A comparative study of partial-threaded cannulated screws and double-threaded cannulated screws in the fixation of vertical femoral neck fractures

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Abstract

Background This study purposed to compare the partial- threaded cannulated screws (PTCS) and the double-threaded cannulated screws (DTCS) in vertical shear femoral neck fractures both clinically and biomechanically.

Methods Clinally, the radiographs of 81 patients with Pauwels Ⅲ femoral neck fractures, including 54 fractures fixed with PTCS and 27 fractures fixed with DTCS were analyzed. Complications consist of fixation failure (nail withdrawal, obvious fracture displacement, varus deformity or femoral neck shortening), bony nonunion and avascular necrosis (AVN) were determined. Biomechanically, twenty femur synthetic bones were equally divided and made to a vertical femoral neck fracture model, then fixed with three parallel PTCSs or DTCSs respectively. All specimens were tested for axial stiffness and a maximum load to failure with a loading rate of 2 mm/min.

Results Clinically , 22 fractures in the PTCS group experienced fixation failure, including 19 nail withdrawal, 18 femoral neck shortening, 14 varus deformity and 8 obvious fracture displacement; while only 5 fractures showed up with fixation failure in the DTCS group, including 3 nail withdrawal, 4 femoral neck shortening, 4 varus deformity and 1 obvious fracture displacement. Additionally, 11 fractures in the PTCS group had nonunion while only 3 in the DTCS group and 9 fractures with AVN in the PTCS group while only 2 in the DTCS group. Biomechanically, The axial stiffness of DTCS was 152.89±22.74 N/mm, greater than PTCS (134.68±26.61), moreover, the failure load in DTCS was significantly greater than PTCS (1148.11±124.80 vs 795.88±162.50).

Conclusion DTCS may exert more advantages than PTCS for vertical femoral neck fractures, including stronger fixation stability, lower rate of fixation failure and nonunion.

Background

Femoral neck fracture in young adults is usually the result of high energy,salvage of the femoral head with anatomic reduction and stable fixation is preferred [1, 2]. Cannulated screws have become the most common fixation device due to its liner dynamic compression during weight bearing, less invasive surgery, less blood loss, and a shorter hospital stay [3]. However, for vertical shear femoral neck fractures, high rates of complications including displacement, screw withdrawal, nonunion and

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femoral head avascular necrosis have been reported by many authors when fixed with ordinary

cannulated screws[4, 5].

The double-threaded cannulated screws (DTCS) have been used for fractures of many sites such as

scaphoid [6], medial malleolus[7] and olecranon[8] with favorable clinical results reported in

literatures, while rare outcomes of DTCS with the femoral neck fracture were reported, which

functions through initial linear compression and final locking with proximal lateral femoral cortex. The

purpose of this study is to compare the clinical and mechanical outcomes of the two types of

cannulated screws including the partial-threaded cannulated screws (PTCS) and the DTCS when used

in vertical shear femoral neck fractures.

Materials And Methods
Patients and methods

This research has been approved by the IRB of the authors' affiliated institutions, the office approved

that verbal consent obtained by telephone was required because this study is retrospective and all

the radiographs and data needed in this study were recorded in the case system of the hospital. From

January 2016 to December 2017, 417 femoral neck fractures treated with internal fixation were

retrospectively studied. The exclusion criteria were as follows: 1. Fractures treated with other internal

fixation constructs rather than three parallel cannulated screws, including four cannulated screws

with a cross screw, sliding hip screw plus with an additional anti-rotation screw. 2. Femoral head

fracture together with other ipsilateral or contralateral lower limb fracture. 3. Fractures with ORIF. 4.

Patients without adequate reduction postoperatively. 4. Pathological fractures. 5. Femoral neck

fractures with Pauwels angle less than 50 degrees in standard anteroposterior pelvic radiographs

before or after operation. 6. Fractures with follow-up period shorter than 9 months. Adequate

reduction was considered when a femoral neck angle was < 10° varus or < 15° valgus and the

displacement between the fracture fragments was less than < 3 mm on AP and lateral radiographs,

compared to the contralateral hip on an anteroposterior (AP) pelvis radiograph [9]. The patients

and/or their families were informed and approved that data from the cases would be submitted for

publication.

