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Original Article

Cannulated screws combined with vertical figure-of-eight wire technique in distal pole fractures of the patella

Jian Fan, Xin Zhang, Feng Yuan, Shanzhu Li

Department of Orthopedic Surgery, Tongji Hospital, Tongji University, Shanghai, China

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Abstract: The distal pole of patella plays a crucial role in the biomechanical function of the knee joint and it is extremely surgically challenging to perform a stable fixation for these fractures. To investigate clinical and radiological outcomes of cannulated screws combined with vertical figure-of-eight wire for the treatment of distal pole fractures of patella. Eleven patients with acute distal pole fracture of the patella were operatively treated by cannulated screws combined with vertical figure-of-eight wire. The knee mobility and function evaluated by Böstman scoring were analyzed postoperatively. In addition, fracture healing, fixed position and the length of patellar length were investigated by radiographic examination. Occurrence of complications was also assessed to the effects of this treatment. All patients were assessed at a mean 17.2 months' follow-up. At the 12th postoperative week, all the cases achieved radiological union. At the 12th postoperative month, knee flexion ROM was 132.0˚±4.5˚, knee extension ROM was 0.6˚±1.8˚, and the mean Böstman score was 28.2±0.8 points with 9 excellent and 2 good cases. There were also no statistical difference in the length of the patella between 12 weeks and 12 months and no significant complications were observed during the whole follow-up period. Cannulated screws combined with vertical figure-of-eight wire demonstrated excellent results and could be a recommended surgical method for fractures of the distal pole of the patella.

Keywords: Distal pole fracture of patella, vertical figure-of-eight wire, efficiency analysis

Introduction

The patella is the largest sesamoid bone in the human skeleton, which comprises of the proximal articular body and the extra-articular distal pole. As the origination of patella tendon, the distal pole of patella plays a crucial role in the biomechanical function of the knee joint. The length of the distal pole of the patella is about 15 mm and also accounts for approximately 17% of all the patella fractures. In clinical practice, fracture fragments are usually found small, which sometimes even smashes into pieces [1]. Therefore, it is extremely surgically challenging to perform a stable fixation without disrupting the anatomical structure and disturbing the vascular circulation in such narrow area.

The surgical management of the distal pole fractures of the patella is variable and requires individualization of technique [2]. Partial patellectomy and reattachment of the patellar tendon has been gradually abandoned for obvious limitations such as the significant loss of extensor strength and the delayed rehabilitation so on [3, 4]. Kirschner wires and cannulated screws with tension band are the commonly accepted, particularly for transverse patellar fracture cases. However, these techniques are not applicable for the cases with small bone fragments due to the difficulty in surgical procedure and the high risk of fixation failure [5, 6]. Consequently, the modified tension band wiring technique, which can effectively inhibit the interaction between the tibial tubercle and patella, has been developed. But it was also reported to increase the incidence of complications such as implant irritation and loose of Kirschner wires [7, 8]. According, the basket plate, which is designed to embrace and sustain the distal pole fracture fragments, also has been found to have significant disadvantages such as induced extensive soft tissue irritation, destruction and material usage limitation [9-12]. While the technique of non-absorbable suture anchor system could cause minor dam-

Table 1. General characteristics of the patients

Case	Age (y)	Sex	Injury mechanism	Commi-nution	AO/OTA Classification	Time from injury to surgery (days)
1	35	M	Slipping	Yes	34A1	1
2	41	M	Slipping	No	34A2	2
3	48	F	Traffic accident	Yes	34A1	4
4	22	M	Slipping	No	34A1	1
5	67	M	Traffic accident	Yes	34A2	2
6	72	F	Traffic accident	Yes	34A1	8
7	29	F	Slipping	No	34A2	3
8	75	M	Traffic accident	Yes	34A2	9
9	33	F	Slipping	No	34A1	2
10	68	M	Traffic accident	Yes	34A2	5
11	59	M	Traffic accident	Yes	34A1	3

F: female, M: male.

