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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Does closer placement of cerclage wire enhance functional outcomes in tension band wiring of patellar fractures?

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SUMMARY

Introduction/Objective Patellar fractures are commonly treated with tension band wiring (TBW). The distance between the cerclage wire and the superior pole of the patella is crucial for surgical outcomes. This study evaluates the impact of this distance on clinical and functional results.

Methods A retrospective cohort study of 64 patients with transverse patellar fractures treated with TBW was conducted. Patients were categorized based on the distance of the cerclage wire from the bone: < 4 mm, 4–8.5 mm, and > 8.5 mm. Clinical outcomes included bone union, implant failure, and wound complications. Functional outcomes were assessed using range of motion (ROM) and modified Hospital for Special Surgery (HSS) knee score values.

Results Significant differences were observed in outcomes depending on wire placement. Patients with cerclage wires < 4 mm from the bone exhibited poorer functional results, with a mean modified HSS Knee Score of 70 ± 9.2 and an average ROM of 103.6 ± 42.4°. Patients with wires positioned 4–8.5 mm from the bone demonstrated better functional recovery, achieving higher knee scores and greater ROM. Statistical analysis confirmed that closer wire placement negatively affected clinical outcomes ($p < 0.05$).

Conclusion This study suggests that positioning cerclage wires too close to the bone (< 4 mm) may impair functional outcomes despite presumed mechanical stability. An optimal distance of 4–8.5 mm balances mechanical stability and soft tissue protection, offering improved clinical and functional results. These findings challenge conventional surgical approaches, emphasizing the importance of precise wire positioning in TBW procedures.

Keywords: patellar fractures; tension band wiring; cerclage wire; clinical outcomes; functional outcomes; surgical techniques

INTRODUCTION

Fractures of the patella pose a challenge to orthopedic trauma management because of the important role of the patella in the extensor mechanism of the knee. The treatment of patellar transverse fractures has traditionally been performed using tension band wiring (TBW) for restoration of the articular surface and early mobilization [1, 2]. However, it is also noted that there are methodologically more updated approaches and meta-analyses findings which should be incorporated to have a better perspective on TBW outcomes and biomechanics [3, 4]. The configuration of the cerclage wire in TBW, especially its distance from the bone, is important in determining the biomechanical stability of the fixation and therefore clinical results. Early mobilisation and good biomechanical fixation reduce pain and improve quality of life [5].

Among the biomechanical properties, stability provided by the cerclage wire is an important area of concern for TBW that can influence both bone-union rates and the incidence of post-operative complications [6, 7]. The proximity of the cerclage wire to the bone has specific implications for the biomechanics of the fixation [3]. For instance, Zhang et al. demonstrated that TBW with the cerclage wire positioned near the bone surface significantly reduces micromotion at the fracture site, facilitating bone healing [8, 9]. Conversely, an increased distance between the cerclage wire and the bone may lead to sub-optimal compression and stability, raising the risk of implant failure and delayed union [10]. This observation underscores the need for meticulous surgical practice and indicates that further, specific endeavours to clarify these effects are needed [3]. Further, poor positioning of the wire has been associated with increased post-operative complications, including migration of the wire and soft-tissue irritation [11]. Though these problems have been described in prior research, more elaborate investigation and comparison with existing literature would be helpful for a fuller understanding of optimal positioning and its effects [3]. There is a gap in the literature regarding the proximity of the cerclage wire to the bone, and the safe distance

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in patellar fractures treated with tension-band wiring remains under-explored. Therefore, the aim of our study was to calculate the effect of the distance of the cerclage wire to the bone on clinical and functional outcomes and to determine the safe distance in patients with transverse patellar fractures treated with TBW. This will reduce the margin of error in surgical technique and provide a touchstone for the clinician regarding the distance of the cerclage wire during surgery.

METHODS

Study design and population

This is a retrospective cohort study including a total of 108 patients aged 18–65 years with C1 and C2 transverse patellar fractures (AO classification) who had undergone TBW with two Kirschner wires. The patients were treated between January 2015 and December 2022 at a single tertiary-care centre. The exclusion criteria were multiple-trauma patients, multiple fractures of the same limb, systemic, metabolic and infectious diseases, application of cerclage to tension-band wiring, use of cannulated screws, and periprosthetic or pre-existing pathological conditions of the knee. Such criteria were aimed at providing homogeneous groups of patients, thus excluding factors that could influence results.

