

Treatment for transverse patella fractures with minimally invasive techniques (Review)

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Abstract. The transverse fracture pattern is the most common pattern among patellar fractures. Although open reduction with internal fixation using tension band wiring is the common method for treating the majority of transverse patellar fractures with displacement, this approach has distinct disadvantages, including damage to the blood supply and general post-operative complications. Therefore, minimally invasive techniques have been introduced to overcome these problems. In the present review, the advanced surgical procedures using Kirschner wires with cerclage, cannulated screw optioning of supplementary cerclage tension banding, external fixation and combined tension-band braided polyester with a suture button, as well as post-operative rehabilitation, were described in detail. To improve any malreduction due to poor control of the patellar articular surfaces, the utility of arthroscopically assisted techniques was also presented. The advantages and disadvantages of the above-mentioned techniques were also discussed. Minimally invasive techniques were demonstrated to achieve improved knee joint mobility, shorter hospitalization and more favorable outcomes. Such techniques decrease the risk of complications compared to conventional open reduction and fixation. Although specific problems associated with each technique still require to be resolved to reduce late complications, such as the onset of patella-femoral arthritis, minimally invasive techniques remain an alternative option for treating transverse patellar fractures.

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1. Introduction

Patellar fractures account for 1% of all the fractures that occur in adult patients. Approximately 70-90% of the fractures are transverse patterns that involve the middle third of the patella (1). Surgeries are required for patellar fractures with displacement of the fragments and/or articular surfaces. Conventionally, for the majority of transverse patellar fractures with articular incongruence of >2 mm, fragment displacement of >3 mm or a disrupted extensor mechanism, open reduction with internal fixation using tension band wiring is indicated. The goal of the operation is to facilitate anatomical reduction of the patellar fragments and articular surface to allow stable fixation (2). However, the widely used open technique has certain distinct disadvantages, including a large incision and extensive soft tissue disruption for adequate fracture visualization (3), damage to the blood supply (4), peripheral nerve (such as the saphenous nerve) disturbance (5) and the requirement of following prolonged rehabilitation (6). In addition, the open reduction method is associated with specific and general post-operative complications, which are as high as 60% according to the literature (7). These complications include irritation of devices (up to 43%) (8), broken wires (up to 25%), occurrence of infection (up to 14%) (9), delayed wound healing (10) and blood damage-associated patellar necrosis.

Considering the problems and complications of the conventional open reduction, minimally invasive techniques have been proposed to achieve improved knee joint mobility, shorter hospitalization and more favorable outcomes, and to decrease the risk of complications (11). The index procedures consist of fracture fixation through the following minimally invasive approaches: Kirschner wires with cerclage (12), interfragmentary screws and cannulated screws with the supplement of cerclage around or through the screws (13,14), external fixation (15) and combined tension-band braided polyester with suture button (16), which may not be familiar to clinical surgeons. The known advantages of the minimally invasive

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fixation technique are limited incision, which preserves the blood supply of the patella (17), and the simplicity of hardware removal after bone healing (18). However, malreduction of the articular surfaces emerges as the inherent drawback of these minimally invasive techniques. To solve this problem, arthroscopically assisted techniques have been introduced to facilitate anatomical reduction of the articular surfaces of the patella and to reduce the late onset of patella-femoral arthritis.

Although there have been several published articles describing the minimally invasive methods for the treatment of patellar transverse fractures up to date (12-16), there is a lack of summarized findings in this field. As minimally invasive techniques become increasingly common in surgical treatment procedures, an increasing number of orthopedic surgeons hope to obtain an improved understanding of the treatment of patellar transverse fractures with minimally invasive techniques. The aim of the present narrative review is to illustrate the advances in minimally invasive methods for treating patellar transverse fractures and to compare all minimally invasive techniques to provide evidence of successful patellar fracture treatment by minimally invasive techniques.

2. Kirschner wires with cerclage

The initial percutaneous tension band wiring using Kirschner wires with cerclage for the treatment of patellar fractures was documented as early as 1983 (19). During an operation using Kirschner wires, a stab incision at the superolateral margin of the patella was made to reach the fracture line. After drainage of the hematoma within the knee joint, the fracture was reduced percutaneously using a reduction clamp, while the image intensifier confirmed articular congruence. For Kirschner wire insertion, 2 parallel 1.5- or 2.0-mm Kirschner wires were percutaneously inserted into the fracture fragments with the knee placed in 40° flexion. A stainless-steel wire was then placed in a figure-8 fashion subcutaneously from the inferolateral portal toward its inferomedial portal of the patella, with the knee in extension. The wire was then reintroduced diagonally directly toward the superolateral portal through the inferomedial portal. The other side of the wire was reintroduced in the same manner. The knots were applied after the two ends of the wires were joined. The Kirschner wires were then bent proximally and cut at the distal ends with the knee in maximum flexion. Finally, the 4 portals were closed (12). Physiotherapy was performed as early as 12 h after surgery. A knee immobilizer was used for walking and weight bearing as early as post-operative day 2 (8).

