Pauwels screw combined inverted triangle cannulated screws for the treatment of Pauwels type-III femoral neck fracture:- a new surgical method based on the morphology of the fracture

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Research article

Keywords: Pauwels type-III femoral neck fracture, Internal fixation, Pauwels screw, Inverted triangle cannulated screws, Morphological types.

Posted Date: July 2nd, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-38297/v1>

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Abstract

Background: Femoral neck fracture is a serious injury in adults with significant functional consequences. Internal fixation is an established treatment for femoral neck fractures in young adult patients. However, the risk of complications following fixation has plagued orthopedists for decades. In all femoral neck fracture, Pauwels type-III femoral neck fractures with a large vertical shear force were more likely to cause clinical failure. The aim of this study is to introduce a new surgical technique for the treatment of this fracture according to the morphology of the fracture using the combination of Pauwels screw and inverted triangle cannulated screws (PSTCS) and report the clinical effects in a prospective cohort of 14 patients.

Methods: From June 2017 to June 2019, a total of 14 patients (8 males and 6 females) with Pauwels type-III femoral neck fracture underwent the surgical treatment of PSTCS according to the morphological types of fracture in clinical operation in our department. Patients were allowed to perform contraction exercises of quadriceps femoris on postoperative day 1, passive flexion and extension exercises postoperative day 2 onwards, and active flexion and extension exercises postoperative day 7 onwards. Patients were allowed for partial-weight bearing walking postoperative 1 month onwards with axillary crutches. After one month AP and lateral radiograph were taken. Full ambulation was permitted until the presence of radiological consolidation. Intraoperative (Operative duration, Blood loss), postoperation (Fracture union time, The Harris Hip Score, Visual analog score) were recorded for comparison.

Results: All patients were followed up for at least 12 months. In the end point of the follow-up, 12 of the 14 patients (85.7%) with Pauwels type-III femoral neck fractures had achieved satisfactory hip function. Operative duration was a mean of 49.5 ± 10.4 minutes. Intraoperative blood loss was between 26 and 110 ml (mean, 44.4 ± 20.6 ml) and without intraoperative blood transfusion. The Harris Hip Score was between 64 and 95 (mean, 87.6 ± 8.9). Fracture healing was observed in all patients according to the X-ray. No internal fixation was loosened or screw cut-out in the follow-up period. The femoral head necrosis was observed in 1 patient in this study. In addition, there was no obvious fracture displacement, femoral neck shortening, or hip varus.

Conclusions: The study showed that PSTCS can provide satisfactory clinical outcomes for treatment of Pauwels type-III femoral neck fractures. Most patients (85.7%) achieved good or excellent results with the use of PSTCS, which appears to be a reliable method and provides another choice for this problematic fracture. The new internal fixation method of PSTCS can provide mechanical stability and promote fracture healing.

Background

Femoral neck fracture is a serious problem in young adults caused by high-energy trauma, such as road-traffic accidents, sports injuries and falls from heights¹. Although the treatment for this uncommon but

clinically important fracture improving rapidly, The osteonecrosis rate in the femoral head is still as high as 15%-30%, and the nonunion rate as high as 10%-30%². Young femoral neck fracture patients are particularly at risk for experiencing complications, and suffer from re-operations. It continues to be unsolved fractures, and the guidelines for management are still evolving. Internal fixation is a common method for the treatment of the femoral neck fractures in young adult patients, which can preserve the native femoral head and regain the natural structure and biomechanics¹. In contrast, primary arthroplasty is favored for elderly patients. Although great progress has been made in the therapeutic field, the risk of complications following fixation of the femoral head has hardly changed in the past few decades, for example, the collapse of the femoral head, fracture nonunion, etc.³. It still represents a great challenge for orthopedists.

The Pauwels classification has been used worldwide for measuring the shear force by using the angle of the fracture line compared with a horizontal line over the femoral head since first described in 1935. In this classification, femoral neck fractures are divided into 3 types. Type I: up to 30 degrees, type II: between 30 and 50 degrees, and type III: 50 degrees and more⁴. According to the research of Hulth, increasing shear forces with increasing angle leads to more fracture instability, which increased possibility of loss of reduction and non-union⁵. Young adults with Type-III femoral neck fractures hit by high-energy trauma are more vulnerable to internal fixation failure, nonunion and avascular necrosis⁶⁻⁸.