Surgical technique

All surgeries were performed under general anaesthesia. A standard midline knee incision with medial parapatellar arthrotomy was made to gain access to the fracture site. The skin incision was deepened, and the fractures were reduced using reduction clamps, with reduction confirmed under fluoroscopy. From the superior pole of the patella, two K-wires were introduced distally. The cerclage wire was passed around these K-wires and then tightened to compress the fracture fragments. The tips of the proximal end were cut, and the K-wires were then bent and fixed. The surgeon's experience and frequency of performing this technique were recorded to determine whether these factors influenced surgical outcomes. The knee was immobilised using an immobiliser for two weeks post-operatively to facilitate initial healing.

Post-operative care and follow-up

Patients began static isometric quadriceps-strengthening exercises on the first post-operative day. Two weeks later, range-of-motion (ROM) exercises were started under the supervision of a physiotherapist. The follow-up period included evaluations at one, three, six, 12 and 24 months post-operation. Clinical assessments included wound healing, pain level and functional recovery. Radiographic evaluations were performed at each visit to assess both fracture union and fixation integrity.

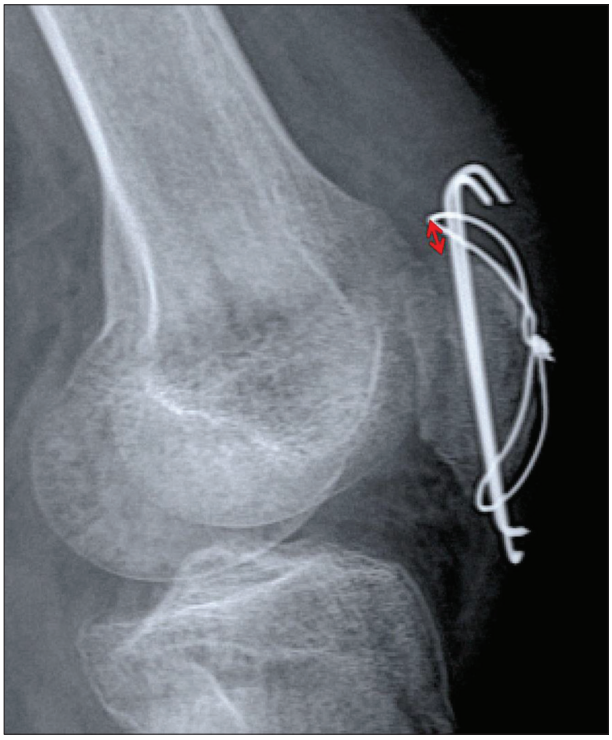

Figure 1. X-ray image of knee with cerclage wire and K-wire fixation

Data collection

The main outcome measurement was the distance of the wire from the bone, measured directly from the lateral postoperative radiograph (Figure 1). A consistent measurement protocol was used to ensure exact values. To ascertain measurement validity, inter-observer and intra-observer reliability tests were performed. The following outcomes were evaluated: clinical and functional outcomes, incidence of wound complications, union rates and overall clinical follow-up. The patients' medical records and radiographs were critically reviewed to support interpretation of the findings. In addition, ROM and functional outcomes were assessed at the last follow-up using the Modified Hospital for Special Surgery (HSS) Knee Scores [12]. The properties and application techniques of the cerclage wires were detailed, including material composition and tensioning method.

Statistical analysis

Data were analysed using IBM SPSS Statistics, Version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were summarised to provide participant demographics and clinical characteristics. Frequencies, means and standard deviations were calculated for age, distance between the cerclage wire and bone, knee ROM values and Modified HSS Knee Scores. Data were tested for normality using the Shapiro–Wilk test. For normally distributed data, Student's t-test was used, whereas Mann–Whitney U tests were applied to non-normally distributed data. Additionally, ROC-curve analysis determined the threshold value of the cerclage-wire distance that best predicted patients' outcomes. Identifying the point that maximises

the sensitivity and specificity of cerclage-wire distance for predicting clinical and functional outcomes is essential. χ^2 tests compared categorical data regarding the presence or absence of wound complications and implant failures, with statistical significance set at $p = 0.05$.

Ethics: All participants provided written informed consent prior to inclusion in the study. The study protocol was approved by the Institutional Ethics Committee of Harran University (Approval No: HRU-24/11/35) and conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments or comparable ethical principles.

RESULTS

This study is a retrospective cohort of 64 patients who had undergone tension-band wiring for transverse fractures of the patella. The following means and ranges were derived from the demographic profile: mean age (years) = 44.8 ± 17.1 (18–65 years) and mean follow-up period = 15.2 ± 5.4 months (range = 9–24 months). The sex distribution comprised 35 male patients (54.7%) and 29 female patients (45.3%) (Table 1).

