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Case report

Intrapelvic migration of hip lag screw of proximal femoral nail-sequle to a paradoxical reverse Z effect and their critical analysis

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ARTICLE INFO

Article history:

Received 23 January 2012

Accepted 20 February 2012

Available online 16 June 2012

Keywords:

Intrapelvic migration

Lag screw

Proximal femoral nail

Z effect

ABSTRACT

A 40-year-male treated with hip screw for unstable inter trochanteric fracture femur, had an implant failure after an aggressive therapy session. The Dynamic Condylar Screw was removed and fracture was fixed with Proximal Femoral Nail. The nail also failed to achieve its goal of fracture union, as a result of a unique type of reverse Z effect, in contradiction to expected Z effect resulting in intrapelvic migration of proximal hip lag screw of the proximal femoral nail.

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1. Introduction

The choice of an appropriate type of implant for osteosynthesis of unstable extracapsular trochanteric femoral fractures remains a dilemma.¹ Both extramedullary and intramedullary implants have their pros and cons and most of the time it is the surgeon's choice and training which decides the nature of implant. The cephalomedullary nail is biomechanically more stable under loading because of the shorter lever arm,² minimal invasive way of insertion; but it can sometimes be

associated with femoral shaft fractures below the nail.^{3,4} The proximal femoral nail (PFN) is designed to overcome the limitations of the previously used cephalomedullary nail and has been used to treat trochanteric^{5,6} and subtrochanteric fractures.⁷ It is sometimes difficult to insert these nails across fracture for which they are deemed worthy that is 'comminuted unstable intertrochanteric fractures'; & so an extramedullary hip screw plate inserted with minimal medial soft tissue dissection is also a viable alternative. The large amount of muscular forces at proximal femur and extensive medial

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^a Consent – The patient families were informed that data from the case would be submitted for publication, and gave their consent. 0976-5662/\$ – see front matter Copyright © 2012, Delhi Orthopaedic Association. All rights reserved.
doi:10.1016/j.jcot.2012.02.002

comminution in unstable intertrochanteric fracture spare no implant. Hence failure of fixation is also seen in PFN which is in form of Z and reverse Z effect. Herein we report a unique kind of reverse Z effect in an adult male.

2. Case report

A 40-year-old male^a who met with a road traffic accident presented to us in the emergency department with pain, swelling over right hip region and inability to stand or walk. On examination patient had tenderness, swelling over the trochanteric region, crepitus was felt on gentle rotation of the limb and patient could not do active straight leg rising. He had no distal neurovascular deficit and no other clinically apparent orthopaedic or systemic injury. Anteroposterior Radiograph of the affected hip (Fig. 1) revealed an unstable intertrochanteric fracture with extensive medial comminution in the calcar region. He was taken up for surgery; indirect reduction and internal fixation with Dynamic condylar screw was done on an orthopaedic operation table (Fig. 1b). Postoperative period was uneventful; patient was discharged from hospital after suture removal at 2 weeks. He was explained to do quadriceps exercises; gentle-assisted range of motion exercises of knee and ambulated by nonweight bearing (on the operated side) crutch walking. At 6 weeks he was send to physiotherapy department for mobilization of his knee. Due to some untoward incident during a mobilization session, a click sound was felt by the

patient in the hip region. He returned to us with severe pain & swelling in the right hip region. Subsequent radiography showed that the barrel plate had cut out of the distal femoral shaft, and the fracture collapsed into varus (Fig. 1c). He was subsequently worked up for a repeat surgery with particular emphasis in ruling out any metabolic bone disease, hormonal disorder or quiescent infection. An intramedullary implant was planned in the form of long Proximal femoral nail. Hence the dynamic condylar screw with barrel plate was removed, tissues sent for histopathological examination and osteosynthesis was done with a long PFN along with iliac crest bone graft (Fig. 2). We used both the hip pin and lag screws of same size (95 mm), although the correct technique is to put hip pin smaller than lag screw. The hip pin appeared longer than lag screw although of same size as it contacted the lateral cortex later than lag screw; the proximal lateral cortex at the level of hip pin being medial and weaker as a result of previous DCS barrel hole than that at the level of lag screw. We made this error with the intention to gain purchase of good femoral head bone in area of hip pin tip as it had no purchase in the lateral cortex; the femoral head also being hollowed by a 12.5 mm lag screw of DCS, so we thought that if we inserted it deeper in femoral head it would have good purchase.

