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ORIGINAL STUDY

Modified tension band wiring in patella fractures : Kirschner wire bending at both ends prevents from loss of reduction and revision surgery

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High rates of reduction loss and revision surgeries have been reported with modified tension band wiring (MTBW) in patella fractures. Bilaterally bending the K-wires has been described to prevent these complications. The purpose of the study was to compare loss of reduction and the need for revision surgery when K-wires were bent at both ends or not in patella fractures treated by MTBW. This is a retrospective study including a consecutive series of 179 patients with patella fractures treated by MTBW. 70 patients had a MTBW with K-wires bent at both ends (group 1), and 109 patients had MTBW with K-wires bent at one end or not bent at all (group 2). Reduction loss was 4.3% in group 1 and 25.7% in group 2 (p=0.0002). Revision surgery was needed for 0% of the cases in group 1 and 9.2% in group 2 (p=0.068). Bending the K-wires at both ends significantly decreased the rate of reduction loss and revision surgery.

Keywords : patella fracture ; modified tension band wiring ; Kirschner wire ; loss of reduction ; revision surgery.

INTRODUCTION

Patella fractures (PF) account for approximately 1% of all skeletal injuries *(4)*, with a yearly incidence of 13.1/100000 *(11)*. For displaced fractures, several types of surgical fixations have been described : tension band wiring (TBW), screw fixation, circular external fixation or internal plate fixation *(6)*. Modified TBW (MTBW) is the most frequently used technique : it consists of an internal fixation by two parallel Kirschner wires (K-wires) tightened by an anterior figure of eight-shaped metallic cable, passed under the K-wires, in contact with the patellar bone, so that the distraction strength can be transformed into a compressive force *(9)*.

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The bending of the ends of the K-wires is not properly defined in the technique. In most of the studies found in the literature, the K-wires are bent at one end only, either proximally or distally, or not bent at all. However, this technique has been associated with mechanical complications such as migration of implants or displacement of fragments *(3)*. A technique which consists of bending the K-wires at both ends has shown some promising results to prevent migration of K-wires and improve the success rate *(5,14)*. A recent report found no difference when the K-wires were bent at both ends compared to K-wires bent at the proximal end *(8)*. Therefore, controversial results have been obtained depending on the method of K-wire bending.

In this study, we retrospectively compared loss of reduction, rate of revision surgery and implants migration in patients with PF treated by MTBW with K-wires bent at both ends or not.

Fig. 1. — AO 34-C2 fracture of the left patella treated by MTBW with bilateral bending of the K-wires. A-D = lateral view, E-H = frontal view. A and E = preoperative X-rays, B and F = immediate postoperative X-rays, C and G = 1 year follow up X-rays, D and H = 18 months follow-up X-rays, after removal of implants.

MATERIALS AND METHODS

We retrospectively reviewed all PF treated by MTBW at two Level 1 academic trauma centers between 2004 and 2014, after obtaining approval from the Institutional Review Board. Exclusion criteria were absence of follow up (loss in follow up, early death or immediate removal of implants due to infection), absence of X-rays, age under 18. A total of 205 PF treated by MTBW were identified during the study period and 26 fractures were excluded because 11 were lost to follow up, 11 had no X-ray available, 1 patient died at day 1 after surgery (accident) and 3 had early infections needing removal of the implants. Thus, we had a population of 179 PF in 179 patients with full operative report, follow up radiographs and clinical history. All fractures were classified according to AO Classification of Fractures after analysis of preoperative X-rays. Two orthopedic surgeons (one junior and one senior) examined together pre-op, post-op and follow-up X-rays (anteroposterior and lateral knee) for loss of reduction ≥ 2 mm and migration of implants. Migration of implants was recorded when any kind of movement (displacement, rotation defined by a rotational movement of the bended ends on AP and/or profile views, rupture) on the K-wires or on the metallic cables was observed between two X-rays. Pre-operative, operative and post-operative data were collected from the patient files, including age, gender, fracture type, fracture open/close, fixation type, post-operative immobilization, physiotherapy, weight bearing. Revision surgery for excessive reduction loss was also recorded. All the fractures were treated with MTBW according to the standard technique with 2 K-wires and a horizontal figure-of-eight metallic cable wiring, but additional K-wires and cerclage wires could be used if necessary. To investigate the role of K-wires bending in the outcome, we classified the treated fractures into 2 groups for further analysis : group 1 had bending of the K-wires at both ends (figure 1), group 2 had K-wires bent at one end only, or not bent at all. The primary endpoint of this study was to determine the impact of K-wires bending on the reduction loss for PF treated by MTBW. Secondary endpoints included revision surgery rate, implants migration and post-operative pain.

