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Original Research Article

An Observational Assessment of the Biomechanical Factors Working Around Hip Which Leads to Implant Failure

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Conflict of interest: Nil

Abstract

Aim: The Purpose of this study was to evaluate biomechanical factors working around hip which leads to implant failure.

Material & Methods: This was an observational study. All 20 cases below 75 years of age with proximal femoral fracture [fracture Inter-trochanteric & Sub-trochanteric included] fixed with PFN irrespective of the centre where surgery was performed attending routine out-door of Department of Orthopaedics for one year with implant failure were registered for the study.

Results: In our study we registered total of 20 cases with mean age of registered cases was 64.86 + 8.50 years. 15 patients (75%) were male and 5 (25%) were females. Except 3, all cases of implant failure in our study were categorized as unstable type according to EVAN's & A.O. classifications preoperatively. Out of 20 cases registered, pattern of implant failure in our study were 6 cases (30%) had implant failure pattern of Z- effect, 5 cases (25%) had implant failure pattern of reverse Z-effect; 2 (10%) had breakage of nails; 1 cases (5%) had both screw breakage with varus collapse; 3 (15%) had single upper proximal screw breakage; & 3 cases (15%) were associated with spiral fracture femur just distal to the tip of PFN.

Conclusion: Proper implant selection is critical and should be done on an individualized patient and fracture pattern basis. Poor surgical technique, implant-related issues, delayed fracture union, and poor patient compliance and health status alone or in combination can lead to breakage of the implants requiring challenging treatment options. Prevention of such catastrophic complications is crucial for the patient's health and quality of life. Biomechanical study of the broken implant may provide useful information regarding failure causes and guide future treatment. Surgeons and mechanics should work hand in hand for implants evolution in order to optimize patient treatment.

Keywords: Trochanteric fixation nail, Dynamic hip screw, Implant failure, Biomechanical forces around hip, Abduction Dynamic hip splint.

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Introduction

Proximal femoral fractures are a subset of fractures that occur in the hip region. They tend to occur in older patients, and in those who have osteoporosis. In this group of patients, the fracture is usually the result of low-impact trauma although, in younger patients they are usually victims of high impact trauma. Intramedullary nailing is used for more than 25 years in the treatment of stable and unstable pertrochanteric fractures. [1,2,3] Due to the continuous increase in the number of proximal femoral fractures and relevant surgeries, complications such as loss of fixation, peri-implant femoral fracture, osteonecrosis, infection, and nonunion [4,5] rise as well. Biomechanically PFN is better choice of implant for fixation of proximal femoral fractures[especially unstable type] compared to DHS and DCS. It has less mobility, provides more stability proximally as well as distally and is a load sharing device. Nail itself gives support as lateral trochanteric wall and itself resist collapse. Less intra-op bleed, less operative time less intra-op muscle damage, immediate post-op mobilization are key points that supports superiority of PFN over DHS. Still there are some pitfalls as implant failure does occur in PFN also; due to specific biomechanical forces acting on implant around hip joint. The proximal femoral nail (PFN) is an osteosynthetic implant designed to treat proximal femoral fractures in the trochanter area with a closed intramedullary fixation method.

Similar to the gamma nail the proximal femoral nail consists of a funnel-shaped intramedullary nail with slight bending to reflect proximal femoral diaphyseal trochanteric morphology. But different to the gamma nail, the proximal femoral nail features two proximal openings, a larger one further distally for a large femoral neck lag screw and a smaller one immediately above for a smaller antirotation screw/pin. There are small holes at the distal end of the nail for locking screws. [4] It can be combined with a wire cerclage with an open reduction for additional stability in complicated subtrochanteric fractures. [6] Subtrochanteric fractures are classically fixed using a sliding hip screw, with a long side plate. [7] Biomechanically, intramedullary devices are superior to traditional extra medullary devices for these fractures. Among the intramedullary devices, proximal femur nailing antirotation (PFNA) (Synthes Inc., Bettlach, Switzerland) is one of the devices in the treatment of unstable intertrochanteric femoral fractures. [8] This device combines the biomechanically favorable characteristics of an intramedullary nail with a minimally invasive surgical technique. [9]

The Purpose of this study was to evaluate biomechanical factors working around hip which leads to implant failure.