Finally, 81 patients with Pauwels Ⅲ vertical femoral neck fractures were included in this study, including 54 fractures fixed with PTCS (7.3 mm) and 27 fractures fixed with DTCS (7.3 mm) (Fig. 1). All patients followed the similar postoperative protocol as follows: no weight bearing of the affected limb within 3 months, partial weight bearing after bone union and totally weight bearing until 6 months postoperatively.

Radiographic analysis

Anteroposterior and the lateral radiographs were taken at 6 weeks, 3 months, 6 months, 9 months, 12 months after the surgery, and any time when pain appeared at the injured hip. Fixation failure was defined as screw withdrawal, obvious fracture displacement (> 5 mm), varus deformity (> 10°) or femoral neck shortening (> 10 mm vertically) compared with preliminary fixation[10–12]. Bone nonunion was defined as lack of any healing on plain or CT radiographs within 9 months. Avascular necrosis was defined as the appearance of subchondral sclerosis or the presence of segmental collapse[12]. All radiographs were collected and analyzed by the authors with a consensus.

Specimen preparation

Twenty femur synthetic bones with the same shape were equally divided into two groups with 10 treated with PTCS and another 10 with DTCS. All specimens were predrilled under C-arm fluoroscopic guidance prior to osteotomy to facilitate an anatomic reduction and ideal implant positioning. The vertical fracture model was osteotomized with an oscillating saw at an 80° angle to the horizontal line and then repaired with three parallel PTCS or DTCS with the same configuration. Distally,all the models were osteotomized horizontally at the inferior segment with the same height from the apex of greater trochanter.

Biomechanical analysis

The biomechanical analysis was done using an Instron test system (Instron, Norwood, MA, USA). Proximally, two magnets were placed respectively on the femoral head and proximal femur to record the displacement of the femoral head with an axial loading. Distally, the femur was fixed to the base of a mechanical tester with dental powder at a shaft adduction angle of 7◦ to simulate normal walking. All tests were conducted with an axial compressive loading which was performed with a loading rate of 2 mm/min, the maximum load for failure was defined by the destructive construct

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failure followed by a marked decrease in the applied load value[13, 14] (Fig. 2).

Statistical analysis

The data including the gender and hip affected was compared using chi-square test, all measurement

data including the age, Pauwels angle, follow-up period, the axial failure load and stiffness between

the two groups were expressed with mean ± standard deviation, and compared using Independent

sample t test, The statistical analysis was performed with SPSS and significant difference was

considered when $P < 0.05$.

Results

At the beginning, we performed the retrospective study, the mean age of patients in the PTCS group

was 49.1 ± 12.5 years with no statistical difference with the patients in the DTCS group (45.8 ± 14.2).

There were 30 (55.6%) males included in the PTCS cohort and 17 males (63%) in the DTCS cohort, 31

patients (57.4%) in the PTCS group had the right hip affected and 16 (59.3%) in the DTCS group. The

mean follow-up period of patients treated with PTCS was 18.15 ± 6.45 months, which is similar with

that in the DTCS group (18.48 ± 3.47) (Table 1).

Table 1

Patient demographics and clinical characteristics

	PTCS	DTCS	p
number	54	27	-
Age(years old)	49.1 ± 12.5	45.8 ± 14.2	0.372[a]
Sex (M/F)	30/24	17/10	0.524 [b]
Hip (R/L)	31/23	16/11	0.874 [b]
Follow-up period(month)	18.15 ± 6.45	18.48 ± 3.47	0.803 [a]
Pauwels angle(°)	58.64 ± 5.23	57.54 ± 5.62	0.807 [a]

Data are expressed as mean ± standard deviation unless stated otherwise; [a] independent sample t test; [b] chi-square test;

For these fractures, no obvious difference was found between the Pauwels angle in the two groups

(58.64 ± 5.23 in the PTCS group vs 57.54 ± 5.62 in the DTCS group), which were measured on the

standard antero-posterior pelvic X ray before or after the surgery (Table 1). However, distinctly

different radiographic outcomes were observed between them. Twenty-two (40.74%) fractures in the

PTCS group experienced fixation failure, including 19 (35.19%) screw withdrawal, 18 (33.33%)

femoral neck shortening (> 10 mm vertically), 14 (25.93%) varus deformity (> 10°) and 8(14.81%)

obvious fracture displacement (> 5 mm), since different types of fixation failure always appears

together; while 5(18.52%) fractures showed up with fixation failure in the DTCS group, including 3

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(11.11%) screw withdrawal, 4 (14.81%) femoral neck shortening, 4 (14.81%) varus deformity (> 10°) and 1 (3.70%) obvious fracture displacement (> 5 mm) (Fig. 3). Additionally, 11(20.37%) fractures in the PTCS group had nonunion but only 3 (11.11%) fractures in the DTCS group (Fig. 4). Furthermore, we observed 9 (16.67%) AVN in the PTCS group and only 2 (7.41%) AVN in the DTCS group (Table 2).