Table 1. Demographic data

Variable		Value
Age, years		44.8 ± 17.1 (18–65)
Sex	Men	35
	Women	29
Follow-up, months		15.2 ± 5.4 (9–24)
Cerclage wire – patella superior pole distance, mm		6.3 ± 4.03 (1–20.4)
İmplant failure		10
Cerclage wire breakage		2
Cerclage wire displaced over K-wire		7
K-wire migration		1
Nonunion		2
Wound complications		3

The mean distance between the cerclage wire and the superior pole of the patella was 6.3 ± 4.03 mm. The distance ranged 1–20.4 mm. Clinical outcomes showed non-union in two cases (3.1%), in which partial patellectomy was performed. Site complications occurred in three wound-site cases (4.7%), and implant failures were noted in 10 cases (15.6%) (Table 1).

We observed K-wire migration in one patient (1.6%). Displacement of the cerclage wire over the K-wire was observed in seven patients (10.9%). Wire breakage was also observed in two patients (3.1%).

To assess the predictive value of cerclage-wire distance for clinical and functional outcomes, ROC-curve analysis was employed. The area under the curve (AUC) of 0.91 indicates high prognostic accuracy. This study also showed that this distance has high sensitivity and specificity for predicting implant failure (Figure 2).

Mean Modified HSS Knee Scores for different cerclage-wire distance categories were plotted to visualize the effect

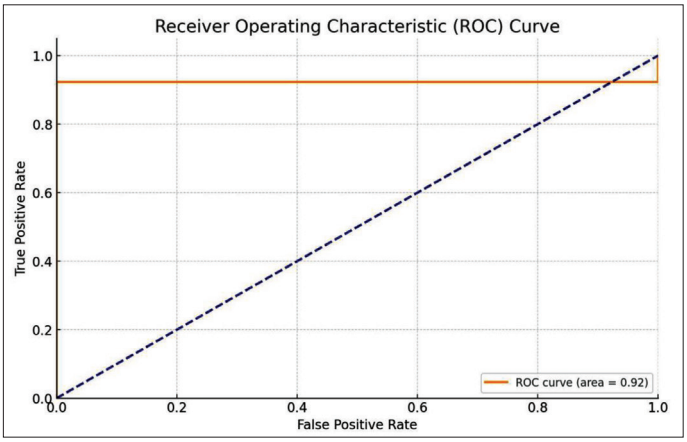

Figure 2. ROC curve predicting implant failure based on cerclage wire distance

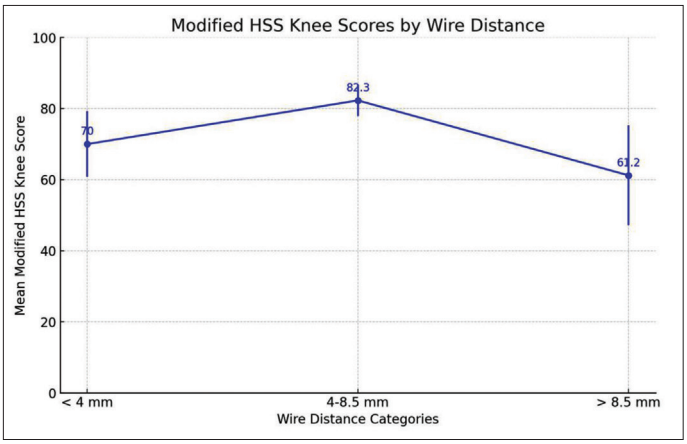

Figure 3. Modified Hospital for Special Surgery (HSS) Knee Scores by wire distance

of wire distance on functional outcomes (Figure 3). The highest mean score was observed in the 4–8.5 mm category, indicating better functional outcomes.

The effects of the distance between the bone and the cerclage wire on knee range of motion (ROM) were investigated. The knee ROM is illustrated in Figure 3 for different distances of the cerclage wire. The data show that there is a relationship between knee ROM and the distance from the cerclage wire to the bone. Patients with a distance < 4 mm had an average knee ROM of 108.6°. On average, patients with a 4–8.5 mm distance exhibited the highest knee ROM at 126.6°, whereas those with a distance > 8.5 mm reached only 80.6°. These results indicate that cerclage-wire distance significantly affects knee ROM. Placing the wire close to the bone (< 4 mm) or within the mid-range (4–8.5 mm) increases joint flexibility [11], whereas distances > 8.5 mm reduce motion. These findings are essential for defining an ideal cerclage-wire-to-bone gap. Patients with a distance between the cerclage and the superior pole of the patella < 8.5 mm were divided into two groups: group 1 and group 2. Age, union rates, implant failures and wound-site problems were analysed, showing no significant relationship with patient outcome. Among patients who did experience non-union, two of them (100% of non-union cases, 3.1% of all cases) also suffered implant failures. Of the three patients with wound complications, two (66.7%) also experienced implant failure (3.1% of cases) (Table 2).

