 9.4	135.4° ± 6.0	< 0.01
Extension°	0°	0°	-
Thigh circumference (cm)	49.6 ± 5.9	50.0 ± 5.8	0.77
Patellar Morphology Ratio	1.5 ± 0.2	1.4 ± 0.1	< 0.01
Insall-Salvati Index	0.9 ± 0.2	1.0 ± 0.1	< 0.01
SD: Standart Deviation, °: Degree, KOOS: Knee Injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Living, QOL: Quality of Life, Uninjured: Contralateral healthy knee, p: level of significance.			

Implant irritation, felxion deficit more than 5°, malunion, patella baja, and elongated patella were the major complications. Regarding implant irritation, there were four patient groups: those who had implant irritation and demanded implant removal (II+IR+ group) (25 patients, 59.5%), those who had implant irritation but were satisfied and did not demand implant removal (II+IR- group) (3 patients, 7.1%), those who had no implant irritation and did not demand implant removal (II-IR- group) (10 patients, 23.8%), and those who demanded implant removal even if they did not have implant irritation (II-IR+ group) (4 patients, 9.5%). The study group had no nonunion, infection, or wound complication. Reoperation/refixation was recommended for all patients with malunion in the early postoperative period, especially for patients with malreduction. None of them accepted this proposal because either they were satisfied with their condition or due to the fear of a second surgery, or due to a loss of confidence in the surgeon performing the surgery. All reduction losses were due to implant failure.

K wire migration was seen in two patients, and cerclage stripping off from K wires was seen in the other two patients. All four patients with reduction loss were offered revision surgery, but none accepted this offer. They were satisfied with their condition. Malunion developed in these patients, but nonunion was observed in none of them. Complication profile and reoperation results were demonstrated in Table 3.

Table 3. Complication profile and reoperation rate.

Complications	(n, %)
Implant irritation	28 (66.7%)
Malunion	17 (40.5%)
Reduction loss	4 (9.5%)
Malreduction	13 (31%)
Patella Baja	7 (16.7%)
Elongated patella	7 (16.7%)
Flexion deficit more than 5°	26 (61.9%)
Thigh circumference difference > 2 cm	1 (2.4%)
Patients with at least one complication	28 (66.7%)
Reoperation	29 (69.1%)
Implant removal	29 (69.1%)
With implant irritation demanding removal	25 (59.5%)
Without implant irritation demanding removal	4 (9.5%)

According to the KOOS, ROM, TC, PMR, and ISI results, there were no differences between sex, side, or fracture type groups (all $p > 0.05$). The statistically significant results were observed between the patients with and without complications regarding flexion degree and KOOS subscales (all $p \leq 0.01$). There were statistically significant differences in all KOOS subscales and knee flexion degrees between patients with and without malunion (all $p < 0.05$). There were statistically significant differences in all KOOS subscales and knee flexion degrees between patients with and without elongated patella (all $p < 0.05$). There were statistically significant differences in all KOOS subscales between patients with and without flexion loss (all $p < 0.05$). There was a statistically significant difference in flexion degree between patients with and without implant irritation ($p < 0.01$). The comparison of KOOS, ROM, TC, PMR, and ISI results between sex, side, complication, and fracture type groups was given in Table 4.

Table 4. Comparison of KOOS, range of motion, thigh circumference, patellar morphology ratio, and Insall-Salvati Index results between sex, side, complication and fracture type groups.

