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Original Research Article

Evaluation of the Biomechanical Hip Variables That Contribute to Implant Failure: A Retrospective 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 a retrospective study. All 40 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 Orthopedics for one year with implant failure were registered for the study.

Results: In our study we registered total of 30 cases with mean age of registered cases was 62.88 + 8.52 years. 30 patients (75%) were male and 10 (25%) were females. Out of 40 cases registered, pattern of implant failure in our study were 10 cases (25%) had implant failure pattern of Z- effect , 9 cases (22.5%) had implant failure pattern of reverse Z-effect; 7 (17.5%) had breakage of nails; 6 cases (15%) had both screw breakage with varus collapse; 4 (10%) had single upper proximal screw breakage; & 4 cases (10%) were associated with spiral fracture femur just distal to the tip of PFN.

Conclusion: Various complicated forces are there that acts on hip joint in different direction. Each force has its own direction. These biomechanical forces are due to body-weight while standing and walking. To minimize damage to joint & implant these forces vectors has 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.

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

Introduction

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. [1] For further stability in complex sub-trochanteric fractures, it might be used in conjunction with a wire cerclage and open reduction. [2] More and more hospital resources are being used to treat patients with osteoporosis-related femoral fractures. [3] The already high morbidity and death rates of these individuals are further exacerbated by loss of fixation or implant failure. [4,5]

The bony skeleton transfers the loads occurring at the foot to the hip joint. Peak loads occurring during impact activities are dampened through soft tissues in the foot and cartilage in the ankle and knee joints. The anatomy and bipedal gait of humans create lever arms between the point of ground contact of the foot and the point of reaction in the hip joint, resulting in bending and torsional moments along the shaft of the long bones and particularly in the femoral neck. The GRF and the moments create the external forces acting on the bony skeleton. However, these forces are amplified by internal forces created by the muscles. Muscle forces are required for maintaining body balance and accomplishing movement tasks.

Typically, internal forces created by the muscles exceed external forces acting on the body. Due to the small lever arms between the muscular attachments at the greater trochanter and the center of the hip joint, as compared with the larger lever arm between the center of the body mass and the hip joint, muscle forces of more than 2 times body weight are required to properly maintain balance. During 1-legged stance, the contact forces in the hip joint resulting from the vector sum of the muscle forces and gravitational body weight amount to 250% body weight. [6] Forces during slow-level ground walking are of the same magnitude but increase with increasing walking speed or during walking on stairs. [7] For more demanding activities, the hip joint contact forces can dramatically increase. Activities involving load lifting or load carrying have shown to result in hip joint contact forces between 400% and 600% of body weight. [8] The highest forces were observed during load transfers involving squatting, 1-legged weight bearing, or uncoordinated movement like stumbling.

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

Materials and Methods

This was a retrospective study. All 40 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, SNMMCH, Dhanbad, Jharkhand, India for one year with implant failure were registered for the 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 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

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

Variables		Number	%
Mean age (in years)		62.88 + 8.52	
Gender	Male	30	75
	Female	10	25
Fracture pattern	Unstable	37	92.5
	Stable	3	7.5
Mal-union	Present	29	72.5
	Absent	11	27.5
ıechanical Pattern of implant failure	Z-effect	10	25
	Reverse Z – effect	9	22.5
	Nail breakage	7	17.5
	Screw breakage with varus collapse	6	15
	Upper proximal screw breakage	4	10
	Spiral shaft femur fracture	4	10

In our study we registered total of 30 cases with mean age of registered cases was 62.88 + 8.52 years. 30 patients (75%) were male and 10 (25%) were females. Out of 40 cases registered, pattern of implant failure in our study were 10 cases (25%) had implant failure pattern of Z- effect , 9 cases (22.5%) had implant failure pattern of reverse Z-effect; 7 (17.5%) had breakage of nails; 6 cases (15%) had both screw breakage with varus collapse; 4 (10%) had single upper proximal screw breakage; & 4 cases (10%) were associated with spiral fracture femur just distal to the tip of PFN.

Discussion

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. [9-11] 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 [1,12] 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. An emerging trend in locking PFP development involves combining fixed-angle technology with parallel telescoping screws, which allows controlled compression via a dynamic sliding mechanism. Constructs that incorporate these features have the potential to utilize the respective benefits of both CS and hip screw methods, by allowing compression of the fracture site while preserving cancellous bone and providing a rotationally stable healing environment. [13,14]

In our study we registered total of 30 cases with mean age of registered cases was 62.88 + 8.52 years. 30 patients (75%) were male and 10 (25%) were females. Out of 40 cases registered, pattern of implant failure in our study were 10 cases (25%) had implant failure pattern of Z- effect , 9 cases (22.5%) had implant failure pattern of reverse Z-effect; 7 (17.5%) had breakage of nails; 6 cases (15%) had both screw breakage with varus collapse; 4 (10%) had single upper proximal screw breakage; & 4 cases (10%) were associated with spiral fracture femur just distal to the tip of PFN. 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. [15]

Clinical recommendations for implant usage must often rely on findings from biomechanical testing. Clinical studies comparing outcome for different implant designs typically lack statistical power to identify differences in clinical outcome measured by functional outcome scores or by patient satisfaction. Thus, if reassuring findings from multiple biomechanical studies can be identified, this can lead to strong recommendations for or against the use of specific implant configurations. However, it is not only the type of implant but also the type and remaining stability of the fracture that strongly affect the mechanical performance of an osteosynthesis construct. [16,17] The remaining stability of the fracture determines the amount of load that the implant can share with the bone. For stable fractures, the implant can be more load sharing, whereas for unstable fractures, the implant needs to be load bearing.

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. [18] 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. [19] 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. In general, basicervical fractures or Pauwels type III fractures and comminuted fractures can be considered as mechanically unstable, requiring a load-bearing implant, such as hip screws, with antirotational screws or intramedullary nails. Sub capital or trans cervical fracture patterns and non comminuted fractures enable load sharing and can be securely fixed with CS or solitary hip screw systems without compromising fixation stability. However, despite all the biomechanical evidence that is available, the choice of implants for femoral neck fractures in young adults remains to be controversial. [20]

Conclusion

Various complicated forces are there that acts on hip joint in different direction. Each force has its own direction. These biomechanical forces are due to body-weight while standing and walking. To minimize damage to joint & implant these forces vectors has 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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