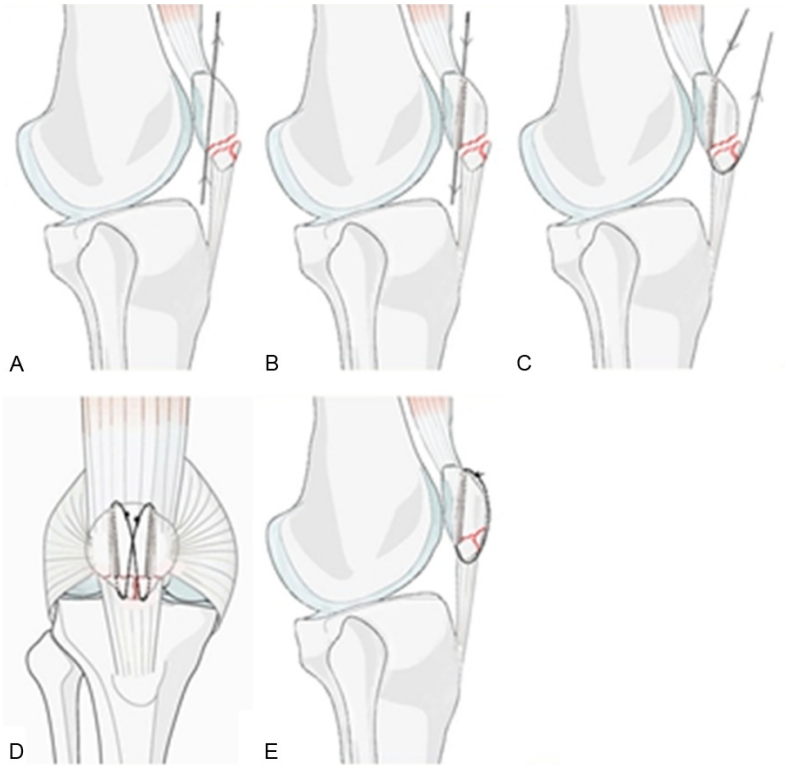

Figure 1. A schematic photograph of cannulated screws treatment combined with figure-of-eight wire for distal pole fractures of the patella. A. Two guide pins were penetrated the cortex of the patella in a proximodistal direction. B. 4.0-mm-diameter cannulated screws were inserted along the pin tracts in a cephalocaudal direction until the whole screw was embedded into the patella. C, D. 1.2-mm-diameter wire was inserted into cannulated screws from tail side to head side and penetrated through the patellar ligament to be placed in a figure-of-eight pattern. E. The wire was tightened following satisfied reduction.

ages and avoid the second-stage surgery; its use still remains controversial owing to its uncertain endurance of early functional rehabilitation [13]. In 2003, separate vertical wiring technique, which has a number of advantages such as providing stable internal fixation, causing less damage of soft tissue and permitting early functional rehabilitation, was introduced by Yang and used in clinic as a recommend method [14]. But after ten more years, obvious flaws including friction and/or displacement of bone fragments, especially for the patients with osteoporosis, were also exits along with this technique in practice. Thus, an optimal surgical approach is still being sought in clinical practice.

Based on anatomy and morphology, we optimized Yang' separate vertical wiring technique and introduced cannulated screws combined with vertical figure-of-eight wire for the treatment of distal pole fractures of the patella. This treatment was aimed to maintain the stability of internal fixation as well as reduce the friction and/or displacement of bone fragments. Therefore, it could provide satisfied clinical outcomes and cause less clinical complications. The primary goal of the current study was to evaluate the clinical and radiological outcomes of this technique in an effort to determine its whole clinical effectiveness.

Materials and methods

Patients

A series of 11 cases that underwent cannulated screws combined with vertical figure-of-eight wire for the fracture of the distal pole of the patella at XX hospital affiliated XX University between September 2013 and July 2015 were identified and reviewed in the study.