All the data were tabulated in JMP 10.0 (SAS inc.). Most continuous variables didn't have a normal distribution and non-parametrical statistics were performed. Qualitative variables were compared using Fischer's exact test. Multivariate analysis was performed to determine factors influencing loss of reduction, using stepwise logistic regression including age, sex, AO category, open/close fracture, MTBW alone or in association, K-wires bending (2 ends or not), postoperative weight bearing, bracing and physiotherapy.

RESULTS

We found 179 fractures in 179 patients during the study period. There were 94 women (52,5%) and 85 men (47,5%). The median age was 53,3 years, men being significantly younger than the women. Median follow-up was 175 days. The main fracture type was the transverse AO 34-C1 fracture (85 fractures, 47,5%), followed by AO 34-C3 fractures (65 fractures, 36,3%), AO 34-C2 fractures (16 fractures, 8,9%) and avulsion AO 34-A1 fractures (13 fractures, 7,3%). There were 21 open fractures (11,7%). MTBW alone was performed in 134 fractures (74,9%), and 45 fractures needed a complementary fixation, by additional K-wires or metallic cable, associated to the MTBW (25,1%).

There were 70 fractures in group 1 (39,1%) and 109 fractures in group 2 (60,9%). Patients were followed for the mean duration of 205 days. For the postoperative immobilization, 140 patients had a Zimmer brace (78,2%) and 30 had a circular plaster (21.8%). 149 were allowed to walk immediately (83,2%), and 104 to begin their reeducation immediately (58,1%). Pre-operative and post-operative data and comparison between group 1 and group 2 are summarized in table 1.

There were 31 fractures with reduction loss (17,3%), observed at median delay of 31 days. Loss of reduction was observed for 3 fractures in group 1 (4.3%) and for 28 fractures in group 2 (25.7%), the difference was statistically significant (p=0.0002). In the multivariate analysis, only the K-wires bending appeared as significantly associated with loss of reduction.

Revision surgery was needed for 10 patients (5.6%), none in group 1, and in 10 fractures in group 2 (9.2%, median delay at 44 days), the difference was statistically significant (p=0.0068). There were 80 patients with material migration (44,7%), observed at median delay of 47.5 days. Implants migration was observed in 16 fractures in group 1 (22.9%, median delay at 50.5 days), and in 64 fractures in group 2 (58.7%, median delay at 47.5 days), the difference was statistically significant (p<0.0001). Sixty patients reported postoperative pain (33,5%), and 51 of them (28,4%) reclaimed that the pain was due to the implants. Post-operative pain rate was 34.4% in group 1 and 33.3% in group 2 (not significant). The results are summarized in table 2.

Table 1. — Preoperative and postoperative characteristics and comparison of group 1 (bilateral bending) and group 2.

Variables	Group 1 (n=70)	Group 2 (n=109)	P Value
Sex (Female)	58.6%	48.6%	0.2
Median Age (year)	55.6	51.8	0.2
Open fractures	12.9%	11.0%	0.8
Immediate weight bearing	81.4%	84.4%	0.68
Post-operative bracing	82.9%	75.3%	0.27
Immediate post-operative physiotherapy	62.9%	55.1%	0.35

Table 2. — Comparison of loss of reduction, hardware migration, revision surgery and post-operative pain between group 1 (bilateral bending) and group 2

Variables	Group 1 (n=70)	Group 2 (n=109)	P Value
Loss of reduction (%)	4.3% (3/70)	25.7% (28/109)	0.0002
Revision surgery	0% (0/70)	9.2% (10/109)	0.0068
Hardware migration	24.3% (17/70)	58.7% (64/109)	<0.0001
Post-operative pain	34.3%	33.3%	1

Other complications were observed for 38 patients (21,2%) : 7 late infections (3.9%), 3 hematomas, 2 deep vein thrombosis, 6 stiff knees, 6 secondary skin wounds due to the implants.