Table 2

Radiographic analysis of fractures fixed with PTCS and DTCS

	PTCS (%)	DTCS (%)
Number	54	27
Nail-withdrawal	19(35.19)	3(11.11)
Femoral neck shortening	18(33.33)	4(14.81)
Varus deformity	14(25.93)	4(14.81)
Fracture Displacement	8(14.81)	1(3.7)
Nonunion	11(20.37)	3(11.11)
ONFH	9(16.67)	2(7.41)

The axial stiffness of DTCS was 152.89 ± 22.74 N/mm, which was greater than PTCS (134.68 ± 26.61), although not significantly. Moreover, the axial compression yielding fixation failure in DTCS was significantly greater than PTCS (1148.11 ± 124.80 vs 795.88 ± 162.50), indicating stronger biomechanical stability of DTCS than PTCS (Fig. 5).

Discussion

High rates of complications with Pauwels Ⅲ vertical femoral neck fractures has been reported by many authors, especially for fractures fixed with PTCS. In this study, we compared the fixation outcomes of PTCS and DTCS both clinically and biomechanically, our results showed that DTCS had less fixation failure rates and stronger stability than PTCS, indicating DTCS was a promising fixation constructs for vertical femoral neck fractures.

For more vertical femoral neck fractures that are axial and rotationally unstable, strong shear forces across the hip frequently led to fixation failure, with overall complication rates ranging from 20–86% [9, 15, 16]. No standard internal fixation has been clinically proven to be superior for vertical fractures, although the addition of a cross screw or combination of a sliding hip screw and an additional anti-rotation screw has been recommended[17], but higher nonunion and AVN rates was reported by Parker [18]. In addition, a medial buttress plate was proposed to augment the fixation of ordinary cannulated screws, which still need longer follow-up and larger sample size[3].

DTCS exerts both linear compression and angle stability with proximal cortex locking. At the beginning of fixation, the near thread supplies the compression between fractures by screwing in, and

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finally, the proximal thread makes the femoral head and the screws a whole. This locking effect provides enough support on the lateral femoral cortex to significantly lessen the rate of varus deformity compared to PTCS [19], moreover, the occurrence of screw withdrawal was also reduced in DTCS as observed in our retrospective study.

Fracture union depends on the stability between fractures, for vertical femoral neck fractures fixed with PTCS, the strong shear force leads to displacement and finally nonunion due to slide of screws, while for DTCS, fracture displacement and nonunion were significantly reduced as a result of lateral cortex locking, even for femoral neck fractures with posterior neck comminution[20], the angle stability also decreases the fracture displacement and facilitates the union of fractures. Our mechanical analysis further illustrated stronger fixation stability of DTCS than PTCS.

AVN is one of the most common complications of femoral neck fractures due to the damage of the special blood supply of the femoral head, the overall occurrence of AVN is as high as 20–30% after fractures[21], although a lower rate of AVN of DTCS than PTCS was observed in our study, but symptomatic AVN may appear as late as 6 years post injury and 29% of patients with AVN showed no significant symptom [20]. Therefore, due to the limited and non-scheduled follow-up of this study, the finding means little.

Several limitations of this study including the retrospective nature, the small number of patients available for radiographic follow-up and synthetic bones rather than fresh-frozen human cadaveric specimens were acknowledged. Despite that, we clearly proved the advantages of DTCS for vertical femoral neck fractures, of course, a larger scale study is still needed to strengthen these conclusions.

Conclusion

In summary, DTCS may exert more advantages than PTCS, especially for Pauwels Ⅲ vertical femoral neck fractures, including stronger fixation stability, lower rates of fixation failures and nonunion.

Abbreviations

DTCS: double-threaded cannulated screws. PTCS: partial- threaded cannulated screws. AVN: avascular necrosis.

Declarations

Ethics approval and consent to participate

This research has been approved by the IRB of the authors' affiliated institutions, the office approved that verbal consent obtained by telephone was required because this study is retrospective and all the radiographs and data needed in this study were recorded in the case system of the hospital.