Technical difficulty was deemed the major disadvantage of the percutaneous Kirschner wire fixation method (8). This disadvantage was observed not only for the placement of K-wires with steel wires in a figure-8 fashion, but also when the knot was submerged percutaneously (12). The main reason for fixation failure was a technical fault in the placement of the tension-band wire and wire twists (20). When it was not possible to achieve satisfactory reduction, it may have been necessary to resort to open reduction. After the operation, patients suffered from distinct disadvantages of implant irritation and incidence of palpable implants (13). This technique was used for a long time and was mainly replaced by other techniques such as percutaneous cannulated screw fixation.

3. Cannulated screws

The use of cannulated screws was introduced as a minimally invasive treatment approach to overcome the disadvantages of implant irritation by Kirschner wires. Satisfactory reduction was achieved using a reduction clamp along with an assessment of the image intensifier. Thereafter, Kirschner wires were percutaneously placed with the knee flexed to 15-25° for fragment stabilization. A total of two cannulated screws with diameters of 3.0/4.0 mm and lengths of 35-60 mm were inserted percutaneously to the fracture line percutaneously to fix the fragments with the assistance of guide wires. After cannulated screw insertion, the screw head was to be buried into the cortical bone (13). Knee flexion and extension were performed to check the stability of the knee joint. A third cannulated screw maybe used to enhance stability, particularly to treat patients diagnosed with osteoporosis or osteopenia. Soon after the operation, patients were allowed to perform quadriceps-femur contraction. Passive range of motion (ROM) began at the early time-point, depending on the pain tolerance of patients. Patients were encouraged to perform the active ROM 3 weeks post-operation and full weight bearing along with flexion-extension exercise started at 8 weeks post-operation (6,14).

Lin *et al* (13) once reported that cannulated screw fixation in a minimally invasive manner had significantly improved clinical results compared to open reduction and internal fixation groups measured using the score. Favorable ROM, lower pain scores, early mobilization and a lower incidence of complications were also noted (13). Early knee motion was beneficial for joint cartilage nutrition, thus preventing intra-articular adhesions and muscular atrophy owing to immobilization (21). At the 12-month follow-up, patients from both minimally invasive and open reduction and internal fixation groups had similar outcomes, including the mean time to union (13). Biomechanical studies indicated that the tension band wiring was only able to transform the distraction force into a compression force and was not able to achieve direct fracture site compression. By contrast, percutaneous cannulated screws were able to provide a direct compression force among the fragments. These screws were more stable and rigid for fracture fixation in the patella (22-24). Therefore, certain studies demonstrated that stabilization of patellar transverse fractures with screws or screws with tension band sled to significantly reduced displacement (25) and soft-tissue irritation and a lower rate of hardware removal (20) than fixation with Kirschner wires and modified tension bands. However, a previous clinical report by Berg (26) demonstrated that the result of this technique was similar to that of modified tension band wiring.

4. Cannulated screws with cerclage

Carpenter *et al* (27) once demonstrated that the combination of cannulated screw and tension band principles provided improved fixation strength compared to that of using the cannulated screw approach alone. During an operation using cannulated screws with cerclage, cannulated screws were first inserted by the means mentioned above. It should be noted that the screws must be shorter than the cortex to avoid cutting the wires through attrition. Figure-8 wiring was performed after the first monofilament stainless steel wire (1.2 mm) passed through the first

cannulated screw antegradely. The distal side of the wire was removed from the distal incision. As a cannula, a suction tip was inserted subcutaneously into the distal incision of the first screw from the proximal incision of the second screw. The wire was then guided toward the proximal incision of the second screw within the suction tip. A similar step was duplicated for the second stainless-steel wire. Finally, the proximal sides of the two wires from both proximal incisions were twisted. The reduction of fragments and the stability of fixation were inspected under fluoroscopy with knee flexion of 90°. This method was reported to allow easy penetration of the wires that passed through the cannulated screws and to permit straining of the wires for extra strength (14). After the operation, neither a splint nor a brace was used. The rehabilitation schedule was similar to that of patients when they were treated with the simple cannulated screw technique. The biomechanical analysis performed by Carpenter *et al* (27) indicated that the figure-8 wiring passing through the cannulated screws created more rigid internal fixation and provided increased mechanical strength compared to the modified tension band technique or screws alone.

