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Biomechanical rationale for implant choices in femoral neck fracture fixation in the non-elderly

Michalis Panteli [a], Paul Rodham [b], Peter V. Giannoudis [a,b,c,d,*]

[a] Academic Department of Trauma & Orthopaedics, School of Medicine, University of Leeds, UK
[b] Newcastle University, UK
[c] LIMM Section Musculoskeletal Disease, University of Leeds, UK
[d] NIHR Leeds Biomedical Research Unit, Chapel Allerton Hospital, LS7 4SA Leeds, West Yorkshire, UK

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ABSTRACT

Femoral neck fractures represent a relatively uncommon injury in the non-elderly population often resulting from high-energy trauma. The cornerstone of their management is anatomic reduction and stable internal fixation of the femoral neck in an attempt to salvage the femoral head. Complications including avascular necrosis of the femoral head, non-union and post-traumatic osteoarthritis are not uncommon. The clinical outcomes of these patients can be improved with good pre-operative planning, optimization of surgical procedures and introduction of new improved implants and techniques.

In the herein study, we attempt to describe the biomechanical properties of the hip and compare the performance of the most commonly used devices. Experimental evidence suggests that in Pauwels type III fracture patterns a cephalomedullary nail was significantly stronger in axial loading. Moreover, in unstable basicervical patterns cannulated screws (triangular configuration) demonstrated a lower ultimate load to failure, whereas in subcapital or transervical patterns both the cannulated screws (triangular configuration) and the sliding hip screw demonstrated no compromise in fixation strength. The fracture pattern appears to be the major determinant of the ideal type of implant to be selected. For a successful outcome each patient needs to be considered on an individual basis taking into account all patient and implant related factors.

Introduction

Femoral neck fractures include injuries involving the area between the head of the femur and the intertrochanteric line. They are divided into intracapsular and extracapsular, according to their relation to the hip capsule [1]. These fractures represent an increasing burden on healthcare globally, with the number of hip fractures occurring worldwide expected to increase from 1.66 million in 1990 to 6.26 million fractures in 2050 [2]. In 2005, it was calculated that the total associated cost in England reached £384 million, a figure that is expected to rise along with their increasing frequency [3].

The incidence of femoral neck fractures is unimodal, increasing exponentially with age [4]. The mechanism of injury generally reflects the bone mineral density with the elderly population sustaining fractures from low-energy falls, whereas non-elderly patients sustain these fractures following significant high-energy trauma [5]. Generally, patients under the age of 65 years old are considered as young patients, in contrast to patients older than 75 years of age considered as elderly [6]. The remaining group of patients is judged on the basis of their “physiological” age [6].

Several studies have established a number of risk factors for these fractures, including low bone mass index (BMI), low sunlight exposure, prolonged corticosteroid treatment, previous osteoporotic fracture, low bone mineral density (BMD), weak hand grip strength and reduced mobility [7–11].

The aim of this study is to outline the biomechanical properties of the hip and present current evidence with regards to the implant choice in the operative management of displaced femoral neck fractures in the non-elderly population.

Hip anatomy

The hip joint is a synovial joint providing a substantial range of movement due to its shallow articulation with the acetabulum.

* Corresponding author at: Academic Department of Trauma & Orthopaedics, Leeds General Infirmary, Clarendon Wing, Level A, Great George Street, LS1 3EX Leeds, UK. Tel.: +44 113 392 2750; Fax: +44 113 392 3290.
E-mail address: pgiannoudi@aol.com (P.V. Giannoudis).

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Nonetheless, it is a joint possessing great strength through the capsule, the supporting ligaments and muscular attachments [12]. The normal neck-shaft angle is $131^\circ \pm 5^\circ$ in men and $129^\circ \pm 5^\circ$ in women [13]. With regards to the anteversion of the hip, a wide variation is reported between studies with an average of 8° in men and 14° in women [14].

Blood supply of the femoral neck/head

When treating patients with intracapsular hip fractures, problems are often encountered due to its vulnerable blood supply. The blood supply to the femoral neck relies on an extracapsular arterial ring formed around the femoral neck, derived mainly from the medial femoral circumflex artery, anastomosed anteriorly with some smaller branches of the lateral femoral circumflex artery. The superior and inferior gluteal arteries further enhance the blood supply to some extent, with the artery of ligamentum teres (a branch of the obturator artery or medial femoral circumflex artery), also contributing to the blood supply [15]. The branches of the extracapsular ring reflect beneath the capsule as retinacular vessels, ascending to the neck to form the subsynovial intracapsular ring in the proximal neck, branches of which contribute to the blood supply of the head of the femur [16–18]. As a result of this configuration, any fracture within the capsule has the potential to damage the blood supply to the femoral head with this risk increasing with greater levels of displacement [1,19]. Therefore, re-establishing blood supply to the femoral head by prompt reduction and stable fixation is critical and should be achieved as soon as possible.