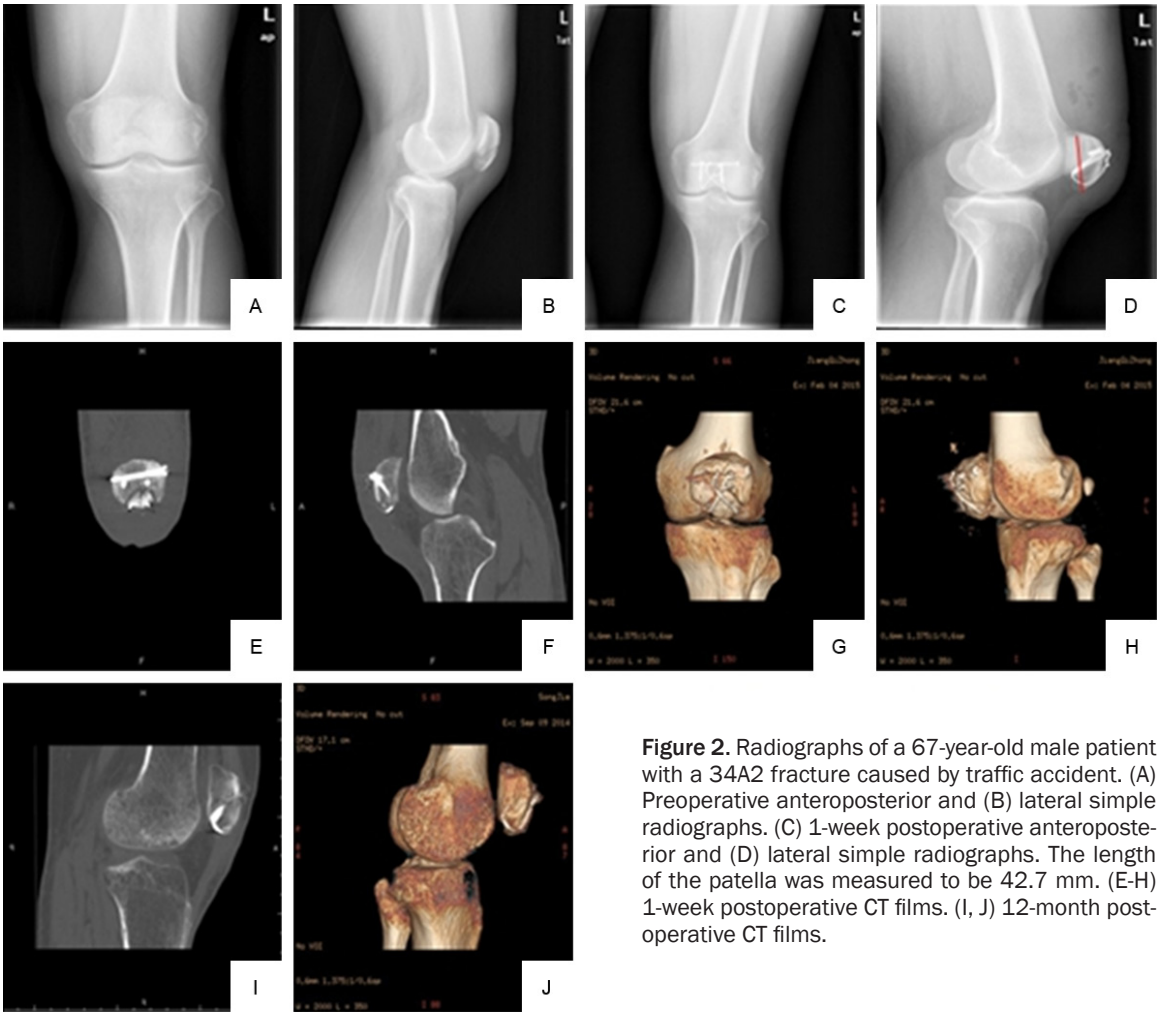

Figure 2. Radiographs of a 67-year-old male patient with a 34A2 fracture caused by traffic accident. (A) Preoperative anteroposterior and (B) lateral simple radiographs. (C) 1-week postoperative anteroposterior and (D) lateral simple radiographs. The length of the patella was measured to be 42.7 mm. (E-H) 1-week postoperative CT films. (I, J) 12-month postoperative CT films.

