

Adjustment of Bolt Length in the Femoral Neck System for Femoral Neck Fracture: Technical Note

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Technical advance

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Abstract

Background: The depth of bolt in Femoral neck system (FNS, DePuy Synthes, Oberdorf, Switzerland) is difficult to finely control as the length of the bolt is in units of 5 mm. Thus, this study introduces a method to control the depth of FNS bolt in analogue scale in patients with femoral neck fracture.

Methods: By the technique of control of reaming and retraction of bolt, the tip of implant could be positioned close to subchondral bone without harming it. The position of implant tip in four cases who was operated with the introduced technique was compared to that of eight cases with standard technique.

Results: The average tip-apex distance measured in the group that underwent surgery with the technique suggested in this study was statistically significantly shorter than that in manufacturer guide group ($p < 0.05$).

Conclusion: Even though the bolt of FNS is manufactured in the unit of 5 mm, the technique proposed in this study helps surgeons to adjust the depth of bolt for the fixation of femoral neck fracture using FNS.

Background

The surgical treatment of femoral neck fracture can be classified into internal fixation and arthroplasty. In order to determine the surgical method, various factors such as the patient's age, bone density, fracture dislocation, and type of fracture must be considered [1]. Among them, internal fixation is preferred for undisplaced fracture or for relatively young patients, and either closed or open reduction can be performed [2–4]. Implants for internal fixation in femoral neck fracture include cannulated screws, dynamic hip screw (DHS) with or without antirotation screw, DHS with blade instead of screw or similar implants [5–7]. Parallel multiple cannulated screws (MCS) are commonly used in relatively young patients with femoral neck fractures, but it has lower mean axial stiffness and the number of cyclic loadings compared with DHS in biomechanical tests [8–10]. Although DHS provides more stability to femoral neck fractures than MCS, it requires larger skin incision and more extensive soft tissue dissection [11].

The recently introduced implant, the Femoral neck system (FNS, DePuy Synthes, Oberdorf, Switzerland) (Fig. 1.), has both advantages of above two implants. It requires small incision like MCS and provides angular stability like DHS [9].

The FNS is composed of (1) a plate with a barrel and threaded screw holes which accommodates 1 or 2 locking screws, (2) an antirotation screw, and (3) a bolt that supports the head fragment. The proximal fragment with femoral head is held tight by the bolt and antirotation screw, thus it can slide through the axis of barrel to obtain dynamic compression of the fracture site (Fig. 1).

The depth of implant insertion of DHS and multiple cannulated screws are easy to adjust as both use screw mechanism. As the pitch of lag screw of DHS is 3.5 mm, half turn which is the minimum unit of adjustment the operator can make is 1.75 mm. Although the cannulated screws are generally manufactured in the unit of 5mm, surgeon can control the depth of insertion in analogue scale and has more option with washers to adjust the depth. However, the depth of bolt in FNS is difficult to finely control as the length of the bolt is in units of 5 mm.

The manufacturer recommended the subtraction of 5 mm from the measured depth read on the direct measuring device and choose the next shorter bolt size [12]. For example, if you placed the tip of central guide wire into the subchondral bone and the measured depth was 102 mm in measuring device, it is recommended to choose 95 mm bolt.

It is a concern whether the method will ensure the insertion of bolt into sufficient depth and stable fixation of femoral neck fractures. Thus, this study introduces a method to control the depth of FNS bolt in millimeter unit in patients with femoral neck fracture.

Technical Note

The technique to be introduced in this study is possible for all fixations of femoral neck fracture using FNS, and all the indications and contraindications of this technique follows those indicated on the surgical manual.

Operative technique

After reduction of the femoral neck fracture, the central guide wire is placed into the surgeon's targeted position under the guidance of image intensifier (Fig. 2). After the depth of central guide wire embedded in the subchondral bone is measured, the next longer construct size is selected (For example, the depth of guide pin indicates between 97 mm and 98 mm, then 100 mm-length bolt would be chosen.). At this step, further advancement of central guide wire would prevent unintended pull-out of the central guide wire while following procedures.

The operator can control the depth of reaming by dividing the reaming procedure into two steps.

The first step is to countersink the lateral cortex of femur. By sliding the reamer-component over the drill bit into the remarked numbers, the limit of reamer tip advancement can be controlled by the remarked numbers. Assembling the reamer to set the depth of reaming for 10 mm less than the implant size, the surgeon can achieve countersinking for the barrel of the plate without penetration of articular surface (Continuing the former example, the reamer of the first reaming step should be set at 90mm.).

To make room for bolt at the target position, the final advancement of reamer tip is adjusted finely on the second reaming step. After the reamer was re-assembled to indicating number on the reamer as the same number of the implant size (continuing the former example, the reamer of the second reaming step should be set at 100mm), the reamer without power tool is pushed manually back into the pre-reamed hole to touch the blind end of reamed hole with

reamer tip. The manual advancement and rotation in counterclockwise of the reamer without power tool ease the reinsertion of reamer without unintended harm of osteoporotic trabeculae. After reaching the end of blind pipe, the reamer is assembled to the power tool and image intensifier is used to estimate the remaining distance to reach the target. Under the guidance of image intensification, the reamer is advanced to the target carefully.

The plate, bolt, insertion handle, and insert are assembled by tightening of black screw as the surgical manual. After then, FNS is inserted. The cylinder can be used to tap manually the plate on to the bone. When the tip of bolt reaches the target depth, plate does not touch the lateral surface of femoral cortex as the length of bolt is longer than the depth of reaming (Fig. 3.). By untightening of the black screw, bolt is retracted backward. After retraction of bolt, plate could contact the lateral surface of femoral cortex with tapping (Fig. 4.). After removal of central guide wire, distal locking screw is inserted, taking care not to insert eccentrically into the subtrochanteric area (Fig. 5.). During this procedure, the bolt could be retracted more than intended. If black screw is re-tightened, the bolt protracts to reach the base of reamed bone (Fig. 6). After the surgeon confirms that the tip of bolt is positioned on the target and the plate is set on the lateral cortex with the image intensifier, the anti-rotation screw is inserted (Fig. 7–9). Inter-fragmentary compression is up to surgeon's decision.