Postoperative period was uneventful, histopathology showed normal tissues with sparse chronic inflammatory cells. He was followed up at every 3 weeks. Muscle strengthening exercises were continued and toe touch weight bearing was started at 6 weeks. At 9 weeks radiograph was done which

Fig. 1 – a: Unstable intertrochanteric fracture with medial comminution. Red and yellow arrow showing extensive segmental medial comminution. b: Osteosynthesis with a dynamic condylar screw. c: Failure of dynamic condylar screw.

Fig. 2 – Second osteosynthesis with long proximal femoral Nail.

showed that the implant and the bone was in an anatomical position. But when patient returned to us at 12 weeks; to our utter dismay the radiograph of the hip with thigh showed a recurrent implant failure. The proximal most of the proximal group of screw had broken and the distal one had migrated into the joint (Fig. 3). The fracture had collapsed into

Fig. 3 – Failure of PFN: proximal most hip pin broken and migrates laterally. The distal lag screw of proximal screw combination migrates medially into pelvis.

varus; hence it was decided to remove the victimized proximal interlocking screws and accept the deformity (Fig. 4). The patient was allowed gradual weight bearing with the nail in situ. At the last follow-up of 2 years patient is able to stand and walk unaided & painlessly. He has full range of motion at knee though with 1.5 inch shortening. He is able to squat and do straight leg raising (Fig. 5).

All the implants used were of standard orthopaedics grade stainless steel 316L.

The patient gave consent for that his case details may be used for publication.

3. Discussion

Our case elucidates all the causes of implant failure. So, Why did the implant fail in this case? The main reasons being (1) Host factor: Comminution at the fracture site and that too at the most important bio mechanically site, as in our case: there was a segmental comminution of calcar femorale (Fig. 1a,b). (2) Inappropriate implant choice for a particular fracture personality: In our case some may say that an Intramedullary implant was a better choice in the first setting instead of an extramedullary dynamic condylar screw. But a dynamic condylar screw inserted with indirect reduction and no medial soft tissue stripping is an adequate procedure for this fracture. (3) Conditional/postoperative rehabilitation/compliance factors: The first procedure that is the extramedullary dynamic condylar screw required a cautious postoperative regime which was followed, as the patient was allowed toe touch weight bearing and more aggressive knee mobilization at 6 weeks when a faint medial fracture callus was seen. But so to blame his and surgeon/therapist fate an aggressive physiotherapy session did the unintentional damage; and the implant failed. (4) Peculiarities/unique inherent weakness of an implant: Failure of fixation seen in PFN is evident in two forms (of implant failure) -Z effect and reverse Z effect. The more common event is proximal migration of the oblique

Fig. 4 – (a) Final X-ray anteroposterior view after removal of PFN with coxa vara & broken hip pin in situ. (b) Final X-ray-lateral view after removal of PFN showing union of two cortices with broken hip pin in situ.

proximal most interlocking screw. This may arise due in part to the poor bone density of the femoral head with limited screw purchase as in elderly, osteoporotic bone.⁸

Migration of the proximal group of interlocking screws occurs within the nail as these do not secure rigidly within the device itself and is described in the literature as “Z” effect (Medial migration of the proximal screw or lateral migration of distal lag screw) and the “Reversed Z” effect (Distal migration of the proximal screw).^{9,10} The Z effect phenomenon was originally describe by Werner-Tutshcku et al¹¹ The PFN is fixed with 2 screws, the larger –distal screw (lag screw) is designed to carry out most of weight and smaller proximal screw (hip pin) is designed to provide rotational stability. If the hip pin is longer than lag screw, it becomes the main weight bearing screw and vertical forces would increase on hip pin and start to induce cut out, Z effect or knife effect. This forces the hip pin to migrate in the joint and lag screw to slide laterally (Z effect). Werner-Tutshcku et al also advised that fixation of the fracture at a cervico-diaphyseal angle of $<125^\circ$ is a predisposing factor for the Z effect and reverse Z effect, as well as for cut out of the femoral head by the screw.

Although the cause of this Z phenomenon has been explained by varus collapse of the fracture and the lack of medial cortical support, its precise aetiology requires further clarification.¹² Strauss et al¹² have reproduced the migration of the cephalic screws from the intramedullary nail in the laboratory with the aid of a polyurethane model. These authors observed that when the compressive forces on the femoral head were greater than those on the femoral neck, the inferior screw migrated laterally. However, no reverse Z effect was observed when the strengths of the respective forces were transposed. The finite element-based analysis used by

these authors indicated that the differences in bone density at the locations where the two screws were fixed represented an important factor in understanding the independent performances of the screws. When the femoral neck presented a lower bone density than the femoral head, which is typical of unstable fractures, there was a tendency for the inferior screw to migrate as seen in this case. Strauss et al¹² also suggested that the use of femoral nails comprising two interlocking head screws should be avoided in cases of fractures with intense comminution and loss of medial support.