Consent for publication

The patients and/or their families were informed and approved that data from the cases would be submitted for publication.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

YLZ collected and analyzed the data, searched the literatures and drafted the manuscript. GW and WZ participated in study design, collected and analyzed the data, revised the manuscript, and acted as the co-corresponding authors. All authors read and approved the final manuscript.

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Figures
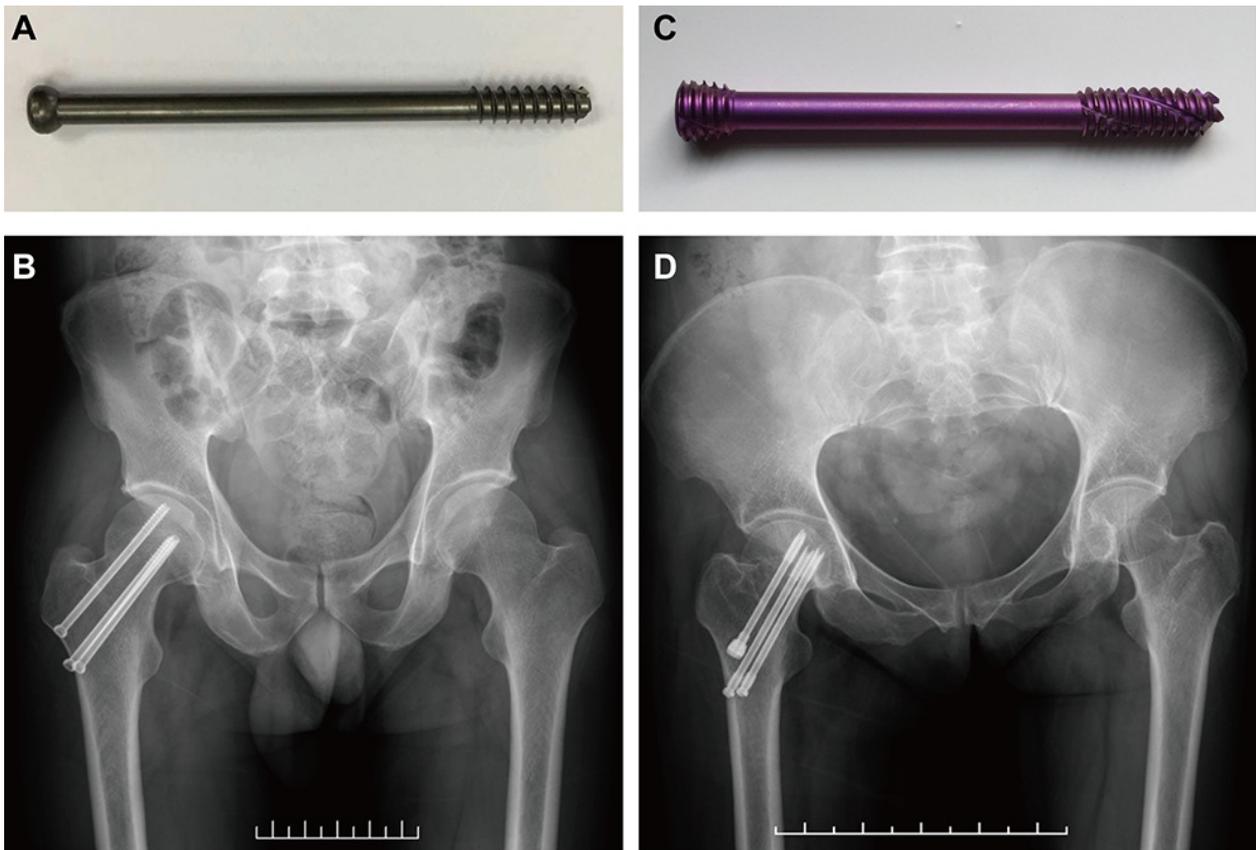
Figure 1