Results

From September 2019 to September 2020, investigation for radiographs was conducted on 14 patients who were hospitalized for femoral neck fracture at our hospital and underwent surgery using FNS. All radiographs were retrieved from a PACS system of M-view (version 5.4.10.38, Infinitt Healthcare Co., Seoul, South Korea). All radiographs were calibrated before their evaluation using the known diameter of the bolt (10 mm).

In both hip AP with 15° internal rotation view and translateral view of affected hip, the tip-apex distance (TAD) was measured for the tip of bolt [13].

The average TAD measured in the group that performed surgery with the manufacturer's surgical technique (10 patients) was 16.3 mm (range 14.6 to 18.1 mm), and the average TAD measured in the group who performed surgery with the technique suggested in this study (4 patients) was 7.2 mm (range 6.1 to 12.2 mm). On the Mann-Whitney U test, TAD of the group that underwent surgery with the technique suggested in this study was significantly shorter than that of the group with the method of manufacturer's guide ($p < 0.05$).

Discussion

Previous comparative biomechanical studies between FNS and other implants in cadaveric femoral neck fracture showed that the FNS can provide superior stability to the femur neck fractures [9, 14]. Stoffel et al. performed a biomechanical test after insertion of DHS, MCS and FNS in a cadaveric femoral neck fracture model with posteromedial bone defect [9]. The results of their study showed that FNS provided superior stability compared to MCS and had comparable stability to that of DHS. Schopper et al. performed a biomechanical test by inserting FNS and Hansson pins in the cadaveric model of Pauwels type II [14]. They reported that FNS was more resistant in varus deformation and less sensitive to variations in implant placement compared to Hansson pins. In both studies, the length of the bolt during FNS fixation was determined to make the tip-apex distance be within 20 mm which is originally from the evaluation method of DHS or proximal femoral nails in intertrochanteric fractures [13]. Surgery according to the surgical guide of manufacturer also makes the tip-apex distance within 20 mm. However, although FNS is morphologically similar to DHS, it does not seem to be proven whether it is reasonable to apply the same evaluation method for the position of FNS in femoral neck fractures which has a shorter length of proximal fragment than that of intertrochanteric fractures.

With MCS, the length as well as the diameter and position of the screw are important [15, 16]. Lindequist reported that the screws must be located within 3 mm of the femoral head cortex to achieve cortical support [16]. They recommended the insertion of screws with enough length to increase mechanical stability. Rau et al. showed that the insertion of the DHS screw into the subchondral region of the femoral head provided satisfactory clinical results of the femoral neck fractures [17]. They also reported that the depth of the DHS screw is an important factor related to the unsatisfactory result. Therefore, the depth of the implant plays an important role in stabilizing the femoral neck fracture. However, it is difficult to achieve an ideal depth of FNS bolt following the manufacturer's surgical guide alone. We believe the technique of this study can help to overcome the limitation of the implant manufactured in 5mm unit and additionally contribute to increase fixation stability.

One concern of the technique is the disengagement between insertion handle and FNS while inserting the assembly of implant and instruments. Theoretically, the disengagement before the insertion of distal locking screw and antirotation screw can block right insertion of screws. However, as complete disengagement requires complete clearance of the insert from the plate and the insertion handle holds the plate tight, the implant cannot disengage from the insertion handle while using our technique. Also, the thread of black screw is on the track of the thread on the insertion handle even in a loose manner, the connecting part to the bolt of the insert block the plate slit form the disengagement (Fig. 10–11).

The limitation of this study is that it has not been proven that a difference in fixation of several millimeters causes a clinical difference in treatment of femoral neck fracture using FNS, and the number of cases is small. Further research on this is needed to delineate the clinical difference.

In conclusion, even though the bolt of FNS is manufactured in the unit of 5 mm, the technique proposed in this study helps surgeons to adjust the depth of bolt for the fixation of femoral neck fracture using FNS.

Declarations

Competing Interests: The authors declare that they have no conflict of interest.

Funding: The authors declare they have no financial interests.

Ethical approval: We received Institutional Review Board approval (IRB No. EMC 2020-09-009) of Daejeon Eulji Medical Center.

Ethics and consent to participate: An explanation of the implant and surgical technique to be used for fixation of the femoral neck fracture was performed with informed consent from the patient and family before surgery. In addition, the implant, technique, and study design presented in this study were approved by IRB.

all authors have read and approved the manuscript.

Authors' contribution statements.

YHC implemented the technique in clinical setting and wrote the draft.

JUS and JIY elaborated the technique.

CHP and KHP contributed to the final version of the manuscript.

JTK: conceived the present idea.

WSC: supervised the project.