Hip biomechanics

The femoral head is located medially and anteriorly to the anatomical axis of the femoral diaphysis. Consequently, compressive, tensile, and torsional strains act on the femur during human locomotion, whereas their distribution varies according to the weight-bearing status and spatial position of the hip (Fig. 1) [15,20–23]. The two dominant forces acting on the femoral neck include: one lying perpendicular to the long axis of the femur providing downwards compression on the femoral neck, generating shearing stress on any implant inserted through the neck's long access [24,25]; and a second one lying parallel to the long axis of the neck [24,25].

The direction of these forces also reflects on the development of the trabecular lines, which represent increased bone mineral density to specific areas of the hip. Since early in life, the medial and lateral trabecular systems are evident [26], whereas the secondary trabecular systems appear on the superolateral third of the neck in late adolescence [27]. Whilst it is generally accepted that the medial trabecular system is under compression, there has been dispute as to whether the lateral trochanteric trabecular system is in tension as a result of the abductor influence, or in compression due to the transmission of force from the femoral head [28–30]. Recent evidence however suggests that the lateral trabecular system is in fact predominantly under compression [29,30].

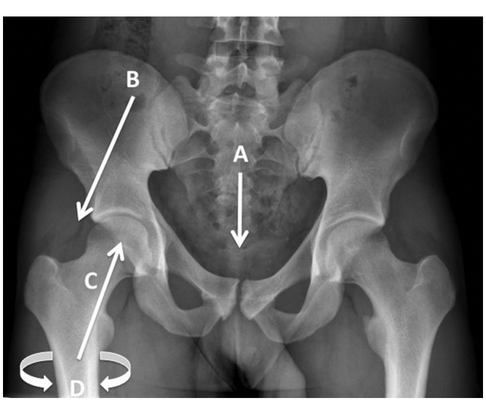

Fig. 1. Forces transmitted by the hip joint. (A) Force of body weight (passing through the centre of gravity). (B) Force exerted by the abductor muscles. (C) Force transmitted through the hip joint. (D) Rotational forcers transmitted through the hip joint.

Hip geometry

Several authors have suggested that the geometry of the hip plays a crucial role in the incidence of neck of femur fractures [31–33]. Increased hip-axis length, increased neck length, increased neck length/width ratio, reduced cortical bone thickness and changes in the neck-shaft angle are all factors increasing the risk of sustaining a femoral neck fracture [32–34]. Furthermore, the hip strength reduces with an increased hip-axis length, whereas the neck-shaft angle does not affect the strength of the hip [31]. On the other hand, the fracture line geometry generally depends on the energy of the injury and the patient's age [21]. These distinct biomechanical features of the femoral neck, and more specifically the high concentration of stresses to this region, make the management of such fractures even more challenging [21].

Epidemiology

Femoral neck fractures represent a relatively uncommon injury in the non-elderly population; nevertheless, they are linked to high morbidity and reduced quality of life [4,35]. Their incidence has been reported as low as 5 in 10,000 population per annum [4]. Concomitant injuries often confound the management of these fractures, especially in the background of polytrauma [36,37]. The overall mortality in the non-elderly population has been previously reported as high as 5.7%, within the first year post injury [38]. Although uncommon, metabolic bone disease has also been implicated to contribute to this group of fractures [39,40].

Management

The cornerstone of managing femoral neck fractures in the non-elderly population is anatomical reduction and stable internal fixation of the femoral neck, in an attempt to salvage the femoral head, even in grossly displaced fractures. Total hip arthroplasty and hip hemiarthroplasty is generally reserved for use in the elderly, where the survival of such implants and need of revision is of secondary importance [41]. A good understanding of the differences between non-elderly active patients and elderly frail patients will facilitate treatment.

The clinical outcomes in the non-elderly patients sustaining femoral neck fractures can be further improved with good pre-operative planning, optimization of surgical procedures and introduction of new improved implants and techniques [21]. The choice as to which type of fixation and device is the most beneficial to the patient is not straightforward and should be made by the treating physician on an individual basis, taking into account such factors as the "personality" of the fracture, physiological age of the patient and pre-injury mobility [42].

Operative implant devices

Several implants (intramedullary or extramedullary in nature) are available for the fixation of these fractures, each one with its