Although Anatomical reduction and firm internal fixation are the main actions required to achieve a good outcome for type-III fracture, the appropriate therapeutic schedule for these injuries is still controversial⁹. Comparatively, multiple cannulated lag screws have the advantage of a relatively minimally invasive technique, shorter operative time, and sufficient fixation, which is preferred by most surgeons. Closed reduction and internal fixation by three cannulated screws is an accepted method with good results for the surgical treatment of Pauwels type-I and type-II fractures. Due to type-III femoral neck fracture has its own peculiar biomechanics distinct from other types, the frequency of complications such as nonunion and femoral head necrosis incidence was high with the treatment of traditional inverted triangle cannulated screw configuration. Pauwels type-III femoral fracture has a large vertical shear force. Conventional internal fixations are not sufficient to provide satisfactory stability, which prompted us to find a better surgical method to address this problem.

Pauwels screw which was inserted perpendicularly to the fracture line has higher internal fixation stability, especially anti-shear force capacity, so it has been paid increasingly more attention in clinical practice of type-III femoral neck fracture¹⁰. Hawks demonstrated that the technique using a screw perpendicular to the fracture plane can significantly improve mechanical performance compared with the traditional technique¹¹. Meanwhile, innovative configurations with four cancellous screws have been proposed by Kauffman, which has a good mechanical properties in the femoral neck fracture with posterior comminution¹². Based on previous studies and our experience, we describe a new surgical technique for the treatment of Pauwels type-III femoral neck fracture, which is the combination of Pauwels screw and

inverted triangle cannulated screws(PSTCS) ,and represent the clinical outcomes in 14 patients after treatment with using this technique in this study.

Materials And Methods

From June 2017 to June 2019, a total of 14 patients underwent surgical treatment for Pauwels type-III femoral neck fracture in our level I trauma center (Table 1)Femoral neck fracture was suspected in patients whose Lower extremities are different in length and injury limb is in external rotation .Patients included who had acute trauma (within 24 hours of trauma), Ages younger than 60 y,there was no open fracture, all femoral neck fracture comes under pawels classification as type-III and were mentally stable and conscious. All of them had no surgical contraindication or any severe chronic systemic disease, were informed and agreed to consent of surgical protocol, follow up study and research. Patients who were excluded from study were pediatric patients, patients with old fractures, patients had a history of hip disease or hip surgery.All patients who met these criteria had the above-described surgical treatment performed.The study protocol and amendments were approved by the local institutional review boards.

Table 1
Baseline Demographics of Participants and Follow-up Results

Age	operative	Blood	Time	Follow-	Severe	Visual	Harris
Duration	Loss	union	UP	Complication	analog	hip	
NO	Sex	(Year)	(min)	(ml)	(week)	(Month)	score score
1	M	57	36	35	12	13	/ 0 95
2	F	56	64	32	16	18	/ 0 93
3	F	55	56	42	12	21	Avascular 3 64
							necrosis
4	M	47	43	54	14	24	/ 1 86
5	F	56	49	40	18	12	/ 1 84
6	F	45	45	34	12	21	/ 0 93
7	F	56	37	42	16	12	/ 0 92
8	M	57	64	26	12	15	/ 0 93
9	M	53	45	32	14	20	/ 0 87
10	F	59	49	37	16	17	/ 2 73
11	M	49	38	36	12	13	/ 0 92
12	M	44	63	48	16	23	/ 0 93
13	M	30	62	54	14	14	/ 0 92
14	M	42	42	110	12	18	/ 0 90

The *patient* was placed supine on the radiolucent operation *table* under General anesthesia or epidural anesthesia. The foot of the injured lower extremity is fixed for further traction. meanwhile, The contralateral lower extremity is fixed with hip joint flexion, abduction, and external rotation and knee joint flexion ,which can get a proper lateral view of the injured extremity. Closed reduction of the femoral neck is performed with the patient using image intensification. Longitudinal traction is applied in line with the femur to restore the length of the injured lower limb while abducted position is maintained. the limb is then circumducted into an internal rotation and adduction position to reconstruct the femoral neck and to achieve an optimal reduction(Fig. 1). A prefect reduction can be obtained by closed means, as verified on both the AP and lateral fluoroscopic views¹³ ,otherwise, the minimally invasive Watson–Jones approach was adopted¹⁴