Application of PTCS (partial-threaded cannulated screws) and DTCS (double-threaded

cannulated screws) in femoral neck fractures. A, B. The partial- threaded cannulated screws.
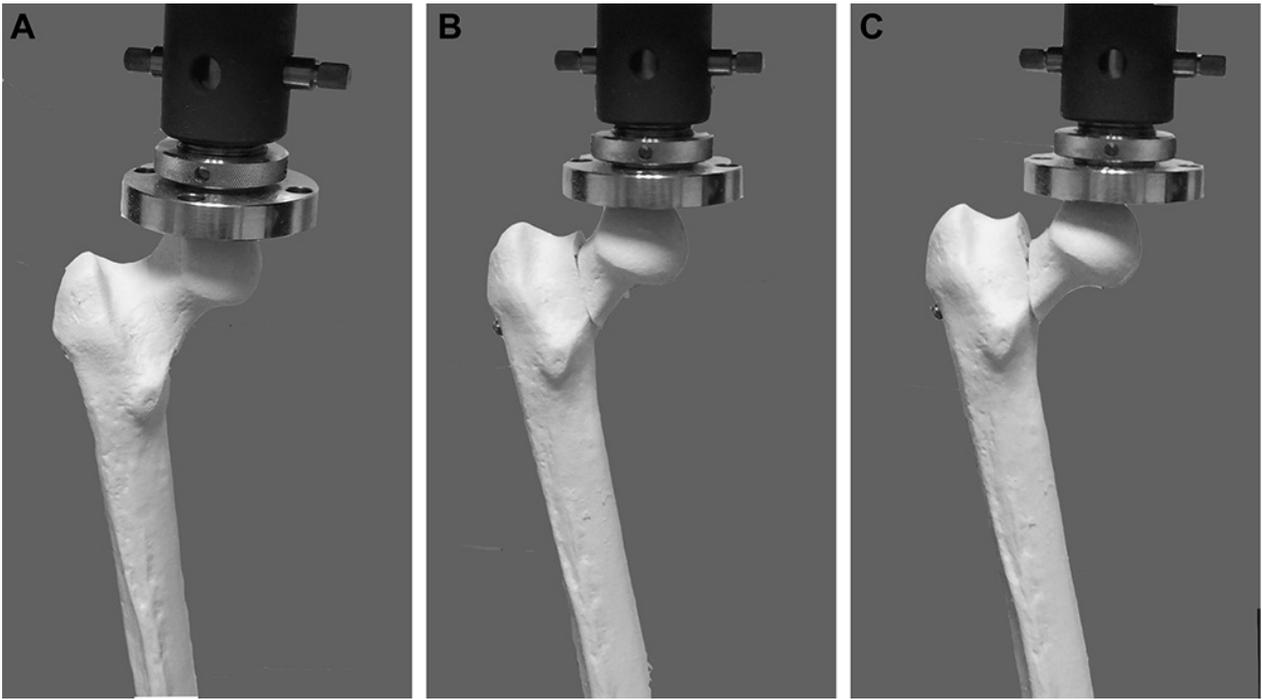
C, D. The double- threaded cannulated screws