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Figures

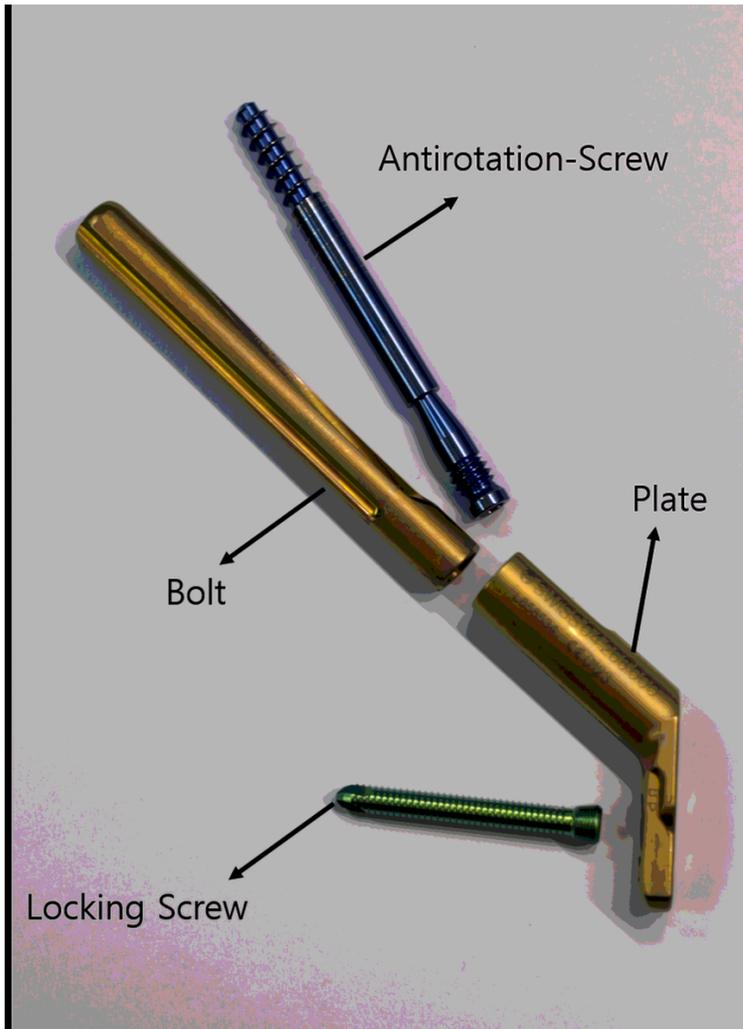


Figure 1

Femoral neck system consists of bolt, plate, antirotation screw and locking screw

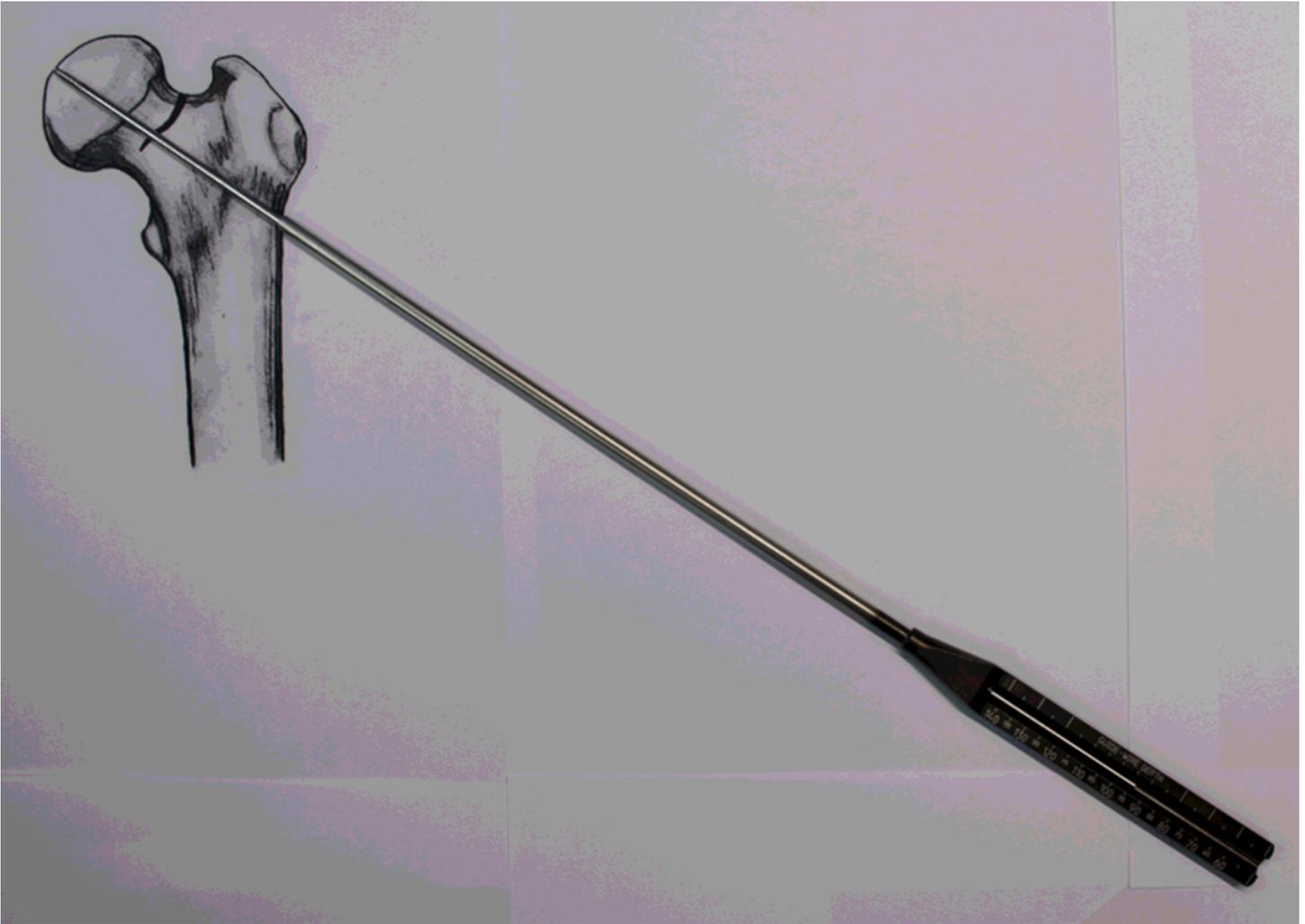


Figure 2

After the depth of central guide wire embedded in the femoral bone is measured, the size of bold is selected which is next longer construction size.