Table 2. Parameter measurements

Variables	Group 1 (> 8.5 mm)	Group 2 (< 8.5 mm)	p
Knee ROM	126.6 ± 17.3°	80.6 ± 27.5°	> 0.001
Modified HSS Knee Score	82.3 ± 4.4	61.2 ± 14	> 0.001

ROM – range of motion; HSS – Hospital for Special Surgery

The mean arc of motion for the knees was 103.6 ± 22.4°, ranging from 60°–150°. The arc of motion differed significantly between the < 8.5 mm groups ($p = 0.001$) (Figure 3). The mean Modified HSS Knee Score was 71.7 ± 9.2, and individual scores ranged 45–100. The Modified HSS Knee Score was significantly reduced for cerclage-wire distances > 8.5 mm (p = 0.001) (Figure 2). Subgroup analysis, further within group 1, including patients whose cerclage-wire distances were > 4 mm and < 8.5 mm, showed that the former subgroup of patients had significantly lower clinical scores and ROM when compared to the latter subgroup at 4 mm and below (p = 0.03 and 0.04, respectively) (Table 3).

Table 3. Subgroup analysis

Variables	Group 1 (> 8.5 mm)		p
	> 4 mm	4–8.5 mm	
Knee ROM	120.4 ± 24.6°	132.9 ± 10.1°	0.04
Modified HSS Knee Score	74.2 ± 5.3	90.4 ± 3.5	0.03

ROM – range of motion; HSS – Hospital for Special Surgery

DISCUSSION

Our study aimed to evaluate how the distance that separates the cerclage wire from the bone affects clinical and functional outcomes in patients treated for patellar fractures using tension-band wiring (TBW). With wires in cerclage, we assumed that closer proximity would yield better function, reflecting the traditional surgical belief that greater mechanical stability leads to superior results.

In our results, the complications and clinical outcomes we observed with cerclage wires mirror similar studies in the literature. In the study conducted by Zhai et al. [13] it was reported that all patella fractures treated with percutaneous cerclage wire in geriatric patients healed and there were no serious complications such as infection or wire migration. In this study, one case of wire breakage was reported after six months. Yan et al. [14], in another study, treated combined patella fractures with a separate vertical-wire method supported by a cerclage wire. According to the study results, no complications such as loss of reduction, implant breakage, non-union or skin irritation were observed during an average follow-up period of 18.9 months. Li et al. [15] evaluated patellar fractures treated with modified cerclage wire in elderly patients. During a mean follow-up period of 22.2 months, fracture healing was achieved in all patients and no significant postoperative complications were reported [15]. Monaco et al. [16] compared patellar fractures treated using suture tape and metallic cerclage wire. The study reported no significant differences in re-operation rates, fracture-healing rates and functional outcomes between the two methods [16].

Our findings demonstrate that cerclage wire remains an efficacious technique in patellar-fracture management and, despite complications in some instances, generally produces good clinical results. Research studies reviewed here support the efficacy and safety of cerclage wire in treating patellar fractures.

Our findings reveal the influence of the distance between the cerclage wire and bone on knee ROM and functional outcomes. Modified HSS Knee Scores averaged across different distance categories showed that the 4–8.5 mm category achieved the highest scores. This is indicative of better functional outcomes. Therefore, we evaluated the effects of different cerclage-wire distances on knee ROM and their relationship. According to Yan et al. [14], using a separate vertical-wire method with a cerclage wire at an optimal distance yielded an average knee ROM of 131.3°. Kumar and Kumar found that anterior cerclage-wire insertion allowed knee flexion up to 125.4° [17]. Ninety-two percent of patients in a study by Kachare et al. [18] attained active flexion of 90° after one week following cerclage wiring with a figure-of-eight TBW technique. It clearly showed better functional results with correct placement of cerclage wires at an appropriate distance.

Our results confirm the effect of cerclage-wire distance on knee ROM and functional outcomes. Average Modified HSS Knee Scores again showed that the 4–8.5 mm group had the highest average score. It shows better functional results. Zhai et al. [13] reported effective treatment with percutaneous cerclage wire in elderly patients, with all fractures healing successfully. Mahajan et al. [19] indicated that stable fixation was achieved with low non-union rates when cerclage wire was used in combination. Meng et al. [20] found satisfactory clinical outcomes and low complication rates when using modified cerclage wire. A study by Raja et al. [21] demonstrated clinical improvement and reduced complications with cerclage-wire application. These findings suggest that correct use of cerclage wire improves knee ROM and functional outcomes.

