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A novel anatomical patellar plate for transverse patellar fracture – A biomechanical in-vitro study

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ABSTRACT

Objective: The aim of this study was to assess the safety and stability of our novel anatomical patella plate and to compare its stability with tension band-wire technique.
Methods: A total of 12 cadaveric preserved knees (six right and six left patellae) with close patellar size were chosen to form two groups of six samples. Each group received either plate or tension band-wiring fixation for an experimentally created patella fracture. Cyclic load of an average of 350 N was applied for all specimens and after accomplishing 50 cycles the displacements of all fracture edges were recorded.
Results: After completing 50 cycles in each group, the average fracture edges displacement measured in the plate group was 1.98 ± 0.299 mm, whereas the average fracture edges displacement measured in the tension band-wire group was 2.85 ± 0.768 mm ($p = 0.016$).
Conclusion: In the operative treatment of displaced transverse patellar fractures, the strength of fixation obtained by titanium curved plates is highly stronger when compared to the fixation with a tension band-wire technique. Fixation with titanium curved plates provides satisfactory stability at the fracture site which allow withstanding the cyclic loads during the postoperative rehabilitation.

Introduction

Transverse patella fractures are commonly encountered in trauma surgery, open reduction and internal fixation are considered the gold standard treatment modality that could permit early knee motion and immediate rehabilitation.[1,2] Many fixation methods had been defined and compared to each other's in many clinical and biomechanical studies.[3–5] However, the tension band fixation method is still the most commonly used technique in patellar fracture fixation.[5,6] K-wire migration, tension band failure and surrounding soft tissue irritation are very common complications encountered in 22–30% of all cases. Consequently implant removal revision surgery may be required in 65% of cases.[7–9]

Inspired by the success of inter-fragmentary lag screw implants in various clinical applications, we introduced a double anatomical curved-plates specifically designed for fixation of patellar transverse fractures.

The goal of this study is to assess the biomechanical properties of the novel anatomical patellar plate and compare it to the most widely applied internal fixation devices, i.e. tension band-wire technique, in cadaveric patella fractures.

Material and method

After obtaining the approval of the ethical committee, resembling to previous studies,[10,11] out of 38 cadavers, 12 knees (six right and six left knees) with close patellar size were selected from our anatomy department for biomechanical examination. They were preserved in formalin based dilution for at less than 1 year. Donors were 10 men and 2 women. The selected 12 knees were divided into two groups (the right patellae were used for the titanium plate group and the left patellae were used for the tension band-wire group), each group contains six cadavers. The soft tissue was dissected leaving the knee joint capsule, ligaments, medial and lateral retinaculum and extensor mechanism intact. All patellae were horizontally osteotomized by an electrical saw to obtain a transverse patellar fracture before performing the fixation.

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K-wire tension band technique

The classical modified anterior tension wire technique is performed with two 2.0 mm stainless steel K-wires, which were drilled into the patellae parallel to each other and perpendicular to the osteotomy line. A 1.25 mm stainless steel wire loop was inserted around the protruding superior and inferior ends of the K-wires, to form a figure-eight on the anterior surface of the patella. The wires were twisted manually and tightened until a stiff and stable fixation was achieved (Fig. 1).

Anatomical curved-plate technique

The 3.5 mm titanium anatomical curved plate (TIPSAN CO. Company, Izmir-Turkey) has a 1 mm body thickness, 1 cm body width and two hook-like blocks at both ends. The anatomical patellar plate is available in eight variable lengths ranging from 25 mm to 60 mm, which were specifically designed to fit on the patellar anterior surface. One hole is present on each hook-like end blocks of the plate, the proximal hole of the plate is not threaded, designed to receive the screw head, whereas the distal hole is threaded to receive the threaded part of the screw. The plate is prebent in a semicircular shape to anatomically fit the anterior patellar surface. When the screw is introduced through the proximal non-threaded block, it passes to the distal threaded block, where the screw can exert its lag effect. The flexible nature of the plate allows lag effect compression of the screw which happens between the head of the screw settled in the non-threaded proximal block and the threaded distal block. Additionally it maintains the reduction by buttressing the anterior surface of the patella against deforming forces. After reduction of the transverse fracture, two 1.6 mm guide K-wires are placed parallel to each other's to stabilize the fracture. A 3.2 mm canulated drill pit is used to open the tract for screw entrance, then a 3.5 mm tap is used to prepare the tract for lag screw insertion. After getting the appropriate plate and screw sizes, the proximal part of the plate is placed through the guide wire, whereas the distal part is inserted through the distal part of the guide wire to rest on the anterior surface of the patella to prepare for screw insertion (Fig. 2). A 1/3 threaded canulated cancellous 3.5 mm screw can then be advanced through the guide wire till it meets the threaded distal end of the plate to exert it's inter-fragmentary compression (Fig. 3).