Among the 11 cases, 7 of them were males and 4 were females with an average age of 49.9 years (range, 22 to 75 years). All cases were fresh enclosed single-side fracture, 4 of which were simple fractures and 7 were comminuted fractures. According to the AO/OTA fracture classification scheme, 6 cases were classified as 34A1 and the other 5 were classified as 34A2. The cause of injury was traffic accident and slipping in 6 and 5 cases, respectively. In addition, preoperative CT was conducted for each patient. The mean time from injury to surgery was 3.6 days (range 1 to 9 days). All the operations were performed by the same surgical team under the C-arm image intensifier control (**Table 1**).

Measurement

Following anesthesia, positioning, exposure and reduction, cannulated screws combined with vertical figure-of-eight wire technique was conducted (**Figure 1**). Firstly, the position of wire was determined based on the midpoint of the fracture fragments. Two guide pins were then penetrated the cortex of the patella from the posterior fracture line, which is closely approached to patellar articular surface and with slightly lateral deviation, to the anterior musculus quadriceps femoris. Subsequently, screw lengths were measured and 4.0-mm-diameter cannulated screws were drilled in a cephalocaudal direction along the pin tracts until the whole screw was embedded within the patella. Thereafter, 1.2-mm-diameter wire was inserted into cannulated screws from tail side to head side and the wire tip was penetrated through the patellar ligament at Margo inferior of middle point of the distal fragment. Consequently, the steel wire was placed in a figure-of-eight pattern and tightens by a wire cutter. For the majority of cases, the distal frac-

Table 2. Clinical examination results at 12th postoperative week

Case	Knee flexion ROM	Knee extension ROM	Flexion lag versus contralateral healthy leg	Böstman Score	Complication
1	137˚	0˚	0	30	No
2	133˚	3˚	0	30	No
3	129˚	-2˚	5	29	No
4	130˚	-5˚	3	28	No
5	132˚	4˚	0	28	No
6	127˚	5˚	8	27	No
7	129˚	3˚	0	29	No
8	134˚	1˚	0	29	No
9	139˚	0˚	0	30	No
10	124˚	5˚	10	26	No
11	128˚	-4˚	5	25	No

Table 3. The length of the patella at different time points

Cases	Length of the patella (mm)		
	Immediate postoperative	12th postoperative week	12th postoperative month
1	37.4	38.1	37.6
2	40.8	40.5	40.7
3	41.8	40.9	41.3
4	41.3	41.3	41.1
5	42.7	41.8	41.9
6	38.2	37.9	38.4
7	38.9	38.9	40.0
8	40.3	40.6	40.1
9	43.1	43.4	43.7
10	39.1	39.0	39.5
11	44.3	43.9	44.1

ture of the patella could be effectively fixed. Separated vertical wiring and Kirschner wire techniques could also be performed to make an additional fixation for large bone fragment. Besides with visual examination, the stability of reduction and fixation were evaluated with C-arm image intensifier by the intraoperative flexion-extension activities of the knee joint. Then, routine suture of subcutaneous tissue and skin was conducted and external immobilizer was not utilized for any of the patients.