	Sex (Male vs Female)	Side (Left vs Right)	Complications (Patiens with complications vs without complications)	Fracture Type (AO-A1 vs C1 vs C2 vs C3)
KOOS functional results				
Symptoms (points) (mean ± SD vs mean ± SD)	p: 0.15 (74.9 ± 19.1 vs 63.9 ± 15.3)	p: 0.19 (68.3 ± 17.8 vs 75.9 ± 19.2)	p < 0.01 (68.3 ± 17.8 vs 75.9 ± 19.2)	p: 0.17 (71.2 ± 17.7 vs 74.6 ± 20.3 vs 85.7 ± 13.1 vs 64.5 ± 17.4)
Pain (points) (mean ± SD vs mean ± SD)	p: 0.23 (72.8 ± 20.9 vs 62.5 ± 14.9)	p: 0.11 (65.2 ± 19.5 vs 75.0 ± 19.7)	p: 0.01 (61.9 ± 14.8 vs 87.1 ± 18.7)	p: 0.17 (69.1 ± 17.5 vs 73.6 ± 21.2 vs 83.8 ± 14.7 vs 61.2 ± 19.5)
ADL (points) (mean ± SD vs mean ± SD)	p: 0.16 (74.7 ±19.0 vs 63.6 ± 14.5)	p: 0.22 (68.1 ± 17.1 vs 75.7 ± 19.4)	p < 0.01 (64.3 ± 13.3 vs 87.7 ± 18.0)	p: 0.17 (70.2 ± 17.3 vs 74.2 ± 20.4 vs 85.5 ± 13.2 vs 65.0 ± 16.8)
Sports/recreation (points) (mean ± SD vs mean ± SD)	p: 0.28 (64.0 ± 26.1 vs 53.0 ± 12.7)	p: 0.39 (57.0 ± 22.0 vs 65.4 ± 25.5)	p < 0.01 (50.8 ± 15.4 vs 82.5 ± 24.6)	p: 0.38 (56.6 ± 23.1 vs 63.4 ± 27.0 vs 77.0 ± 22.8 vs 55.8 ± 20.0)
QOL (points) (mean ± SD vs mean ± SD)	p: 0.12 (70.7 ± 21.5 vs 58.7 ± 9.8)	p: 0.13 (62.8 ± 19.4 vs 72.4 ± 19.6)	p: 0.01 (59.5 ± 12.5 vs 84.3 ± 22.0)	p: 0.24 (63.1 ± 17.2 vs 66.7 ± 24.4 vs 82.5 ± 16.7 vs 66.6 ± 15.1)
Range of motion				
Flexion° (mean ± SD vs mean ± SD)	p: 0.09 (127.5 ± 9.6 vs 122.0 ± 7.5)	p: 0.78 (125.7 ± 7.4 vs 126.5 ± 11.0)	p < 0.01 (121.7 ± 7.0 vs 135.0 ± 7.0)	p: 0.11 (123.8 ± 7.4 vs 126.8 ± 10.4 vs 135.0 ± 3.5 vs 123.3 ± 9.3)
Extension° (mean ± SD vs mean ± SD)	-	-	-	-
Thigh circumference (cm) (mean ± SD vs mean ± SD)	p: 0.94 (49.5 ± 5.9 vs 49.8 ± 6.0)	p: 0.32 (48.5 ± 4.8 vs 50.6 ± 6.7)	p: 0.99 (49.7 ± 6.0 vs 49.5 ± 6.0)	p: 0.72 (47.6 ± 5.1 vs 49.6 ± 5.9 vs 50.8 ± 6.9 vs 50.6 ± 6.4)
Patellar morphology ratio (mean ± SD vs mean ± SD)	p: 0.90 (1.45 ± 0.17 vs 1.43 ± 0.13)	p: 0.63 (1.43 ± 0.14 vs 1.47 ± 0.17)	p: 0.89 (1.47 ± 0.19 vs 1.40 ± 0.05)	p: 0.16 (1.47 ± 0.18 vs 1.44 ± 0.12 vs 1.34 ± 0.04 vs 1.48 ± 0.21)
Insall-Salvati Index (mean ± SD vs mean ± SD)	p: 0.99 (0.89 ± 0.19 vs 0.89 ± 0.19)	p: 0.20 (0.91± 0.22 vs 0.87 ± 0.15)	p: 0.08 (0.85 ± 0.21 vs 0.97 ± 0.10)	p: 0.41 (0.79 ± 0.25 vs 0.91 ± 0.17 vs 0.93 ± 0.12 vs 0.91 ± 0.16)

KOOS: Knee Injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Living, QOL: Quality of Life, vs: versus, SD: standart derivation, p: level of significance.

DISCUSSION

The study's most important finding was that considering the mid-term results of patellar fractures treated surgically with TBW, the clinical and radiological results were significantly worse than the contralateral healthy knee, despite all fractures achieving union. These findings were consistent with Lebrun's study (10), which demonstrated 62 points for pain, 65 points for symptoms, 67 points for activities of daily living, 44 points for sports/recreation, and 44 points for the quality of life in KOOS subscale scores with a mid-term follow-up. We attribute these poor results to the subcutaneous location of the patella, the small amount of prepatellar soft tissue covering the anterior compartment of the knee, initial chondral injury, and residual joint incongruity, as previous studies mentioned (18, 19). The second most important finding of the study was implant irritation, knee flexion deficit, malunion, and patella baja were the major complications. The third most important finding of the study was that the patellar fractures were prone to developing elongated patella.

The complication, the reoperation, and the implant irritation rates of TBW surgery for patella fractures vary among studies, but they were reported as high as 75%, 58%, and 48% in the literature, respectively (20). Similarly, the complication and the reoperation rates were high due to the high implant irritation rate (the major complication) in this study. Therefore, with implant irritation a significant problem, it is clear that new fixation methods are needed for patellar fractures.