Materials & Methods

This was an observational study. All 20 cases below 75 years of age with proximal femoral fracture [fracture Inter-trochanteric & Sub-trochanteric included] fixed with PFN irrespective of the centre where surgery was performed attending routine out-door of Department of Orthopaedics, Jawahar Lal Nehru Medical College and Hospital, Bhagalpur, Bihar, India for one year (Jan 2019 to Dec 2019)with implant failure were registered for the study.

Detailed history was taken from patient and close relatives regarding rehabilitation protocol, mode of failure. Information about surgical procedure, approach & implant details from patient records and if necessary, from hospital records.

Radiological evaluation from series of X-rays both pre-op and post-op and follow-up X- rays obtained from patient. Biomechanical force study in reference to implant placement & fixation strength protocol for rehabilitation in different fracture patterns with the help of available literature.

Inclusion Criteria

1. History was taken from patient and close relatives regarding rehabilitation protocol, mode of failure, duration between injury and operation.
2. Information about surgical procedure, approach & implant details from patient records and if necessary, from hospital records.
3. Radiological evaluation from series of X- rays both pre-op and post-op and follow-up X- rays obtained from patient.
4. Biomechanical force study in reference to implant placement & fixation strength; protocol for rehabilitation in different fracture patterns with the help of available literature.

Exclusion Criteria

Cases with infection; poly-trauma and disability in other limb

Till date our study includes 10 cases of proximal femoral fractures fixed with PFNs with implant failure.

Results

Table 1: Demographic details, fracture pattern, and biomechanical pattern of implant failure

Variables		**Number**	**%**
Mean age (in years)		**64.86 + 8.50**	
Gender	Male	15	75
	Female	5	25
Fracture pattern	Unstable	17	85
	Stable	3	15
Mal-union	Present	14	70
	Absent	6	30
echanical Pattern of implant failure	Z-effect	6	30
	Reverse Z – effect	5	25
	Nail breakage	2	10
	Screw breakage with varus collapse	1	5
	Upper proximal screw breakage	3	15
	Spiral shaft femur fracture	3	15

In our study we registered total of 20 cases with mean age of registered cases was 64.86 + 8.50 years. 15 patients (75%) were male and 5 (25%) were females. Except 3, all cases of implant failure in our study were categorized as unstable type according to EVAN's & A.O. classifications

preoperatively. Out of 20 cases registered, pattern of implant failure in our study were 6 cases (30%) had implant failure pattern of Z- effect , 5 cases (25%) had implant failure pattern of reverse Z-effect; 2 (10%) had breakage of nails; 1 cases (5%) had both screw breakage with varus collapse; 3 (15%) had single upper proximal screw breakage; & 3 cases (15%) were associated with spiral fracture femur just distal to the tip of PFN.

Discussion

The proximal femoral nail (PFN) is an osteosynthetic implant designed to treat proximal femoral fractures in the trochanter area with a closed intramedullary fixation method. Similar to the gamma nail the proximal femoral nail consists of a funnel-shaped intramedullary nail with slight bending to reflect proximal femoral diaphyseal trochanteric morphology. But different to the gamma nail, the proximal femoral nail features two proximal openings, a larger one further distally for a large femoral neck lag screw and a smaller one immediately above for a smaller anti-rotation screw/pin. There are small holes at the distal end of the nail for locking screws. [4] It can be combined with a wire cerclage with an open reduction for additional stability in complicated subtrochanteric fractures. [8] Osteoporosis leading to femoral fracture is becoming more common and consuming increasing hospital resources. [10] Loss of fixation or implant failure increases morbidity and mortality in these often-frail patients. [11,12] Biomechanically PFN is better choice of implant for fixation of proximal femoral fractures[especially unstable type] compared to DHS and DCS. Has less mobility, provides more stability proximally as well as distally and is a load sharing device. Nail itself gives support as lateral trochanteric wall and itself resist collapse. Less intra-op bleed, less operative time less intra-op muscle damage, immediate post-op mobilization are key points that supports superiority of PFN over DHS. Still there are some pitfalls as implant failure does occur in PFN also; due to specific biomechanical forces acting on implant around hip joint. One of complication of TFN is implant failure. Implant failure can be due to breakage of implant anywhere; cut-out of implant through bone or back-out of screws.