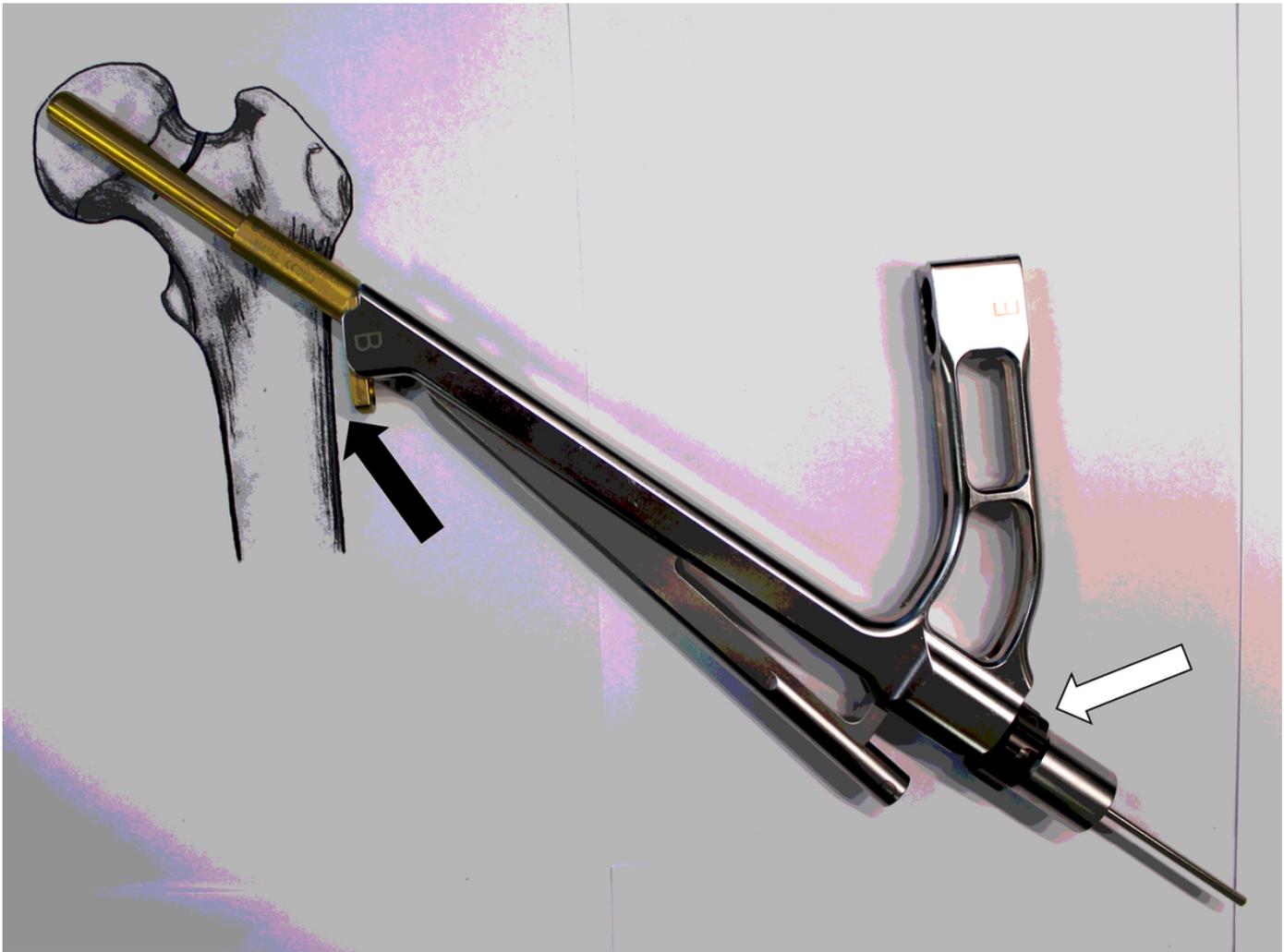


Figure 3
After reaming to target depth under a fluoroscopy, insert bolt and plate by insertion handle. The white arrow indicates black screw which combines the insertion handle, plate, and bolt. The black arrow indicates that plate does not contact with lateral cortex of femur.