Postoperative care and evaluation

All patients received a routine administration of antibiotic reagent in the initial 48-hour postoperative period. In addition, a standard postoperative rehabilitation program was prescribed for each patient. Patients were encouraged to perform isometric quadriceps femoris strengthening exercises soon after the surgery, and passive knee-joint flexion-extension activities from 45^0 to 0^0 by CPM machine three days after the surgery and from 90^0 to 0^0 about seven days after the surgery. Patients were permitted to perform active joint activities from 60^0 to 0^0 as well as partial-weight-bearing walking with crutch assistance at two weeks postoperatively. Active joint activities from 120^0 to 0^0 were allowed at four weeks postoperatively and full-weight bearing takes after radiological union was achieved. All patients were followed up with clinical and radiological examinations at 2, 4 and 12 weeks, 6 and 12 months postoperatively. Annual follow-up was still performed for each patient afterwards.

Clinical outcomes were evaluated by knee joint range of motion (ROM) and Böstman clinical grading scale. According to Böstman scoring, the overall knee function was graded as excellent (28-30), good (20-27), and unsatisfactory (<20) [15]. For radiological assessment, union of the fracture, the length of the patella and the position of internal fixation were examined (**Figure 2**). The length of the patella, which presents the distance from the upper pole to the distal pole of the patella and is briefly parallel with the articular surface (**Figure 2D**). Meanwhile, the surgical complications such as soft tissue infection, implant irritation, wire breakage and migration were also followed up.

Statistical analysis

Statistical analyses were performed by using SPSS (version 13.0; SPSS Inc, Chicago, IL, USA). All parameters were expressed as mean ± standard deviation (SD). The significant differences in the length of the patella among different time points were identified by One-way Analysis of Variance (ANOVA) and Tukey's post-hoc. $P<0.05$ was considered statistical significant.

Results

Average follow-up period of all these 11 patients was 17.2 months (range, 12 to 32 months). At the 2nd postoperative week, incision of each

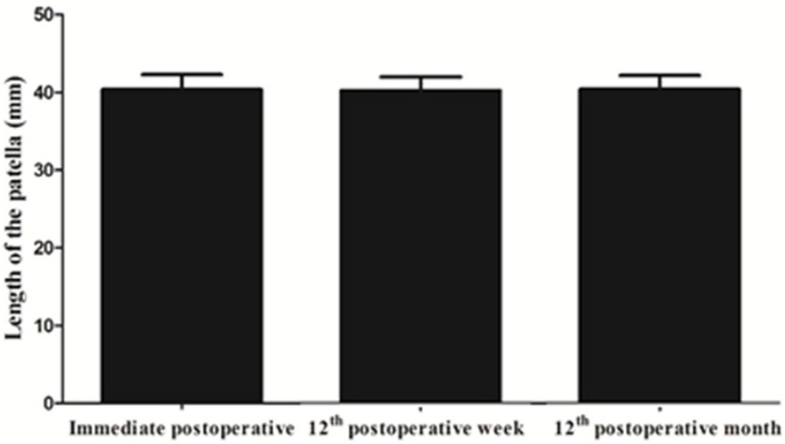

Figure 3. Differences in the length of the patella. No significant difference was observed according to the results obtained immediate postoperatively, 12 weeks postoperatively and 12 months postoperatively.

case was well healed and sutures were then removed. Meanwhile, radiological examination also demonstrated appropriate places of internal fixation and continuous fracture lines. At the 12th postoperative week, all the cases achieved radiological union described as the loss of the fracture line and the continuity of trabeculae. Moreover, according to the clinical examination, knee flexion ROM was 124.0˚± 5.5˚, knee extension ROM was 2.0˚±2.7˚. The mean Böstman score was 26.7±1.3 points with 7 excellent and 4 good cases. At the 12th postoperative month, knee flexion ROM was 132.0˚±4.5˚, knee extension ROM was 0.6˚±1.8˚, and the mean Böstman score was 28.2±0.8 points with 9 excellent and 2 good cases (**Table 2**).

In addition, apart from the immediate postoperative phrase, the lengths of patella were also measured at the 12 weeks and 12 months postoperatively (**Table 3**). There was no statistically significant difference in the length of the patella was found among the results obtained from different time points (**Figure 3**). Furthermore, no significant complications such as loss of reduction, migration of hardware and irritation of implants were observed during the whole follow-up period.