Figure 2

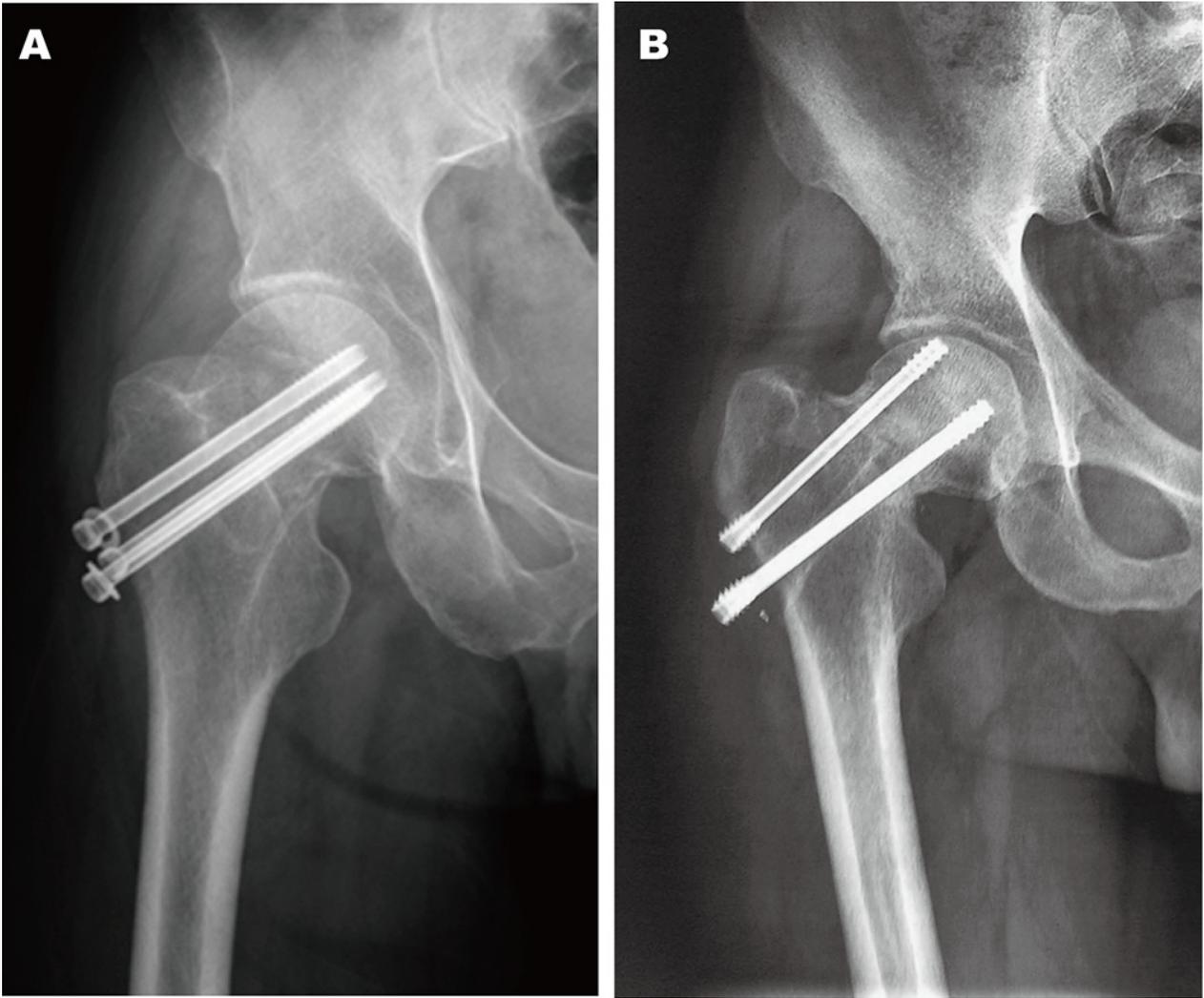Biomechanical process of a femur synthetic bone model fixed with cannulated screws.

Figure 3

Typical radiographs with fixation failures. A. Radiographs with screw withdrawal, varus

deformity and shortening 12 months after fixation with PTCS. B. Radiographs with screw