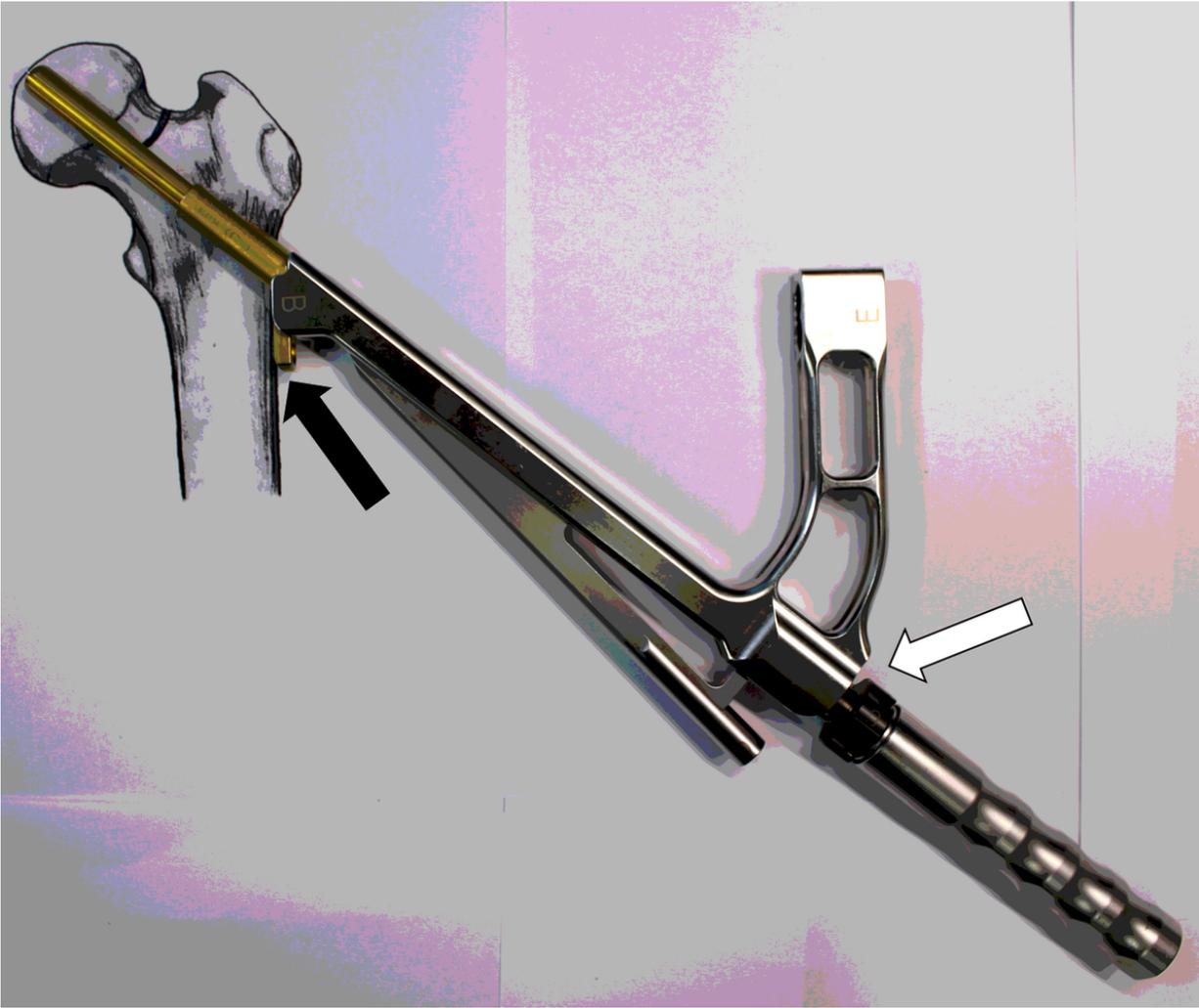


Figure 4

Loosen the black screw and impact the plate using the cylinder impactor. It makes contact between the plate and the lateral femoral cortex. The white arrow indicates the loosened black screw, and the black arrow indicates the contact between the plate and the lateral femoral cortex.

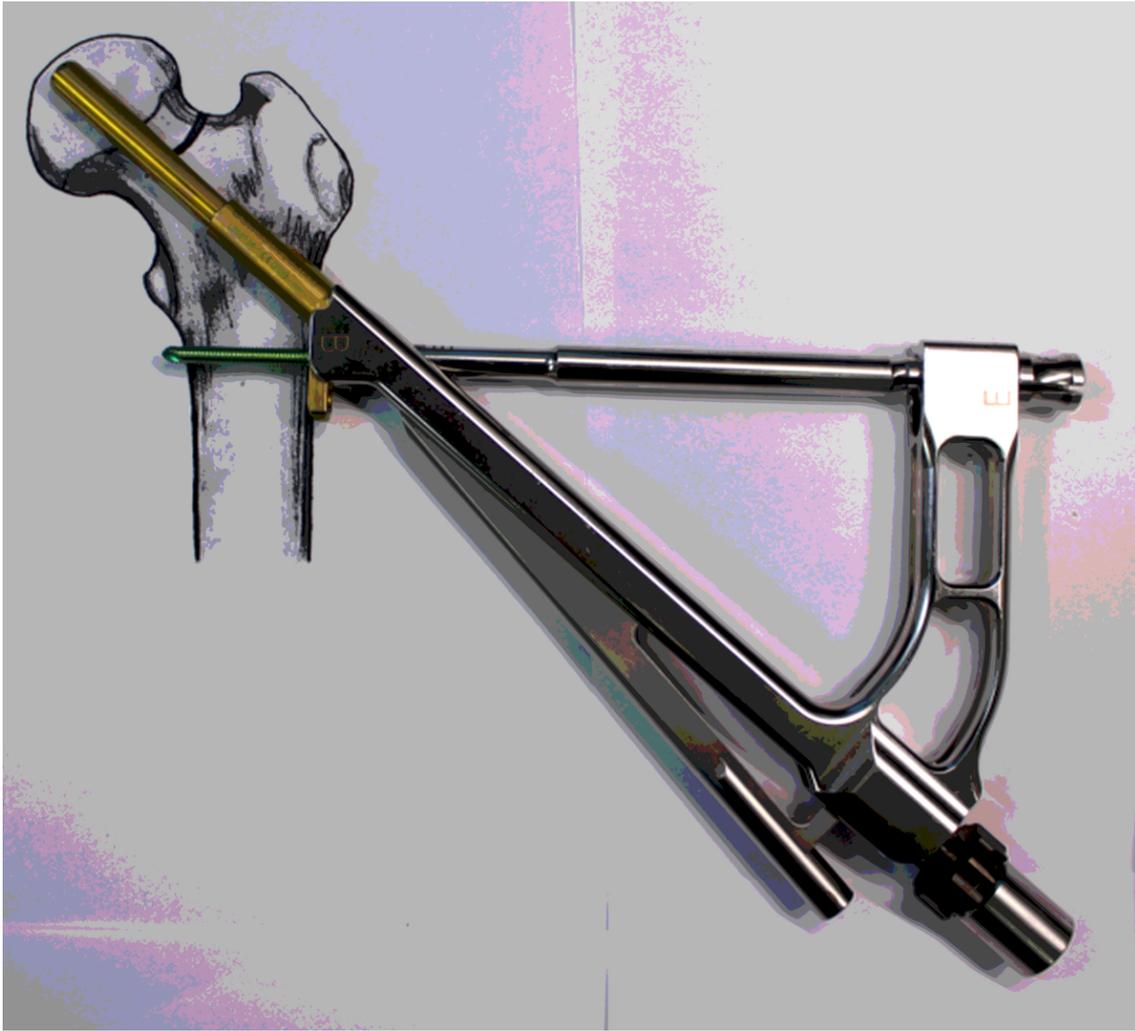


Figure 5

Insert distal locking screw, taking care not to insert eccentrically into the subtrochanteric area.