DISCUSSION

MTBW is widely used for its technical simplicity. It needs common materials in orthopedic use which are Kirshner wires and a metallic cable. With correct application of the technique, the security of fixation allows early weight bearing and mobilization to prevent joint stiffness. However, several studies reported high rates of reduction loss and revision surgery *(7,13)*. Technical errors and failure by patients to comply with postoperative restrictions were suggested to be the reasons for these complications. Several biomechanical and clinical studies have compared various types of constructs and issued technical guidelines in order to produce the greatest interfragmentary compression and have the maximum stiffness : horizontally oriented figure of eight is stronger than the vertically oriented ones *(10,12)*, placing two twists of wire at adjacent corners increases interfragmentary compression *(1,10)*, the tension band should be adjacent to the bone surface and not over the tendinous tissue *(2,8)*, concurrent application of an augmented circumferential cerclage wiring does not provide a better treatment outcome *(15)*, and K-wires should be placed superficially in the patellar bone *(8)*.

In our retrospective cohort study, we can reject the null hypothesis and there is evidence that bending of K-wires at both ends has a beneficial effect to prevent from loss of reduction in MTBW for PF. Loss of reduction was only 4.3% when K-wires were bent at both ends, and it was 25.7% when the K-wires were bent at one end, or not bent at all. This high rate of loss of reduction is consistent with the 22% found by Smith et al. *(13)*. Prevention of loss of reduction by bending K-wires at both ends is however controversial in the literature. The initial report of the technique by Wu et al. did not focus on loss of reduction but on fracture union of 62 patients all treated with bending at both ends *(14)*. Another study by Eggink et al. with small number of patients concluded that bending K-wires at both

Fig. 2. — AO 34-C1 fracture of the left patella treated by MTBW with proximal bending of the K-wires. A-C = lateral views, D-F = frontal views. A and D = preoperative X-rays. B and E = immediate postoperative X-rays. C and F = 3 weeks follow-up X-rays with pulling out of the K-wires and loss of reduction.

ends prevented implants migration and reduced the risk of osteoarthritis of the patellofemoral joint *(5)*. However, a recent retrospective study by Hsu et al. including 170 patients found that K-wires bending had no effect on the reduction loss *(8)*. This could be induced by the different definition given for reduction loss which is 2mm in the study of Eggink et al., and 3mm in the study of Hsu et al. Therefore, in this last study, if we add the cases of minor loss of reduction to the cases of major loss of reduction, we find 14/38 (36.8%) reduction loss in the proximal bending group, and 29/132 (22%) in the both ends bending group, with p-value=0.09, which shows a tendency for less loss of reduction in the both ends bending group. The rate of revision surgery for loss of reduction was not determined in this study.

Revision surgery due to fixation failure was required for 5.6% of our patients, which is consistent with the rate found by Hoshino et al. (3.5%) *(7)*, by Smith et al. (5%) *(13)* and by Yang et al. (5.6%) *(15)*. Revision surgery is decided when loss of reduction is important enough, and the three loss of reduction observed in group 1 were considered tolerable. The decision to revise was subjective, but as this is a retrospective study, patients and surgeons did not know that the x-rays would be reviewed and thus the subjectivity was the same in both groups. It seems that initial reduction loss stops when the bone meets the bent end-point of the K-wires, which prevents from further movement. Therefore, traction by the quadriceps muscle induces movements between the proximal and distal fragment. This movement should be prevented by the presence of the metallic cable. If the metallic cable is not properly applied on bone, or if it is not sufficiently tightened, then movement between the two fragments appear. Repetitive movements of flexion-extension or quadriceps pulling induce migration of the K-wires (figure 2). Bending the K-wires at both ends should prevent them from pulling totally out of the patella with major loss of reduction needing revision surgery.

Implants migration was important in our series, as all kinds of implants movements were reported. We could often see rotation of the K-wires, with no consequence on the reduction or healing of the fracture, but which could induce pain and skin wounds. Implants migration was lower when K-wires were bent at both ends, as previously observed by Eggink et al. *(5)*. Interestingly, we could see a lot of implants migrations once the fracture was healed. This is probably due to an increase in the forces applied on the implants once the fracture is healed, with more traction of the quadriceps tendon, and more flexion of the knee. Post-operative pain rates were not statistically different in both groups and bending the K-wires at both ends had no effect. Pain due to the implants was consistent with other studies found in the literature *(7)*.

Except for K-wires bending, we found no other pre or postoperative causes for reduction loss. This is consistent with other reports in the literature, where age, sex, smoking status, diabetes, fracture pattern, open or closed fracture, and post-operative bracing had no effect on reduction loss *(7,15)*. Hoshino et al. found that BMI had an effect, but it was not measured in our study *(7)*.