In our case the fallacy was that the hip pin was longer than the lag screw, so according to previous studies, this should produce the Z effect and hip pin should go towards joint and lag screw should slide laterally. But, a peculiar reverse Z effect occurred that too which involved the distal lag screw. At 12 weeks hip pin broke at thread shaft junction and it slid laterally; where as the lag screw cut through the femoral head and acetabulum dangerously into the pelvis, though with no systemic/neurovascular side effect.

The reason for this effect in our index case probably are (1) Unintentional technical error of having put a longer hip pin making it a weight bearing screw for reasons elucidated in case report. So it should have migrated proximally as in a conventional described Z effect under physiological loads. But maybe the not so osteoporotic bone in our case prevented its proximal migration to some extent and for sometime as described by Strauss above. As a consequence before it could proximally migrate, the increased biomechanical loads took its toll on the hip pin and it broke & migrated distally. This was also because the Proximal Screws in PFN designed & inserted in a parallel fashion got non parallel. The reason they got non parallel was that it was a repeat surgery; the lateral proximal

Fig. 5 – Patient doing activities of daily living.

cortex had been already violated by the previously inserted DCS barrel and the femoral head bone by the 12.5 mm DCS lag screw inserted in previous hip surgery; so the parallel inserted screws in operation theatre as checked by C arm per operatively got settled in non parallel fashion. This resulted in increased bending loads on hip pin which broke early. (2) Hence the distal lag screw now became the weight bearing screw, but it could not slide in the nail for the following probable reasons: (a) the fracture collapsed into varus post breakage of hip pin; so the angular orientation of the lag screw in the nail hole changed. It increased friction to lag screw sliding and it became jammed in the nail hole. Consequent to physiological loads and fracture collapse, it cut into the pelvis. (b) Another reason for this penetration of lag screw in joint seems to be that the lateral spike of the distal part of proximal fragment mechanically obstructed the lateral sliding of lag screw.

The uniqueness of our case is that a different kind of reverse Z effect occurred paradoxically; a biomechanical situation in which a reverse Z effect occurred contrary to the literature where a Z effect was expected. Our case also confirms that although the literature describes the Z effect and reverse Z effect as the migration of proximal interlocking screws in opposite directions, in practice, sometimes only one screw actually migrates (here the proximal one broke) and the fracture undergoes an accommodation process that may lead to the perforation of the femoral head by the screw that remains in the normal position.¹³

Intraabdominal migration of lag screw though is also reported in cases of gamma nail,¹⁴ the causes in gamma nail may be incomplete tightening of set screw or Z type of forces as in proximal femoral nails. Additionally, novel devices incorporating helical blades that are introduced under impaction towards the femoral head, have been designed with the aim of increasing rotational stability, preserving the bone material of the femoral head and preventing varus collapse. Although such implants offer greater biomechanical stability in comparison with conventional PFN,¹⁵ they are not free of Z phenomena. Thus, Brunner et al¹⁶ have described three cases of perforation of the femoral head by helical blade devices in patients showing good fracture reduction and satisfactory positioning of the implant. These authors advise that in cases of severe osteoporosis, positioning of the blade at 5 mm or less below the joint should be avoided in order to prevent perforation of the femoral head.

4. Conclusion

Our case elucidates that reverse Z effect can not only be produced because of low bone density of femoral head as described in previous literature; but can also produced due to an obstructing lateral fracture fragment and an anomalous fracture collapse that prevent lateral sliding of lag screw (augmented by breakage of hip pin). It also demonstrates some of the important uncontrollable and controllable factors

of implant failure. A good surgical training experience is also required while using these implants as they are not forgiving implants.

A good preinsertion fracture reduction in order to avoid fixation in varus, meticulous placing of entry point, keeping the hip pin smaller and parallel to lag screw in the proximal head fragment are some of the surgical pearls to be obeyed while using this implant. For fracture patterns in patients presenting severe osteoporosis or medial comminution, the use of helical blades is recommended. Even after these precautions some type of Z effect will occur, if this implant is not used in right way. So all cephalomedullary implants need a vigilant follow-up regarding postoperative pain and clicks. They may need regular radiological follow-ups; and patients may also need to be preoperatively counselled about this sinister complication.

Conflicts of interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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