Discussion

Although the distal pole of the patella does not articulate with the femur in the patella of femoral joint, it is the origination of patella tendon and plays an extremely essential role in the knee movement. The shortness of the length of the patella after fracture was proved to cause a severe motional dysfunction of the knee joint [16]. So, several surgical techniques have been developed for distal pole fractures of the patella. However, each surgical approach has been illustrated to have significant complications and limitations so far. Until 2003, the technique of separate vertical wiring for distal pole fracture of patella was firstly proposed by Yang. It was reported that most cases (92%) obtained ideal clinical outcomes by this method and internal fixation failure caused by wire loosening only occurred in 2 (8%) out of 25 cases. Meanwhile, significantly improved stiffness and the ultimate load to failure were also demonstrated by biomechanical analysis in the study [14]. Since then, this technique has been gradually widely used for acute comminuted fractures of the distal pole of patella owing to its simple procedure, economic cost and reliable fixing strength [17, 18]. However, in clinical practice, several complications such as friction and/or displacement of bone fragments caused not only by 'cheese-wire' effect but also closely related to bone quality and fragment size were found, especially for the elderly patients with osteoporosis. Therefore, we are still looking for a better approach to ensure the fixation strength as well as prevent the complications occurring.

According to anatomic studies and clinical experience, we believe that, there usually exists a 6.6-10.2˚ patellar tilt angle in the sagittal plane of patella pole. In this anatomic situation, the vertical wiring hardly attaches along closely with the surface of distal pole and then leaves a potential space, which develops two mechanical fulcrums at the posterior-inferior side of proximal bone fragment and the inferior point of the distal fragment respectively. This mechanism significantly increases the possibility of 'cheese-wire' effect for bone fragments. In addition, distal pole appears pyramid shape in the coronal plain so that the vertical wire may slip to both lateral sides and affect the stress of

distal bone fragment, resulting in friction and/or displacement fragments. Based on these findings, we modified previous approaches and developed the method of cannulated screws combined with vertical figure-of-eight wire to reduce the incidence of complications. By inserting the wire through cannulated screws into proximal bone fragment, mechanical fulcrums were shifted to both sides of the screw so that the stress of previous fulcrums at the distal pole was dispersed. Consequently, a relative stable frame was formed, which could maximize tension band effect and minimize 'cheese-wire' effect. Moreover, the design of figure-of-eight cleavage wire could tightly hold the distal bone fragments like a basket and enhance the stability of wire fixation, which may fix the slipping problem of pyramid shape at the coronal distal pole and effectively decrease the incidence of friction and/or displacement of bone fragments.

In current study, this technique was observed to provide satisfied clinical and radiographic outcomes. All the 11 cases were examined to obtain stable fixation, fracture healing, restored knee functions, early rehabilitation and mobilization, and develop no complications after surgery. Additionally, the length of the patella was reserved postoperatively, showing that mechanical force line of the patella is maintained and patellofemoral dysfunction is prevented. All the findings indicated that cannulated screw combined with figure-of-eight wire could be an ideal internal fixation technique with high efficiency and safety for distal pole fracture of the patella.

By the technique of vertical figure-of-eight wire, large bone fragment could keep the length and shape of fractured patella; meanwhile small bone fragment could also be fixed by ligaments or other soft tissues with stitches. Hence, it should be emphasized that preoperative CT, which can deliver an accurate assessment of the fragment quantity and size, plays a crucial role in treatment and rehabilitation [19].

Small sample size, short follow-up period, no biomechanical test as well as the lack of analytic comparisons with other techniques are the major limitations of the study. We believe that they should be addressed in further studies. Anyway, cannulated screw combined with vertical figure-of-eight wire could still be considered as an ideal option for distal pole fracture of the patella.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Shan-Zhu Li, Department of Orthopedics, Tongji Hospital, Tongji University, 389 Xincun Road, Shanghai 200065, China. Tel: (086)21-66111094; Fax: (086)21-66111097; E-mail: qidongfanyihang@126.com

References

[1] Cramer KE and Moed BR. Patellar fractures: contemporary approach to treatment. J Am Acad Orthop Surg 1997; 5: 323-331.

