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Original Research Article

Biomechanical Factors which Lead to Implant Failure in Proximal Femoral Fractures: A Retrospective Study

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Abstract

Aim: To evaluate biomechanical factors which lead to implant failure in proximal femoral fractures.

Methodology: This is a retrospective study including 30 cases below 75 years of age in last 10 years with proximal femoral fracture [fracture Inter-trochanteric & Sub-trochanteric included] fixed with PFN in Department of Orthopedics, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India for 12 months. Cases with infection; poly-trauma and disability in other limb were excluded from 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.

Results: In our study we registered total of 30 cases with mean age of registered cases was 65.72 $\pm$ 9.45 years. 21 patients (70%) were male and 9 (30%) 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 30 cases registered, pattern of implant failure in our study were 10 cases (33.3 %) had implant failure pattern of Z- effect, 8 cases (26.7%) had implant failure pattern of reverse Z-effect; 4 (13.3%) had breakage of nails; 2 cases (6.7%) had both screw breakage with varus collapse; 3 (10%) had single upper proximal screw breakage; & 3 cases (10%) were associated with spiral fracture femur just distal to the tip of PFN.

Conclusion: Surgeon's experience & accuracy of procedure is of great importance in preventing implant failure. Various complicated forces are there that acts on hip joint in different direction. Each force [whether it is tractional, compression or rotational force] has its own direction. These biomechanical forces are due to bodyweight while standing and walking. To minimize damage to joint & implant [To prevent implant failure], these forces vectors have to be compensated by forces generated in opposite direction either by body itself [abductor muscle strength etc] 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.

Keywords: Tip-to-Apex Distance (TAD), femoral fractures, biomechanical forces.

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, usually during a car accident.

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 [1]. It can be combined with a wire cerclage with an open reduction for additional stability in complicated subtrochanteric fractures [2].

Osteoporosis leading to femoral fracture is becoming more common and consuming increasing hospital resources [3]. Loss of fixation or implant failure increases morbidity and mortality in these often-frail patients [4, 5]. The sliding hip screw is the most commonly implanted device for intertrochanteric fractures, but intramedullary devices combining the sliding hip screw concept with an intramedullary nail have recently been introduced (Gamma nail, how medica and intramedullary hip screw, Richards) and it has been suggested that there may be biomechanical advantages with these implants [6, 7].

Subtrochanteric fractures are classically fixed using a sliding hip screw, with a long side plate [8]. Some authors recommend the use of a 95” blade plate or 95’ condylar screw plate (originally designed for supracondylar femur fractures), especially for more distal fractures [9].

Unstable intertrochanteric femoral fractures are common in the elderly, and the incidence of these fractures is continuously increasing worldwide [10]. 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 [11]. This device combines the biomechanically favorable characteristics of an intramedullary nail with a minimally invasive surgical technique [12].

Materials and Methods:

This is a retrospective study including 30 cases below 75 years of age in last 10 years with proximal femoral fracture [fracture Inter-trochanteric & Sub-trochanteric included] fixed with PFN in Department of Orthopedics, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, for 12 months. Cases with infection; poly-trauma and disability in other limb were excluded from study.

Methodology:

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.

Results:

In our study we registered total of 30 cases with mean age of registered cases was 65.72 ± 9.45 years. 21 patients (70%) were male and 9 (30%) 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 30 cases registered, pattern of implant failure in our study were 10 cases (33.3 %) had implant failure pattern of Z- effect , 8 cases (26.7%) had implant failure pattern of reverse Z-effect; 4 (13.3%) had breakage of nails; 2 cases (6.7%) had both screw breakage with varus collapse; 3 (10%) had single upper proximal screw breakage; & 3 cases (10%) were associated with spiral fracture femur just distal to the tip of PFN.

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

Variables		Number	%
Mean age (in years)		**65.72 ± 9.45**	
Gender	**Male**	21	70
	Female	9	30
Fracture pattern	**Unstable**	27	90
	Stable	3	10
Mal-union	**Present**	22	73.3
	Absent	8	26.7
Biomechanical Pattern of implant failure	**Z-effect**	10	33.33
	Reverse Z – effect	8	26.8
	Nail breakage	4	13.3
	Screw breakage with varus collapse	2	6.7
	Upper proximal screw breakage	3	10
	Spiral shaft femur fracture	3	10

Discussion:

There are two sources of blood supply in proximal femoral fractures: the trochanteric and cruciate anastomoses [13]. When a fracture of the femoral neck occurs, disruption to these blood vessels can occur result in devascularisation of the femoral head and resulting avascular necrosis. Proximal femoral fractures are therefore divided into groups based on their location with regard to the capsule, i.e., whether they are intracapsular or extracapsular.

Intracapsular fractures are important because of their propensity to damage the small intracapsular vessels that provide the majority of the blood supply to the femoral head. Femoral neck fractures must therefore be diagnosed and treated appropriately in order to reduce the morbidity from the consequences of devascularisation. Fractures outside the capsule do not cause the same degree of vascular damage as intracapsular fractures and therefore can be treated differently. The trochanteric fractures are extracapsular injuries.

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 occur secondary to femoral head dislocation. The cause of fixation of failure of intramedullary devices in unstable intertrochanteric fractures is divided into two major groups [14, 15]. First, patient-related factors like osteoporotic bone are one of the main reasons for failure of fixation in the aging population [16]. Second, the most important preventable factors are surgical techniques like suboptimal positioning of the implant.

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 [17]. 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 [18] despite the use of increasingly massive devices such as the Holt nail [19].

A clinical study of 135 consecutive subtrochanteric fractures found use of the intramedullary Zickel nail to be superior to the nail plate. Intra-operative blood loss was significantly lower using the Zickel nail, but there were more technical errors noted using the intramedullary device [20]. Comminution of the greater trochanter may occur if the device is inserted with inadequate proximal reaming or incorrect rotational alignment, because of the proximal valgus angulation of the nail [21]. Similar problems may be anticipated with use of the Gamma nail with its similar geometry. Particular care must be taken during preparation of the proximal fragment and in the correct choice of the nail entry point, at the lateral border of the greater trochanter. No comminution of the femur was noted during implantation of the Gamma nail into any of the femora tested in this study, but the nature of the extirpated specimens allowed accurate alignment of the femoral shaft and the nail in choice of the entry point without soft tissue considerations.

Varus sitting of implant; lateral entry & short screws [TAD> 25mm] increases strength of deforming forces and increases the chances of implant failure. If tip of screw is till near sub-chondral area of head [TAD< 25mm] then internal strength of bone and screw both tries to resist varus collapsing forces in addition to abductor muscle forces. But if TAD>25mm then it will lead to situation in which internal strength of only bone of head of femur will resist along with abductor muscles and it increases chances of varus collapse; screw breakage; screw cut-out; nail breakage etc.

Conclusion:

Surgeon’s experience & accuracy of procedure is of great importance in preventing implant failure. Various complicated forces are there that acts on hip joint in different direction. Each force [whether it is tractional, compression or rotational force] has its own direction. These biomechanical forces are due to bodyweight while standing and walking. To minimize damage to joint & implant [To prevent implant failure], these forces vectors have to be compensated by forces generated in opposite direction either by body itself [abductor muscle strength etc] 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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