Femoral head fractures are rare intracapsular injuries but are very different from femoral neck fractures in that they do not cause disruption to the vessels that supply blood to the femoral head. They usually occurs secondary to femoral head dislocation. The cause of fixation of failure of intramedullary devices in unstable intertrochanteric fractures is divided into two major groups. [13,14] Patient-related factors like osteoporotic bone are one of the main reasons for failure of fixation in the aging population. [15] Damage during implant insertion is also a potential cause of mechanical failure. In this regard, von Rüden et al. described an implant breakage due to incorrect drilling of the insertion hole for the lag screw in one case of Proximal Femoral Nail Antirotation breakage (PFNA; Synthes, Oberdorf, Switzerland). [16] Malalignment of the aiming device for the proximal screw or blade reamer may cause intraoperative damage to the proximal aperture in the nail, thereby predisposing the nail to failure.[17] Rappold et al. described two cases of PFN breakage. In both cases, significant metal abrasion was seen in the region of the screw hole at the site of nail breakage. This was attributed to tilting of the femoral neck screw which probably had occurred during screw insertion. They assumed that inadequate dimensioning of the guidewire which, in the presence of sclerotic bone structure, deflects cranially, ended in malposition in the screw hole. However, the authors concluded that convergent tilting of the femoral neck screw is probably of minor importance regarding the development and occurrence of nail breakage. [18]

In our study we registered total of 20 cases with mean age of registered cases was 64.86 + 8.50 years. 15 patients (75%) were male and 5 (25%) were females. Except 3, all cases of implant failure in our study were categorized as unstable type according to EVAN's & A.O. classifications preoperatively. Out of 20 cases registered, pattern of implant failure in our study were 6 cases (30%) had implant failure pattern of Z- effect , 5 cases (25%) had implant failure pattern of reverse Z-effect; 2 (10%) had breakage of nails; 1 cases (5%) had both screw breakage with varus collapse; 3 (15%) had single upper proximal screw breakage; & 3 cases (15%) were associated with spiral fracture femur just distal to the tip of PFN. Subtrochanteric fractures represent a different type of problem in that mechanical failure of the fixation device is relatively common. The vast majority of these failures occur in Seinsheimer type III and IV fractures, in which there is comminution and no medial buttress. [19] The segmental subtrochanteric fracture modelled in this study represents the worst possible fracture pattern for stresses on an implant as there is no bony continuity, simulating the type III/IV fracture. It has clearly been shown that internal fixation with nail-plate or screw-plate devices is not sufficiently strong to permit full weight bearing. The high loads across the subtrochanteric region of the femur are the cause of plate failure in up to 40 percent of comminuted fractures [20] despite the use of increasingly massive devices such as the Holt nail. [21]

Conclusion

Proper implant selection is critical and should be done on an individualized patient and fracture pattern basis. Poor surgical technique, implant-

related issues, delayed fracture union, and poor patient compliance and health status alone or in combination can lead to breakage of the implants requiring challenging treatment options. Prevention of such catastrophic complications is crucial for the patient's health and quality of life. Biomechanical study of the broken implant may provide useful information regarding failure causes and guide future treatment. Surgeons and mechanics should work hand in hand for implants evolution in order to optimize patient treatment. To minimize damage to joint & implant, these forces vectors have to be compensated by forces generated in opposite direction either by body itself or biomechanical properties of implant either due to its specific design or due to properties of material which is used. If not compensated implant failure may occur.

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