Our study contains several limitations. First, it is a retrospective study. Second, the data was retrieved from 2 different medical centers with many orthopedic surgeons with different levels of experience. Most of the trauma surgery is performed by young surgeons with low experience, and MTBW was not always performed with a proper technique. There were also different postoperative rehabilitations which could influence the rate of reduction loss. Furthermore, no reasons could be found to why some surgeons preferred bending K-wires at both ends and others at one end only, and there could be a learning curve effect, some surgeons with past experience of loss of reductions with one end bent K-wires would then bend the K-wires at both ends.

Other studies have compared MTBW to other type of fixations. TBW with cannulated screws is gaining in popularity, but screws can sometimes be difficult to position, and a comparative study found less fixation failures with MTBW *(7)*, even if theoretical biomechanical studies show stronger fixation with cannulated screws *(16)*.

In conclusion, MTBW is an efficient technique if it is properly executed. We recommend bending the K-wires at both ends to prevent implants migration, loss of reduction and need for revision surgery.

REFERENCES

1. **Ali M, Kuiper J, John J.** Biomechanical analysis of tension band wiring (TBW) of transverse fractures of patella. *Chin. J. Trauma.* 2016 ; 19 : 255-258.
2. **Baran O, Manisali M, Cecen B**. Anatomical and biomechanical evaluation of the tension band technique in patellar fractures. *Int. Orthop.* 2009 ; 33 : 1113-1117.
3. **Bonnaig NS, Casstevens C, Archdeacon MT, Connelly C, Monaco N, Wyrick JD, Le TT.** Fix it or discard it? A retrospective analysis of functional outcomes after surgically treated patella fractures comparing ORIF with partial patellectomy. *J. Orthop. Trauma.* 2015 ; 29 : 80-84.
4. **Bostrom A.** Fracture of the patella. A study of 422 patellar fractures. *Acta Orthop. Scan. Supplementum.* 1972 ; 143 : 1-80.
5. **Eggink KM, Jaarsma RL.** Mid-term (2-8 years) follow-up of open reduction and internal fixation of patella fractures : does the surgical technique influence the outcome? *Archives Orthop. Trauma Surg.* 2011 ; 131 : 399-404.

6. **Gwinner C, Mardian S, Schwabe P, Schaser KD, Krapohl BD, Jung TM**. Current concepts review : Fractures of the patella. *GMS Interdisciplinary Plastic Reconstr Surg. DGPW.* 2016 ; 5 : Doc01.
7. **Hoshino CM, Tran W, Tiberi JV, Black MH, Li BH, Gold SM, Navarro RA.** Complications following tension-band fixation of patellar fractures with cannulated screws compared with Kirschner wires. *J. Bone Joint Surg.. Am.* 2013 ; 95 : 653-659.
8. **Hsu KL, Chang WL, Yang CY, Yeh ML, Chang CW.** Factors affecting the outcomes of modified tension band wiring techniques in transverse patellar fractures. *Injury.* 2017 ; 48 : 2800-2806.
9. **Hung LK, Chan KM, Chow YN, Leung PC.** Fractured patella : operative treatment using the tension band principle. *Injury.* 1985 ; 16 : 343-347.
10. **John J, Wagner WW, Kuiper JH**. Tension-band wiring of transverse fractures of patella. The effect of site of wire twists and orientation of stainless steel wire loop : a biomechanical investigation. *Int. Orthop.* 2007 ; 31 : 703-707.
11. **Larsen P, Court-Brown CM, Vedel JO, Vistrup S, Elsoe R**. Incidence and Epidemiology of Patellar Fractures. *Orthopedics.* 2016 ; 39 : e1154-e1158.
12. **Lee SK, Hwang YS, Choy WS.** Horizontal versus vertical orientation of the loop for tension band wiring of transverse patella fractures. *Orthopedics.* 2014 ; 37 : e265-271.
13. **Smith ST, Cramer KE, Karges DE, Watson JT, Moed BR.** Early complications in the operative treatment of patella fractures. *J. Orthop. Trauma.* 1997 ; 11 : 183-187.
14. **Wu CC, Tai CL, Chen WJ.** Patellar tension band wiring : a revised technique. *Archives Orthop. Trauma. Surg.* 2001 ; 121 : 12-16.
15. **Yang TY, Huang TW, Chuang PY, Huang KC.** Treatment of displaced transverse fractures of the patella : modified tension band wiring technique with or without augmented circumferential cerclage wire fixation. *BMC musculoskeletal disorders.* 2018 ; 19 : 167.
16. **Zderic I, Stoffel K, Sommer C, Hontzsch D, Gueorguiev B.** Biomechanical evaluation of the tension band wiring principle. A comparison between two different techniques for transverse patella fracture fixation. *Injury.* 2017 ; 48 : 1749-1757.