Abstract

The femoral neck is the weakest and most common site for hip fractures. Pauwels type III fracture, wherein the fracture plane makes an angle of 50^{O}-70^{O} with the transverse plane, is the most unstable femoral neck fracture. Open reduction internal fixation (ORIF) is the preferred technique for younger populations with non-osteoporotic bones. There are various internal fixation devices for treating Pauwels type III fractures. Cannulated cancellous screws (CCS) and dynamic hip screw (DHS), and DHS+Anti-rotation screw (DHS+ARS) are the most used internal fixators for treating femoral neck fractures. In 2018, a new fixation technique, known as the Femoral Neck System (FNS), was introduced by DePuy Synthes. This implant system features a divergent screw mechanism comprising a bolt and an anti-rotational screw. Patients treated with internal fixators often experience complications like non-union (14%) and osteonecrosis (11%). These complications subsequently led to the failure of the fracture reconstruction surgery. Recent global reports have highlighted instances of failure of FNS implants. A few cases of FNS failure have also been observed at the All India Institute of Medical Sciences (AIIMS), wherein all the implant failures occurred within two months of partial weight-bearing. Fractographic analysis, along with scanning electron microscopy, has been conducted on the fractured surfaces of the failed FNS implants to identify probable failure mechanisms. Fracture characteristics showed a mixed ductile-brittle in two failure cases and predominantly fatigue-induced in the other two implant failure cases. In one case, a difference in grain structure was observed near the screw's outer periphery compared to its middle; this discrepancy indicates inadequate cooling during the heat treatment. Experiments were conducted on sawbones® to validate the developed FE modeling framework. The FE-predicted values were close to the experimental values, with deviations of 5.6%, 2%, and 4.9% for intact bone, CCS, and FNS, respectively. Furthermore, subject-specific finite element (FE) models were developed to gain insight into the stresses and strains in implants and bones. Patient-specific heterogeneous femoral FE models were developed from preoperative CT scans. Under stair climbing loading, the elevated von Mises stress (Case 1: 486 MPa, Case 2: 229 MPa, Case 3: 208 MPa, and Case 4: 213 MPa) was observed at the failure site. Additionaly, an FE-based computational study was conducted to compare the biomechanical performance of FNS with other internal fixation devices, such as CCS, DHS, and DHS+ARS. Normal walking and stair-climbing loading conditions were considered in this study. FNS showed the highest inferior axial displacement (normal walking: 3.51 mm and stair climbing: 4.19 mm) of the femoral head, while DHS+ARS exhibited the least inferior axial displacement (normal walking: 2.27 mm and stair climbing: 2.87 mm). DHS+ARS also demonstrated superior performance in terms of long-term bone remodeling response. Finally, an improved design of the FNS implant has been proposed, which provides better stability and reduced von Mises stress in the cortical screw, therefore, reducing the risk of implant failure.