The second major complication of this cohort was the flexion deficit. There was a flexion deficit (injured knee mean flexion angle: 126.2° ± 9.4, healthy knee mean flexion angle: 135.4° ± 6.0) of more than 5° in 61.9% of patients treated with TBW compared to the contralateral healthy knee. We attribute this deficit to the decrease in rehabilitation efficiency due to the patients' pain caused by implant irritation. Unsurprisingly, there was a statistically significant difference in flexion degree loss between patients with and without implant irritation ($p < 0.01$). Lin et al. (12), Chiang et al. (20), and Mao et al. (21) reported similar decreased flexion degrees (136.9° ± 11.0, 132.1° ± 8.5, and 115.0° ± 12.8, respectively) after TBW surgery. There were statistically significant differences in all KOOS subscales between patients with and without flexion loss (all $p < 0.05$). It's evident that the flexion degree affects the functional outcomes. None of the patients in this cohort had an extension deficit. Thus, we speculate that none of the patients were observed to have an extension deficit because all fractures achieved union.

The third most common complication observed in this study was malunion, with a rate of 40.5%. This is the first study to report malunion of patella fractures after TBW. Malunion was caused by two reasons: initial malreduction or gradual reduction loss. K wire migration and cerclage stripping off from K wires, in short, implant failure caused the aforementioned reduction loss. Malreduction occurred due to failure to achieve anatomic reduction during surgery. This failure was because fluoroscopy was not appropriately used to obtain a true lateral and AP view of the patella, some fractures were multi-fragmented, or the surgeon accepted non-anatomical reduction after trying anatomical reduction many times (intraoperative surgeon exhaustion). There were statistically significant differences in all KOOS subscales and knee flexion degrees between patients with and without malunion (all $p < 0.05$. Therefore, reduction loss/malreduction and the resulting malunion should be avoided.

In terms of KOOS, ROM, TC, PMR, and ISI results, there was no difference between female-male patients, left-right knees, and interestingly AO-A1/C1/C2/C3 fracture types. Besides, there were statistically significant differences between patients with or without complications in KOOS and ROM results. Surprisingly, despite the surgeons in our clinic expecting worse outcomes in comminuted fractures, the results were similar. We think the similar results can be attributed to two reasons: the reduction quality and the occurrence of complications. Given the results, a patient with an anatomically reduced comminuted patella fracture would likely have as good clinical outcomes as a patient with a simple patella fracture unless a complication develops. Here, considering the complication rates, it is necessary to focus on implant irritation as it was the major complication. Despite achieving anatomic reduction is at the hands of surgeons, the reason for implant irritation is unclear. We speculate that the skin-patella distance and the length of the K-wires outside the patella may be important. The assessment of this problem is beyond the scope of this study and requires further studies.

Although there are studies reporting patella baja after patella fracture in the literature, there is no study reporting an elongated patella case. After a patella fracture, the reported Patella Baja rate is up to 43.9% (22, 23). Our rate of patella baja (16.7%) is within this limit. It has also been reported that patella baja does not affect clinical results in the short term (22).

We observed elongated patella for seven (16.7%) of our patients. Of these seven patients, three had AO 34-C3 type fracture, two had AO 34-C1 type fracture, and the other two had AO 34-A1 type fracture. All of the patients with elongated patella also had patella baja. There were statistically significant differences in all KOOS subscales and knee flexion degrees between patients with and without elongated patella/patella baja (all $p < 0.05$). Thus, elongated patella/patella baja should be avoided for patellar fractures. This is the first study reporting elongated patella after patellar fractures. The only research in the literature about elongated patella is reported by Visuri et al. (14). In that study, it is speculated that patients with Osgood-Schlatter disease may exhibit elongated patella, which is thought to result from long-standing tension of the extensor apparatus during the growth spurt. Given the results of our study, patella fractures seemed to be the second reason for the elongated patella.

The major limitations of this study were the retrospective design, the small size of the cohort, the lack of presentation of long-term results, and the use of the contralateral healthy knee as the control group (rather than a different fixation technique such as TBW with cannulated screws, or rather than a different fixation device such as patella plates). Also, more than one surgeon performed the surgeries. The positive aspect of the current study was the presentation of the complications in a detailed manner with radiological and clinical results. Besides, this is the first study to define and address the issues of patellar malunion and elongated patella.

CONCLUSION

The mid-term clinical results of patellar fractures treated with TBW were significantly worse than the contralateral healthy knee. Implant irritation, knee flexion deficit, malunion, and patella baja were the significant complications, and efforts should be made to manage these problems. Patellar fractures are susceptible to developing interesting cases of the elongated patella.

DECLARATIONS

Conflict of Interest

The authors have not declared any conflicts of interest.

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