[2] Carpenter JE, Kasman R and Matthews LS. Fractures of the Patella. The Journal of bone and joint surgery. American Volume 1993; 75: 1550-1561.

[3] Gaines RJ, Grabill SE, Demaio M and Carr D. Patellar tendon repair with suture anchors using a combined suture technique of a Krackow-Bunnell weave. J Orthop Trauma 2009; 23: 68-71.

[4] Haklar U, Kocaoglu B, Gereli A, Nalbantoglu U and Guven O. Arthroscopic inspection after the surgical treatment of patella fractures. Int Orthop 2009; 33: 665-670.

[5] Chang SM and Ji XL. Open reduction and internal fixation of displaced patella inferior pole fractures with anterior tension band wiring through cannulated screws. J Orthop Trauma 2011; 25: 366-370.

[6] Hoshino CM, Tran W, Tiberi JV, Black MH, Li BH, Gold SM and 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.

[7] Smith ST, Cramer KE, Karges DE, Watson JT and Moed BR. Early complications in the operative treatment of patella fractures. J Orthop Trauma 1997; 11: 183-187.

[8] Tang XR, Zhang QL, Wang QG and Zhang SC. Preliminary application of decreasing pressure and fixation with Cable-Pin system method in Distal Pole Fractures of the Patella. Chin J Orthop Trauma 2008; 10: 697-698.

[9] Huang HC, Su JY and Cheng YM. Modified basket plate for inferior patellar pole avulsion fractures: a report of three cases. Kaohsiung J Med Sci 2012; 28: 619-623.

[10] Kastelec M and Veselko M. Inferior patellar pole avulsion fractures: osteosynthesis compared with pole resection. The Journal of bone and joint surgery. American Volume 2004; 86-A: 696-701.

[11] Matejcić A, Puljiz Z, Elabjer E, Bekavacbeslin M and Ledinsky M. Multifragment fracture of the patellar apex: basket plate osteosynthesis compared with partial patellectomy. Arch Orthop Trauma Surg 2008; 128: 403-408.
[12] Matejcić A, Smiljanić B, Bekavacbeslin M, Ledinsky M and Puljiz Z. The basket plate in the osteosynthesis of comminuted fractures of distal pole of the patella. Injury 2006; 37: 525-530.
[13] Lin RX, Dong YL, Yu BF, Li B and Yang GJ. Suture anchors fixation in the treatment of acute distal avulsion fracture of patella. Chinese Journal of Orthopaedics 2011; 31: 331-334.
[14] Yang KH and Byun YS. Separate vertical wiring for the fixation of comminuted fractures of the inferior pole of the patella. J Bone Joint Surg Br 2003; 85: 1155-1160.
[15] Bostman O, Kiviluoto O and Nirhamo J. Comminuted displaced fractures of the patella. Injury 1981; 13: 196-202.
[16] Amis AA. Current concepts on anatomy and biomechanics of patellar stability. Sports Med Arthrosc 2007; 15: 48-56.
[17] Kim YM, Yang JY, Kim KC, Kang C, Yong BJ, Lee WY and Hwang JM. Separate vertical wirings for the extra-articular fractures of the distal pole of the patella. Knee Surg Relat Res 2011; 23: 220-226.
[18] Song HK, Yoo JH, Byun YS and Yang KH. Separate vertical wiring for the fixation of comminuted fractures of the inferior pole of the patella. Yonsei Med J 2014; 55: 785-791.
[19] Lazaro LE, Wellman DS, Pardee NC, Gardner MJ, Toro JB, Rd MN, Helfet DL and Lorich DG. Effect of computerized tomography on classification and treatment plan for patellar fractures. J Orthop Trauma 2013; 27: 336-344.