Following routine skin disinfection, the first guide wire were inserted according to the Morphology of the fracture line of pauwels type-III after reduction under the guidance of image intensification, which is the

key to this surgical method. the Pauwels type-III femoral neck fracture basically present the following four Morphological types of fracture line in clinical operation (Fig. 2). Type A: Simple oblique fracture, Type B: Serrated fracture, Type C: Simple comminuted fracture, Type D: Complex comminuted fracture. In this study, five patients were of the Morphological type A, two patients were of the Morphological type B, four patients were of the Morphological type C, and three patients were of the Morphological type D. For type A and B, The first guide-wire was placed upper, inserted from the lateral aspect of the greater trochanter towards the femoral head through a small stab incision, which verticalized the fracture line on both the AP and lateral fluoroscopic views. For type C and D, in addition to satisfying the perpendicular to the fracture plane, the first guide wires should be placed in the position of the anterior of the femoral neck, which is the supportable section for an appropriate compression. Then, the rest three guide wires are inserted into the femoral neck in a parallel inverted triangle configuration (inferior, posterosuperior, anterosuperior) with situation of the screws adjacent to the inferior (calcar) and posterior cortices. All the above manipulations should be performed gently to avoid fracture displacement.

The optimal reduction of the femoral neck fracture site is confirmed once more by the image intensifier. Then after reaming under guidance of the guide wires, the Pauwels cannulated screw is firstly inserted into the femoral neck with appropriate compression to ensure no gaps between fractures. Pauwels cannulated screw is perpendicular to the fracture line on both the AP and lateral fluoroscopic views, which can resist the tremendous shear force of Pauwels type-III fracture. The inserted orders of the remaining three screws were different according to the Morphological types of fracture line. For type A and B, as the conventional surgery procedure, the inverted triangle cannulated screws are inserted into the femoral neck. But for type C and D, Due to the posteromedial comminution of the femoral neck, Priority is given to the anterior-superior screws to insert in the femoral neck. Subsequently, the remaining two cannulated screws were inserted in standard lag fashion. Finally, careful hemostasis, disinfection, and wound suture completed the surgery when the K-wires were pulled out and final fluoroscopic views are obtained.

Patients were allowed to perform contraction exercises of quadriceps femoris on postoperative day 1, passive flexion and extension exercises postoperative day 2 onwards, and active flexion and extension exercises postoperative day 7 onwards. Patients were allowed for partial-weight bearing walking postoperative 1 month onwards with axillary crutches. After one month AP and lateral radiograph were taken. Full ambulation was permitted until the presence of radiological consolidation. Routine radiological and clinical assessment was performed every 1 month until the presence of radiological consolidation and then every 3 months thereafter (minimum time for follow up was one year to a maximum of two years) postoperatively. Fracture healing was considered after bony callus formation across the fracture line, faded fracture line on X-Ray accompanied with that patient had no local pain or tenderness, the ability to walk well without help.

We included intraoperative clinical outcome as operative duration (operative duration was defined as the time from initiation of the incision to the time when suture of the incision was finished), blood loss (recorded in ml by expected value and measured by the hemorrhage through the suction instruction in

operation), fracture union time (Fracture union was defined as a visible callus bridging the fracture site present within 6 months of surgery¹⁵), and postoperative complications. Fracture displacement were evaluated with fluoroscopy 1 month postoperatively. The Harris Hip Score¹⁶ (The Harris hip score was considered excellent at 90 to 100, good at 80 to 89, fair at 70 to 79, and poor at < 70) and visual analog score were recorded for evaluation of hip function at the final follow-up. All patients' outcomes were assessed by the same two observers.