Tandogan *et al* (17) reported a method with figure-0 cerclage over the two cannulated screws. After insertion of cannulated screws, an 18-gauge stainless steel wire was used to pass through the 2 screws. First, the wire was inserted through the first screw subcutaneously from the proximal side to the distal side. Subsequently, the wire was passed from the distal side of the second screw toward the proximal side. The two sides of the wires were tied under tension and buried percutaneously. Although the authors claimed that this method achieved satisfactory results, biomechanical evaluation and long-term results were absent.

Certain minimally invasive integrated devices for internal fixation have also been proposed. For instance, the cable pin system (Cable-Ready; Zimmer®) was proposed to combine the concepts of cables (figure-8 cables) and pins (paralleled pins) (28). One side of the cable pin system contained a partially threaded cancellous screw (4.0-mm) with a length of 35-60 mm. The thread was able to offer compression between fragments. A specially braided cable connected the other side of the system and guided the needle to pass through patellar tunnels. The design provided excellent strength and great pliability to the cable, ensuring increased stability and decreased complications associated with the stainless steel wire (29). The cable pin system using the minimally invasive operation technique was reported to be superior to open reduction and internal fixation with a higher functional score, an improved ROM of the injured knee, reduced early post-operative pain and a decreased incidence of complications (30). However, there is still a lack of research tracking the long-term results.

5. Arthroscopically assisted techniques

Despite the advantages of percutaneous minimally invasive techniques, a potential drawback of the poor reduction of the patellar articular surface has aroused attention. Since Sattler and Schikorski (31) first described percutaneous reduction and fixation with the assistance of arthroscopy for displaced transverse patellar fracture in 1987, arthroscopically assisted techniques have been widely applied in the minimally invasive

treatment of patellar fractures. During the operation, arthroscopy was performed in our group via standard anterolateral and anteromedial portals, at times with the auxiliary superolateral portal, which was 1 to 2 cm superior and lateral to the patellar superolateral corner. After the hematoma was drained and irrigated, clots and debris were removed to visualize the fracture lines. From the superolateral portal, an arthroscopic probe was used to manipulate the fragments to achieve reduction with the potential aid of percutaneously placed towel clamps. All the above techniques were performed under arthroscopic control.

The advantages of arthroscopic assistance in the treatment of patellar fractures are as follows: Visualization of the patellar articular surface for reduction (14), easy removal of small fragments (4,6), decompression of intra-articular hematomas for pain relief (32) and assurance that the implanted screw did not intrude into the knee cavity (6). The reduction and stability of the internal fixation was able to be confirmed with arthroscopy, particularly when flexing and extending the knee (33). All of these advantages indicated that the use of arthroscopically assisted techniques may decrease the risk of nonanatomic reduction as well as the risk of late onset of patella-femoral arthritis (34). However, there were still certain limitations to arthroscopically assisted techniques. These techniques were not suitable for treating comminuted fractures with multiple and displaced fragments or disruption of the extensor mechanism (32).

6. Compressive external fixation

Since Liang and Wu (35) first described the external compressive fixation of patellar fracture in 1987, this method has been unintermittently reported and continuously improved. Referring to the study of Wardak *et al* (2) on a circular external fixation method under arthroscopic control, the fracture fragments were reduced by a percutaneous bone clamp under fluoroscopy guidance in extension. Afterwards, two 1.6-mm wires were placed horizontally through the proximal fragment and another two wires passed through the distal fragment in parallel. The wire pairs were placed far from the fracture line to allow compression between the fragments by bowing the wires. The wires were then passed through the holes of the clamp assembly device. After joining these parts, the nuts were tightened to secure the wires. By turning the nut and tensioning the wires, the two parts of the device were distracted. The stability of fixation was checked through knee flexion and extension under the guidance of fluoroscopy (2). This method achieved a stable construction allowing immediate rehabilitation. The authors declared that, compared to most other post-operative regimens, no imposed activity restrictions or no other bracing were required and no fixation failure was observed.