The study found that clinical outcomes and knee ROM were better in patients with a cerclage-wire distance < 8.5 mm. Modified tension-band wire with cerclage was recorded to reduce postoperative complications by Yu et al. [22]. Harna et al. [23], in surgically managed non-union patellar fractures, demonstrated similar ROM. This is supported by a study by Kachare et al. [18], indicating low complication rates and rapid recovery with cerclage or figure-eight configurations. This therefore substantiates the claim that accurate cerclage-wire placement can improve clinical outcomes. Consequently, according to Xiang et al. [7], patients treated with absorbable cannulated screws and high-strength sutures experienced less displacement and improved clinical results. Such findings show that positioning is crucial for cerclage-wire distance in managing patellar fractures and, if done accurately, can improve overall treatment success.

The study, however, has some limitations: the wide age range (18–65 years) may introduce variability in bone quality and healing capacity that might influence outcomes independently of surgical technique. It is further beyond

our control that the study is retrospective, limiting adjustment for potential confounders.

Another limitation is that fractures were classified by AO type, which could bias results for more complex patterns [24]. Some patients had immobilisation for up to four weeks, especially those with implant failure. This could theoretically affect knee ROM and recovery, confounding the effects attributed to cerclage-wire distance.

To overcome these limits and better validate our results, future prospective studies with narrower age ranges and stronger design are required. Further histological analyses may unveil mechanisms underlying the biological impact of cerclage-wire proximity on surrounding soft tissues. In general, our study highlights an understudied aspect of patellar-fracture treatment. By addressing this gap, we add to refined knowledge of TBW techniques that should foster better surgical outcomes and more-precise treatment protocols.

CONCLUSION

This study assessed the effect of cerclage wire proximity to the bone in tension band wiring for patellar fractures. Contrary to common traditional belief, it was found that wires placed very close to the bone (4 mm and below) resulted in poorer outcomes. This has important implications for wire placement: Mechanical stability must be weighed against tissue integrity, specifically avoiding adverse effects on the quadriceps muscle. These findings challenge existing surgical dogma and suggest that further research is needed to refine surgical guidelines that balance both biomechanical and biological considerations for the ultimate benefit of patient outcomes.

Conflict of interest: None declared.

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Да ли ближе постављање серклажне жице побољшава функционалне резултате фиксације прелома пателе тензионом жичаном траком?

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САЖЕТАК

Увод/Циљ Преломи пателе најчешће се фиксирају техником тензионе жичане траке. Растојање између серклажне жице и горњег пола пателе сматра се пресудним за хируршки исход. Циљ студије био је да процени утицај овог растојања на клиничке и функционалне резултате.

Методе Спроведена је ретроспективна кохортна студија која је обухватила 64 болесника с попречним преломом пателе лечених техником тензионе жичане траке. Болесници су подељени у три групе на основу удаљености серклажне жице од кости: < 4 *mm*, 4–8,5 *mm* и > 8,5 *mm*. Клинички исходи обухватили су срастање кости, отказивање имплантата и компликације ране, док су функционални исходи оцењивани на основу опсега покрета и модификоване *HSS* (*Hospital for Special Surgery*) оцене за колено.

Резултати Исходи су значајно варирали у зависности од положаја жице. Болесници код којих је серклажна жица била постављена на мање од 4 *mm* од кости постигли су слабије функционалне резултате (средња модификована *HSS* оцена 70 ± 9,2; просечан опсег покрета 103,6 ± 42,4). Најбољи опоравак забележен је код болесника са жицом удаљеном 4–8,5 *mm*, који су остварили више оцене функције колена и већи опсег покрета. Статистичка анализа потврдила је да ближе постављање жице негативно утиче на клиничке исходе ($p < 0,05$).

Закључак Постављање серклажне жице сувише близу кости (< 4 *mm*) може да наруши функционалне резултате упркос очекиваној механичкој стабилности. Оптимално растојање од 4–8,5 *mm* обезбеђује бољу равнотежу између механичке стабилности и заштите меког ткива, што доводи до побољшаних клиничких и функционалних исхода. Ови налази доводе у питање конвенционалне хируршке приступе и наглашавају значај прецизног позиционирања жице у техници тензионе жичане траке.

Кључне речи: преломи пателе; тензиона жичана трака; серклажна жица; клинички исходи; функционални исходи; хируршке технике