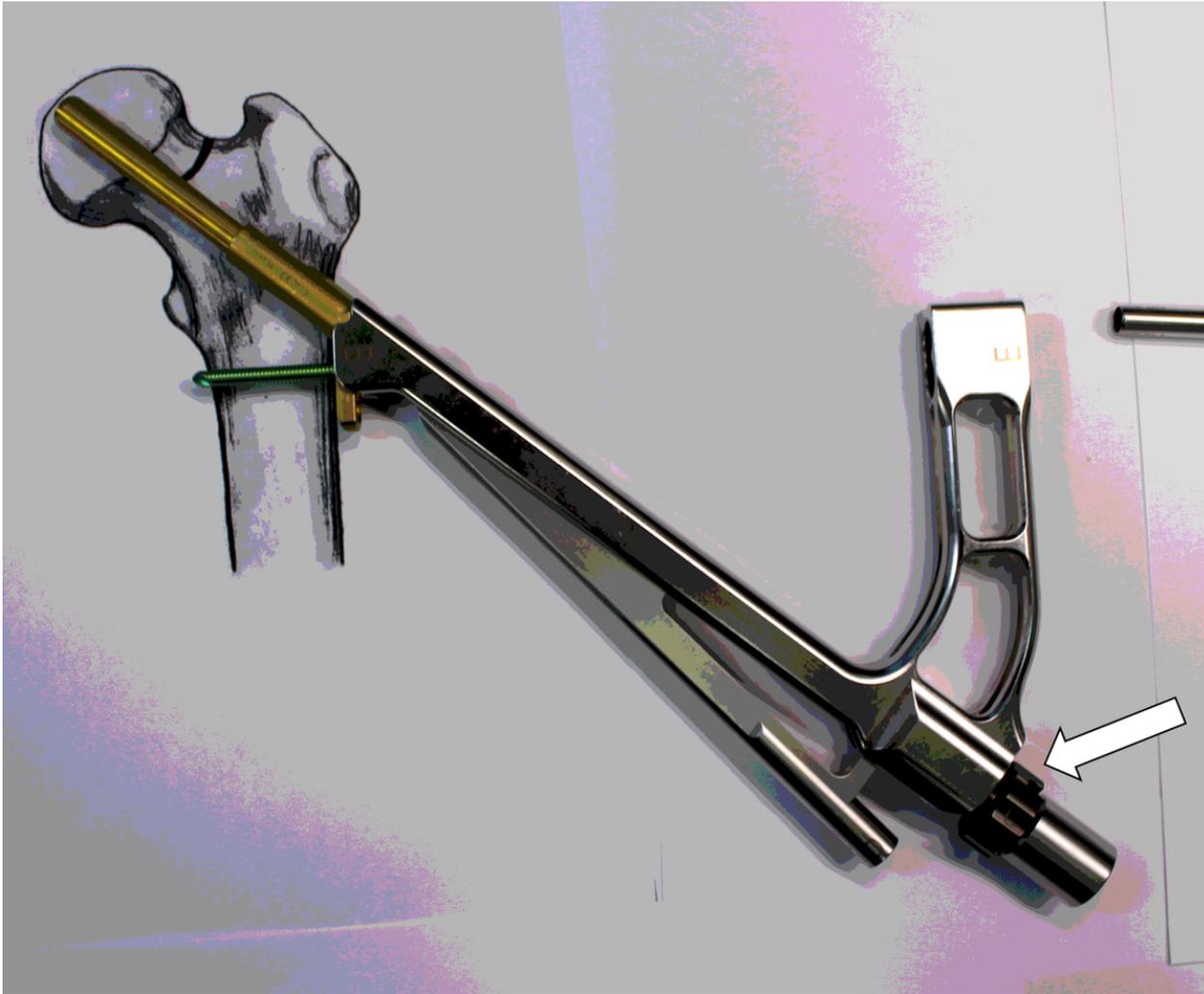


Figure 6

During the impact for contact between plate and lateral femoral cortex, bolt could be pulled out from target depth. In this case, bolt can be inserted back to the target position by tightening the black screw. The white arrow indicates the tightened the black screw.

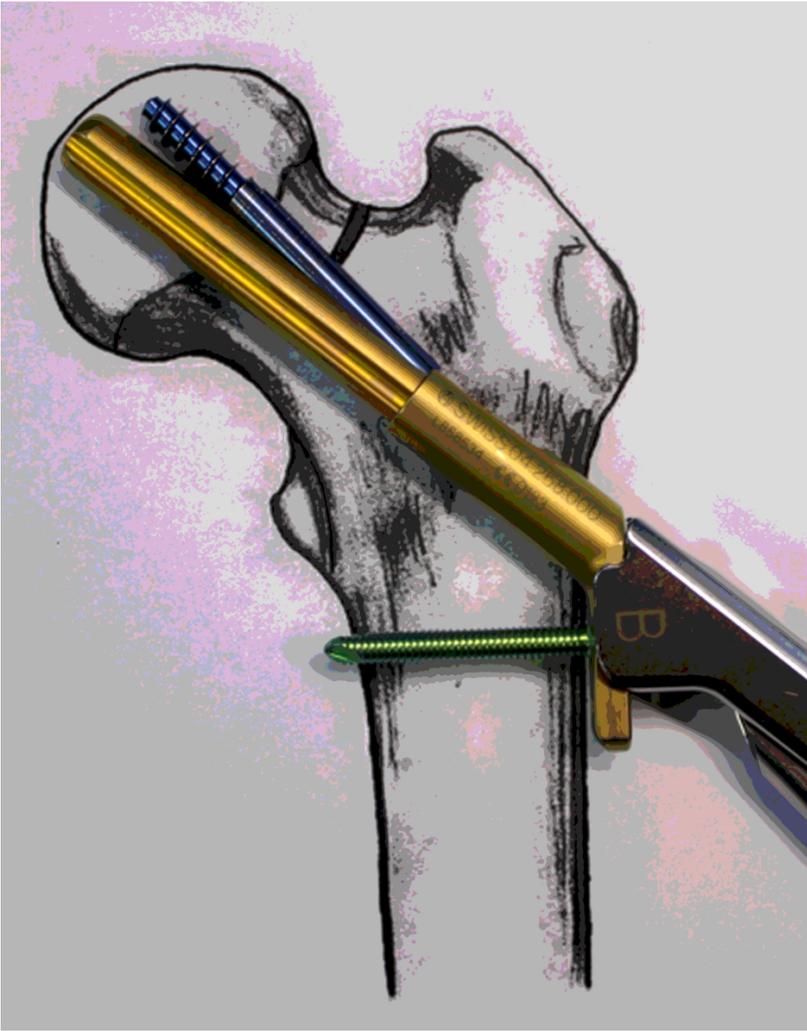


Figure 7

Insert antirotation screw.