Compressive external fixation capitalized on the advantages of both internal compressive fixation and external devices, which were particularly useful in setting open fractures, preventing infection and not aggravating compromised skin. Upon healing, the device could be easily removed. Early discharge and avoidance of another open operation for hardware removal were economic advantages of the technique regarding the cost (36). However, there were issues of concern about the associated complications and the rigidity of fixation (15).

7. Tension-band braided polyester technique

In addition to classic metal internal screws and external fixators, there were also certain other tension-band based constructs used for minimally invasive techniques (36), such as the double parallel suture button technique combined with a braided polyester tension-band (figure-8) suture. This approach was first proposed by Chen *et al* (37) in 2013 and reported afterwards (16). During an operation with this technique, diagnostic arthroscopy was first performed and then, two short incisions were made transversely proximal and distal from the fracture line. After fracture reduction with the help of a pointed reduction clamp percutaneously placed under fluoroscopic guidance, a 2.0-mm hole was drilled retrogradely for preparation of the definitive hardware. After X-ray confirmation, the drill hole was enlarged to 3.5 mm and the suture button (TightRope®; Arthrex) was then passed centrally through the drilled tunnels. The suture button was tightened and the braided polyester suture was added in a figure-8 fashion over the ends of the button. Finally, patellar stability after fixation was examined under the dynamic guidance of arthroscopy. The authors reported that the technique was associated with a lower risk of complications under the promise of adequate fracture healing.

8. Discussion

Displaced patellar fractures require stable anatomic fixation to allow early weight bearing and rehabilitation. In the present study, several minimally invasive patella osteosynthesis techniques were introduced and described in detail. These techniques associated with a lower amount of pain were demonstrated to result in reduced soft-tissue damage, minimal intraoperative blood loss, earlier mobilization and rehabilitation, reduced joint adhesions or ankylosis, a higher functional score of the knee and a lower incidence of wound complications post-operation compared to the outcomes of other methods (38).

Percutaneous tension band wiring using Kirschner wires with cerclage was the first minimally invasive technique introduced. Technical difficulty and implant irritation were the disadvantages of this method. As a result, in clinical practice, this technique was frequently substituted by cannulated screws with or without cerclage (11). Percutaneous cannulated screws are able to provide a direct compression force among the fragments with reduced soft-tissue irritation and a lower rate of hardware removal. The assistance of stainless steel wire as a tension band was partially demonstrated to provide improved fixation strength but was indicated to increase the risk of wire cutting. Regarding the possibility of assistance of stainless steel wire presented in the current literature, the routine use of stainless steel wire for percutaneous cannulated screw fixation should not be recommended except for patients with fragments with severe distraction. The newly introduced integrated cable pin system appears to be an alternative for minimally-invasive surgery but warrants long-term exploration.

Arthroscopically assisted techniques were introduced with the benefit of visualization of the patellar articular surface and removal of small fragments (32). The assistance of arthroscopy for minimally invasive operation of patellar fracture in clinical practice may be generally recommended. However,

the technique was technically demanding and not suitable for fractures accompanied by disruption of the extensor mechanism (4,33). Other minimally invasive techniques were occasionally used in certain special situations. Compressive external fixation was particularly useful for treating patients with open fractures and infection, and those with compromised skin (2). Upon healing, the device may be easily removed.

The limitation of the minimally invasive techniques was that the reduction may be relatively difficult through the minimally invasive incision when there are multiple fragments at the fracture site. Therefore, this approach is not suitable for patients with severely comminuted patellar fractures. It is also possible that minimally invasive techniques are associated with complications that may not have been identified due to the short follow-up time and thus, longer follow-ups may be required in the future.

9. Conclusion

In the present review, the minimally invasive techniques, including the use of Kirschner wires with cerclage, cannulated screws without or with supplementary cerclage tension banding, external fixation, combined tension-band braided polyester with a suture button and arthroscopically assisted techniques, were described in detail. Except for the Kirschner wire technique, minimally invasive techniques are being increasingly frequently applied. Compared to the outcomes of conventional open reduction and fixation, these techniques required a smaller incision that preserved the blood supply of the patella, resulted in lower soft-tissue irritation, provided improved clinical results and complications were reduced. However, each technique still had issues to be resolved to reduce late complications.

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Availability of data and materials

Data sharing is not applicable to this article, as no datasets were generated or analyzed during the current study.

Authors' contributions

XYM designed and wrote the review. BL searched literature. LBX and DPZ revised the review. All authors read and approved the final manuscript. Data authentication is not applicable.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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