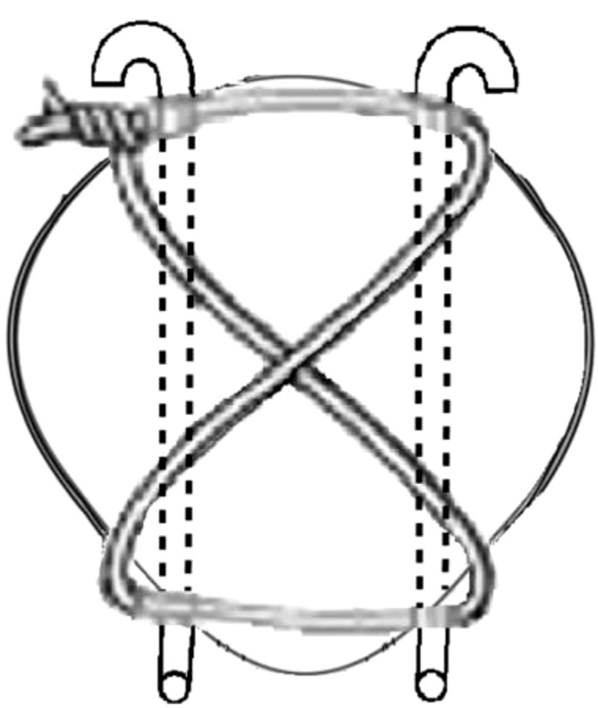

Fig. 1. The classical modified anterior tension band-wire technique.

Mechanical testing

All samples were tested by exerting a knee motion from full extension to 90° flexion by applying traction to the quadriceps tendon (Fig. 4). Due to the different contracture conditions between the cadaveric knee joints, it was not possible to use the same traction load to obtain a full extension in each joint. The fracture gap before starting the test was 0 mm for all specimens and this indicates a successful anatomic reduction of the patella fractures. The testing protocol composed of two parts, the first part consisted of a multiple cyclic loading, composed of 50 cycles for each sample, whereas the second part consisted of loading to failure trial. In each sample a 70 N preload was applied to the steel-sling in order to keep it completely tensioned. A tractional load was applied in each cycle with a speed of 200 mm/min till a full extension takes place. Cyclic loading composed of 50 cycles between 275 N and 420 N at a speed of 200 mm/min. At the end of the 50 cycles the fracture edges displacement in each sample was recorded.

For the statistical analysis the Man Whitney-U test was conducted. Statistical significance level was set at $p = 0.05$.

Results

An average load of 350 N was applied to the quadriceps tendon to obtain a full extension in all knees, the maximum load applied was 420 N, whereas the minimum load applied was 275 N. The load versus displacement for the two techniques were shown in Fig. 5 (Fig. 5).

The fracture gap measurements increased with the load applied up to a point and subsequently decreased. The peak in the fracture gap occurred at the middle of the range of flexion.

In order to obtain the same range of motion (from 90° flexion to full extension) in every sample every test cycle was controlled by the crossbar's travel distance required to simulate the desired range-of-motion. In spite of the anatomical differences between the specimens, the required average load in the plate group was 354.16 N and in the tension band-wire group was 345.83 N, they did not differ significantly ($p = 0.84$) (Table 1). In the first part of the trial, after completing the 50 cycle in each group, the average fracture edges displacement measured at the middle range of flexion in the plate group was 1.98 ± 0.299 mm, whereas the average fracture edges displacement measured at the middle range of flexion in the tension band-wire group was 2.85 ± 0.768 which was statistically significant than the first group with a P value of 0.016.

In the second part of the trial, gradual loading to failure was applied to both groups. In the tension band-wire group only two cadaveric samples completed 100 cycles. Four cadaveric knees failed before completing the 100 cycles at an average of 78 cycles with a minimum load of 480 N and a maximum load of 650 N. The remaining two cadaveric samples which completed the 100 cycles, failed at 685 N and 720 N. Whereas in the plate group, implant failure took place in one cadaveric sample after 85 cycles with a load of 570 N. Two cadaveric samples failure took place after 100 cycles with loads of 650 N and 735 N, three samples completed the 100 cycles and further loading up to 800–850 N leaded to a rupture of the quadriceps tendon at the steel-sling apparatus (Table 2). The results of loading to failure were not comparable due to the rupture of the quadriceps tendons.

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