Results

Fourteen patients were included in the study, 11 patients trauma caused by road traffic accident (7 automobile accidents and 4 electric bicycle accidents), and the remaining 3 patients was caused by sudden fall. Five fractures occurred on the right side and nine on the left side, with the mean age of (50.4 ± 8.1) (range 30–57 years). All patients were followed up for at least 12 months. Perfect reduction were achieved in all patients by closed reduction in this study. Operative duration was a mean of 49.5 ± 10.4 minutes. Intraoperative blood loss was between 26 and 110 ml (mean, 44.4 ± 20.6 ml) and without intraoperative blood transfusion. Fracture healing was observed in all patients. The mean time to radiographic fracture healing was (14.0 ± 2.1) weeks (range 12 to 18 weeks). The hip function was evaluated according to Harris Hip Score system (< 70 Poor, 70–79 fair, 80–89 Good, > 90 excellent) at the final follow-up with the mean score was 87.6 ± 8.9 . Twelve of the 14 patients (85.7%) obtained satisfactory hip function. Thirteen of the 14 patients (92.8%) believed that they had recovered preoperative function at the final follow-up. No internal fixation was loosened or screw cut-out in the follow-up period. The femoral head necrosis was observed in 1 patient in this study. In addition, there was no obvious fracture displacement and femoral neck shortening (measured as described by Zielinski et al¹⁷), or hip varus.

Discussion

Although Pauwels type-III femoral neck fracture represents a relatively uncommon injury in the young population, this type fracture is problematic and challenging¹⁸. It is characterized by a small compression load at the fracture, but a large shear stress and varus load. Given the mechanical behavior of the Pauwels type-III fracture, the internal fixation should withstand the large vertical shear forces to achieve stability of the fracture. There is still no gold standard protocol on the optimal treatment of Pauwels type-III femoral neck fracture. Multiple cannulated screws has its own strengths, which is a relatively noninvasive procedure, shorter operative time, the relatively simpler surgical procedure and an acceptable less intra-operative visible blood loss. However, conventional parallel inverted triangle screws are thought to have poor biomechanical performance for the treatment of Pauwels type-III femoral neck fracture.

Pauwels screw provide a new reference for the treatment of vertical femoral neck fracture. Filipov found that cross-divergent cancellous lag screws can significantly improve the fixation strength of the femoral neck fracture after follow-up of 207 patients in the 5 years period¹⁹. Some studies have shown that the stability of the femoral neck fracture can be significantly increased by use of a Pauwels screw construct.

to fix vertically oriented femoral neck fracture¹¹. In our study, All patients with pauwels type-III femoral neck fractures were fixed with the combination of Pauwels screw and inverted triangle cannulated screws. the configuration of PSTCS present good biomechanical stability. our results show that twelve of 14 patients (85.7%) obtained satisfactory hip function. the femoral head necrosis was observed in 1 patient in this study and the poor glycemic controlling maybe the potential cause of this outcome. No internal fixation failure was found in 14 patients in the follow-up period.

Proper anatomic reduction and stable internal fixation is the key to preserve the femoral head, avoiding avascular necrosis, nonunion, and femur shortening²⁰. The Pauwels type-III femoral neck fractures in young adult patients are often the result of high-energy trauma. approximately 70% of the cases of the fracture are combined with comminuted fractures in the posterior-medial of the femoral neck, which may reduce postoperative fixation stability and increase the risk of complications such as nonunion and osteonecrosis^{21, 22}. moreover, Previous studies have shown that the risk of fracture instability increases significantly when the fracture area exceeded 25% of the posterior femoral neck regions²³. Kauffman et al show that compared with femurs fixed with three screws, four screws have significantly higher resistance to axial and forward displacement, and the axial destructive force continues to decrease¹². In our study, all 14 patients were treated with PSTCS according to the femoral neck fracture morphology, all patient achieved a stable fixation and did not experience re-displacement of the fracture after the operation during follow-up. The PSTCS can stabilize the fracture end in multiple planes, placing a pauwels screw through the fracture line at a 90-degree angle may achieve optimal control of the shear force at the fracture end and effectively reduce the occurrence of postoperative internal failure rate. Besides this, in actual clinical practice, the relatively complete and supportable sections of the fracture ends are fixed preferentially. It also can reduce the incidence and degree of the femoral neck shortening and the rotation of femoral head caused by excessive compression of the screw in the comminuted fracture part. However, the effect of fracture morphology on internal fixation of Pauwels type-III femoral neck fracture is often overlooked by most Orthopedic surgeons in clinical work. Currently, Pauwels classification system is still the practical mainstay of femoral neck fracture characterization that help dictate appropriate treatment, although some scholars believe that Classification of intra-capsular hip fractures according to the Pauwels classification using the Pauwels angle is unreliable and its use should be avoided²⁴.