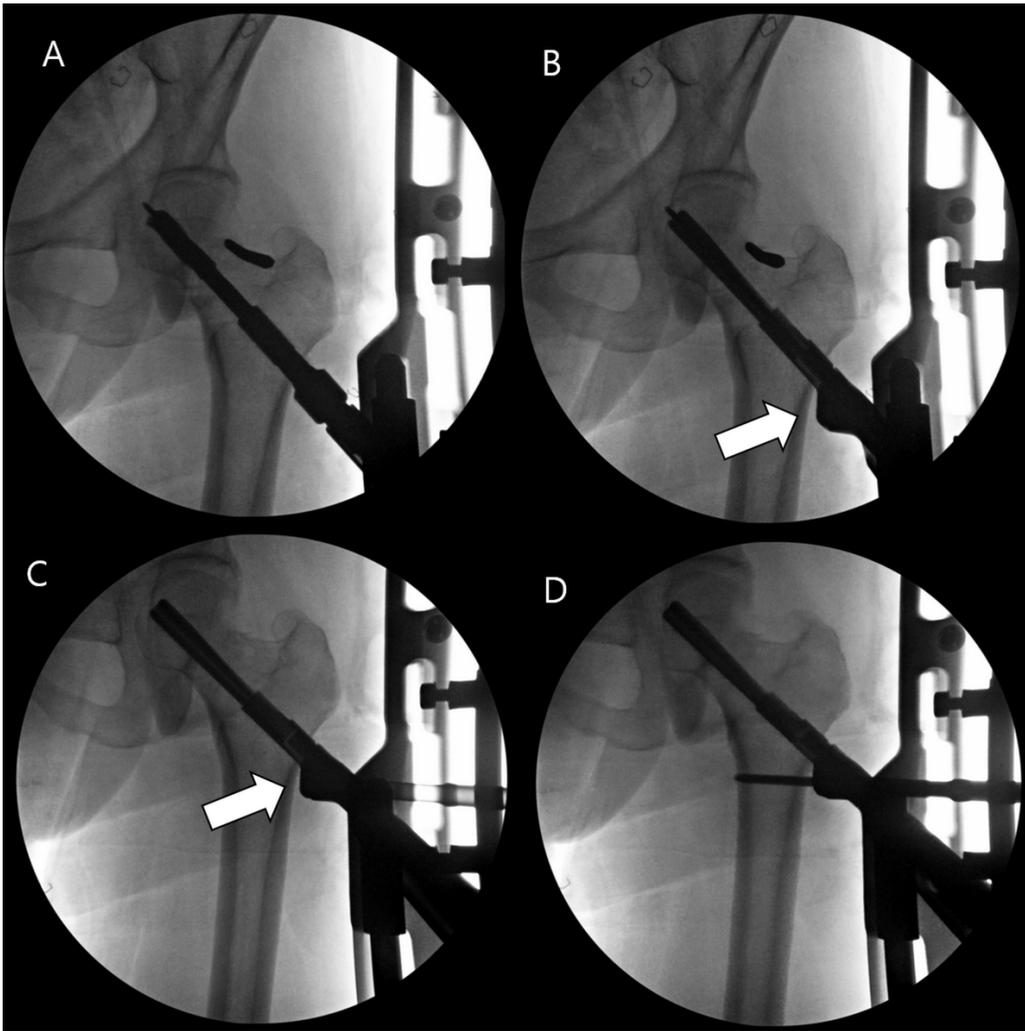


Figure 8

Radiographs show the surgical procedure for femoral neck fracture in a 54-year-old male patient using the Femoral neck system. (A) After closed reduction using a Steinmann pin, a guide pin was inserted and reaming was performed. (B) The femoral neck system inserted with an insertion handle. According to our technique, the plate could not be contacted with the lateral femoral cortex (white arrow). (C) To reduce gap between plate and lateral femoral cortex (white arrow), the black screw was loosened and the plate was impacted. (D) After then, locking screw was inserted.



Figure 9

The radiograph shows the immediate postoperative state.

