Original research article

A study of biomechanical factors working around hip which leads to implant failure: An observational study

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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, Shridevi Institute of Medical Sciences & Research Hospital, Tumkur, India 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

Introduction

Hip fractures include proximal femoral fractures. Osteoporosis and elderly individuals cause them. In this group, low-impact trauma causes the fracture, while younger individuals suffer high-impact trauma. Stable and unstable pertrochanteric fractures are treated with intramedullary nailing for over 25 years [1, 2]. Loss of fixation, peri-implant femoral fracture, osteonecrosis, infection, and nonunion increase as proximal femoral fractures and operations increase [3-5]. PFN outperforms DHS and DCS in biomechanically fixing proximal femoral fractures, especially unstable ones. It's load-sharing, stable, and less mobile. Nail supports lateral trochanteric wall. PFN outperforms DHS due to reduced intra-op bleed, shorter operating time, less muscle injury and rapid post-op mobilisation. PFN implants fail owing to hip joint biomechanical pressures. The closed intramedullary proximal femoral nail (PFN) is an osteosynthetic implant for trochanter fractures. The funnel-shaped intramedullary proximal femoral nail, like the gamma nail, has a little bend to match diaphyseal trochanteric morphology. Unlike the gamma nail, the proximal femoral nail has two proximal apertures, one distally for a big femoral neck lag screw and one above for a smaller antirotation screw/pin. The nail's tip has locking screw holes [4]. Complex subtrochanteric fractures can be stabilised using a wire cerclage and open reduction [6]. Sliding hip screws with lengthy side plates are used to treat subtrochanteric fractures [7]. For certain fractures, intramedullary implants outperform extramedullary devices biomechanically. Proximal femur nailing antirotation (PFNA) (Synthes Inc., Bettlach, Switzerland) treats unstable intertrochanteric femoral fractures intramedullarily [8]. This technology combines the biomechanical advantages of an intramedullary nail with less invasive surgery [9].

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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
Biomechanical 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

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Discussion

The proximal femoral nail (PFN) is an osteosynthetic implant used in a closed intramedullary fixing technique to repair fractures of the proximal femur at the trochanter. Proximal femoral nails, like gamma nails, are intramedullary nails fashioned like a funnel with a small bend to mimic the trochanteric morphology of the proximal femur. The proximal femoral nail differs from the gamma nail in that it has two proximal apertures, one for a big femoral neck lag screw and the other for a smaller anti-rotation screw/pin. The tip of the nail has a few tiny holes for securement screws [4]. For further stability in complex sub-trochanteric fractures, it might be used in conjunction with a wire cerclage and open reduction [8]. More and more hospital resources are being used to treat patients with osteoporosis-related

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femoral fractures [10]. The already high morbidity and death rates of these individuals are further exacerbated by loss of fixation or implant failure [11, 12]. When it comes to fixing proximal femur fractures, PFN is the biomechanically superior option to both DHS and DCS. This load-sharing device is less mobile but offers greater proximal and distal stability. The nail acts as a counterweight to the collapse of the lateral trochanteric wall. PFN is preferable to DHS because it results in less intraoperative bleeding, less surgical time, less intraoperative muscle injury and rapid postoperative mobilisation. However, there are still dangers, since implant failure can happen in PFN as a result of the unique biomechanical stresses operating on the implant close to the hip. Implant failure is one of the risks associated with TFN. Failure of an implant can occur for a number of reasons, including implant fracture, implant removal via bone, or screw back-out.

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 Anti-rotation 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].

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Conclusion

The selection of appropriate implants is of utmost importance and should be based on the individual patient's characteristics and the specific fracture pattern. The breakage of implants can be attributed to a variety of factors, including suboptimal surgical technique, complications related to the implant itself, delayed union of fractures, and inadequate patient compliance and overall health status. These factors, either individually or in combination, can necessitate the implementation of complex treatment strategies. Ensuring the avoidance of such severe complications is of utmost importance for the well-being and overall quality of life of the patient. The investigation of the biomechanics of the fractured implant has the potential to yield valuable insights into the underlying causes of failure and offer guidance for subsequent treatment strategies. There is a need for collaboration between surgeons and mechanics in order to enhance the development of implants and improve patient treatment outcomes. In order to mitigate potential harm to the joint and implant, it is necessary to counterbalance the force vectors through the generation of opposing forces. These opposing forces can be generated either by the body itself or through the biomechanical characteristics of the implant, which may be influenced by its specific design or the properties of the materials employed. In the absence of appropriate compensation, the possibility of implant failure may arise.

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