withdrawal, Varus deformity and shortening 6 months after fixation with DTCS.
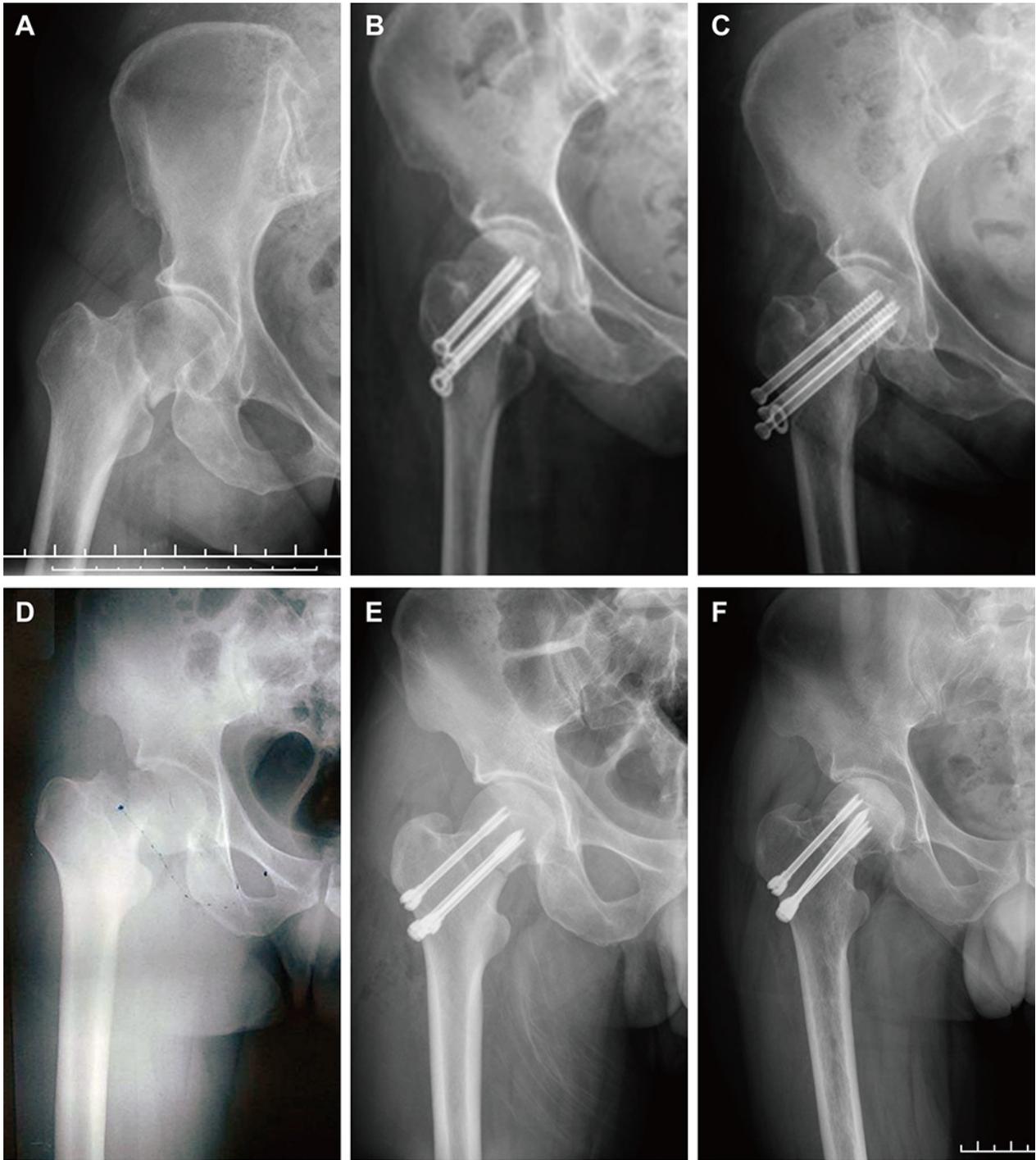
Figure 4

Typical radiographs with nonunion in PTCS and DTCS group. A-C. Radiographs of injury, post-operation and 9 months after operation in PTCS. D-F. Radiographs of injury, post-operation and 12 months after operation in DTCS.
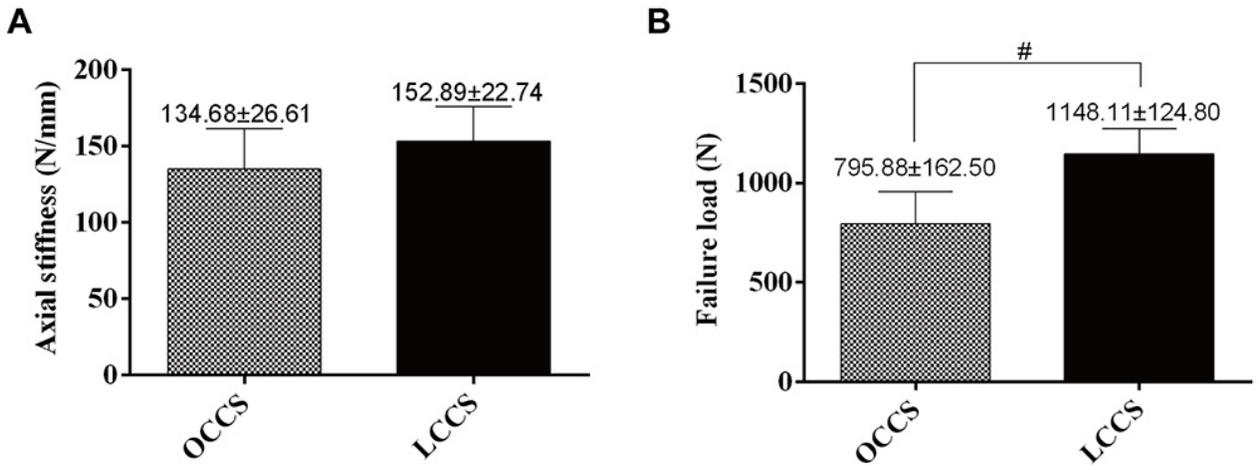
Figure 5

The axial stiffness and maximum load to failure in PTCS and DTCS group. Data was showed with mean ± standard deviation, # significant difference between the two groups (p⬚0.05).