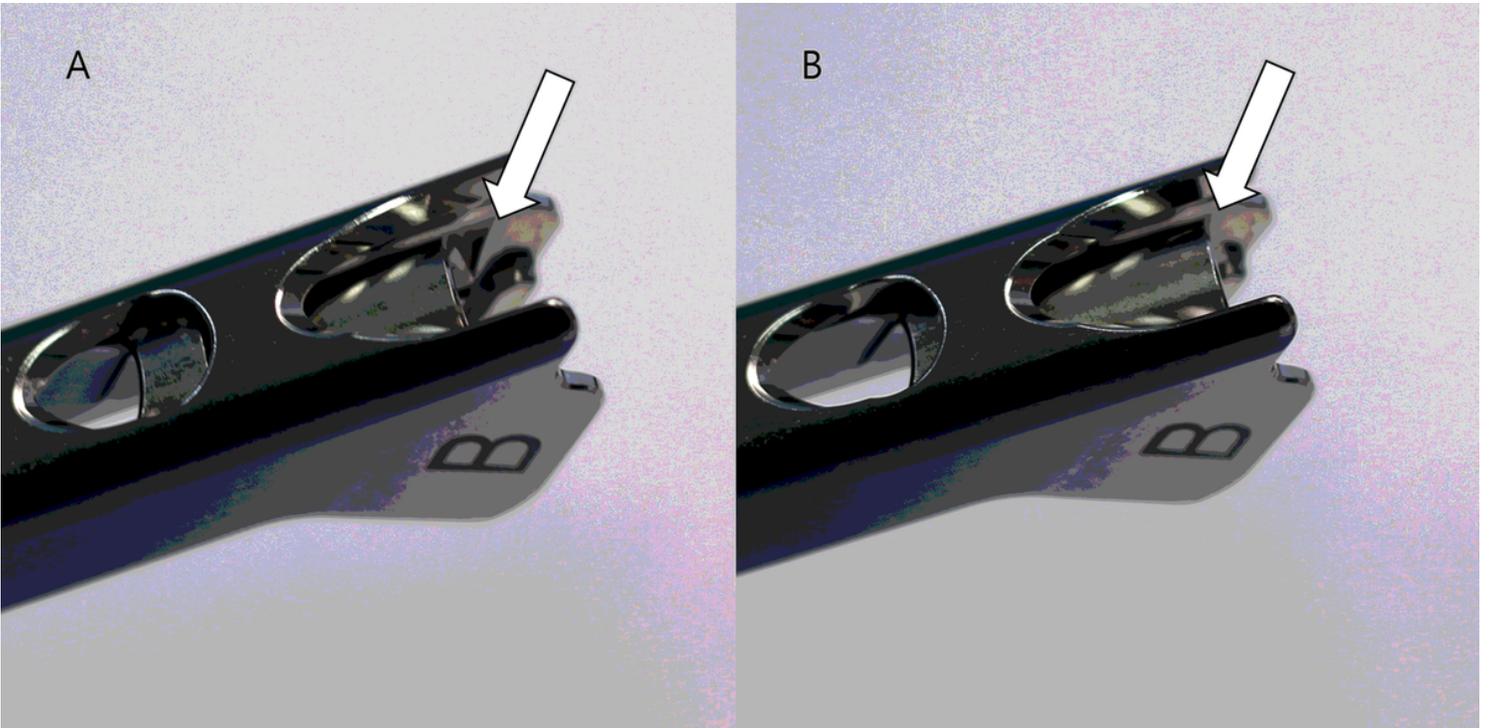


Figure 10

(A) The white arrow indicates the slit for connecting with plate. If the black screw is completely loosened with insertion hand, plate can be disconnected from insertion handle (B) the white arrow means that plate slit is blocked by metal portion of black screw. If the black screw is tightened even a little, plate cannot be disconnected from handle

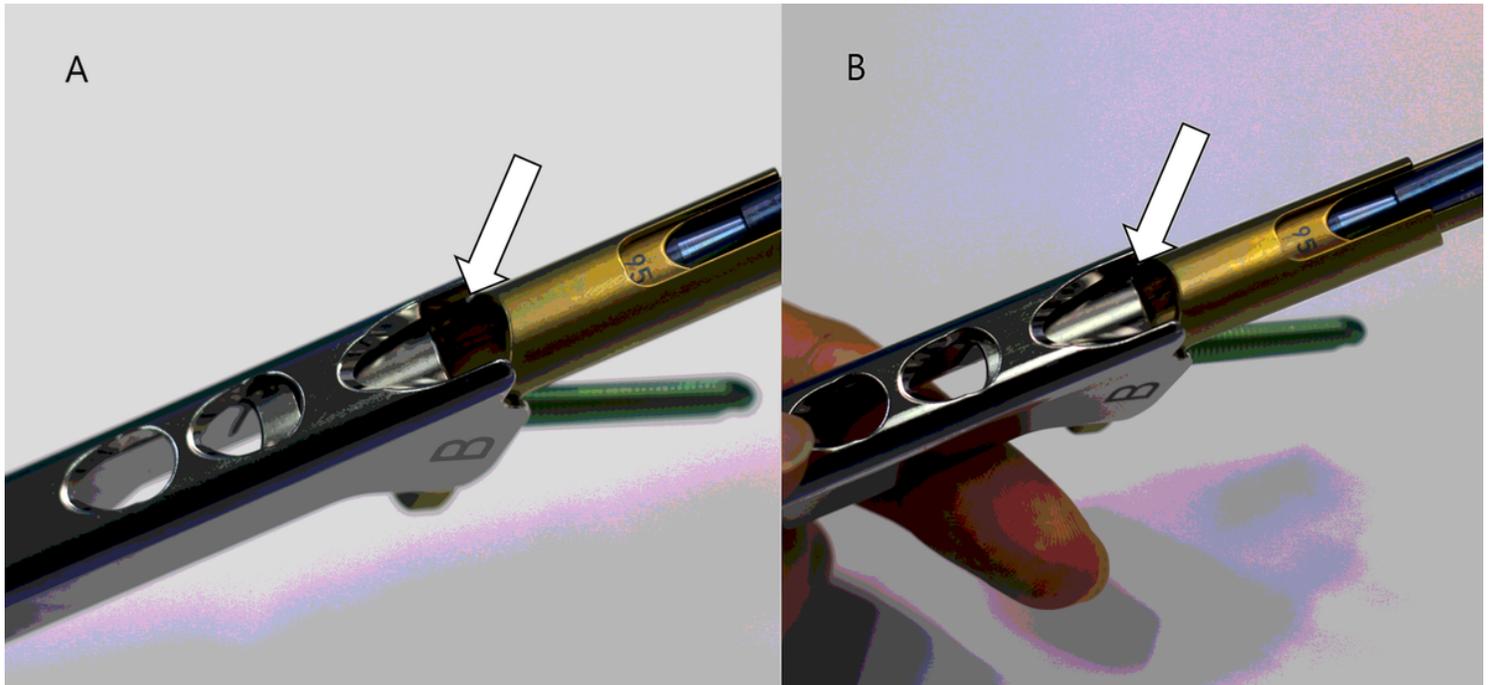


Figure 11

(A) The white arrow show plate slit is not blocked by metal when the black screw is completely loosened (B) The white arrow show plate slit is blocked by metal when the black screw is tightened even a little. It makes prevention of disconnection between plate and handle