For pauwels type III fractures, most clinicians only focus on the choice of internal fixation, but ignore the morphological differences of the fracture line and the associated surgical operation techniques, especially the comminuted posterior-medial fracture of pauwels type-III femoral neck fracture. Theoretically speaking, The final outcome of pauwels type-III femoral neck fracture depends not only on the surgical devices, but on surgical techniques. The morphology of the pauwels type-III fracture may determine the orders of screw compression and the position in the femur neck. As we elaborated earlier, There are 4 types of patterns based on the morphology of pauwels type III fracture, which was found in our Clinical Work Practice. For type A and type B, pauwels cannulated screw was inserted firstly to press the fracture end and eliminate the fracture gap, which can maintain the femoral neck length,

withstand vertical shear forces and achieve bone union during operation. For type c and type D, Comminuted fractures are mainly concentrated on the posterior-medial of the femoral neck. The anterior of the femoral neck is relatively complete. the pauwels screws and the anterior- upper screws can take advantage of this supportable section for a appropriate compression, so pauwels screw and anterior-superior screw were inserted earlier than inferior screw and posterosuperior screw. In our study, the patients of pauwels type-III femoral neck fracture treated by PSTCS achieved good clinic results in this way. there was no obvious fracture displacement and femoral neck shortening. only *one* of the patients developed *necrosis* of the *femoral head*.

Conclusion

The operative treatment of pauwels type-III femur neck fracture is still a challenge even for an experienced surgeon. The study showed that PSTCS can provide a satisfactory clinical outcomes for treatment of this fracture. Most patients (85.7%) achieved good or excellent results with the use of PSTCS, which appears to be a reliable method and provides another choice for this problematic fracture. Larger, randomized controlled studies comparing these operation method are needed to determine which treatment is associated with less complications and more consistent outcomes. This study should provide the rationale and our data can help inform sample- size calculations for such studies.

Abbreviations

PSTCS :Pauwels screw and inverted triangle cannulated screws

Declarations

Acknowledgements

Not applicable

Authors' contributions

M.Y and G.X participated in the recruitment, data collection, and analysis. All the authors contributed to the study design and drafting of the manuscript. All the authors read and approved the final manuscript.

Funding

This study was supported by Young and Middle-aged Project Fund Of Wannan Medical College (No.KY26260426) and Talent Introduction Plan of Yijishan Hospital, Wannan Medical college (No.YR201917)

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article. The raw data can be requested from the corresponding author on reasonable request.

Ethics approval and consent to participate

The ethics committee of Yijishan Hospital of Wannan Medical College approved the development of this research study. Written informed consent was obtained from all patients, which have been performed in accordance with the ethical standards of declaration of Helsinki and its later amendments.

Consent for publication

All patients and caregivers consented to the publication of their personal data in this article

Competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Figures

Figure 1

(A):Surgical posture.(B) Cannulated screws with a diameter of 7.3 mm used in the operation—from The DePuy Synthes Companies—.(C)(D):the anterior-posterior and lateral fluoroscopic views of Pauwels type-III femoral neck fracture after closed reduction during surgical operation.

Figure 2

the morphological types of fracture lines in Pauwels type-III femoral neck fractures .(A):simple oblique fracture.(B):serrated fracture.(C): simple comminuted fracture.(D): complex comminuted fracture.

Figure 3

a 30 years old male patient,he had a Pauwels type-III femoral neck fracture of right lower limb in a traffic accident.(A).X-ray of anterior-posterior showed that the fracture end is significantly displaced,with a pauwels angle of approximately 60 degrees.(B)CT scan showed comminuted fractures of posteromrdial

femoral neck before operation.(C)(D)The x-ray showed that the Pauwels type-III femoral neck fracture got a satisfactory reduction.the pauwels screw was perpendicular to the fracture line on both the AP and lateral fluoroscopic views under the guidance of image intensification.

Figure 4

Postoperative follow-up in the same patient. (A)The fracture plane was stable without redisplacement but the fracture was still obvious at 12 weeks after operation . (B) A callus formation was seen around fracture site and the fracture line was faded on X-ray at 16 weeks after operation.(C).The internal fixation is stable without failure and the pauwels type-3 femoral neck fracture healed completely within 1 year after operation.(D).The incision size was small with a small scars