Abstract

In the present work, experimental and numerical investigations into the load-displacement responses of a human lumbar Truncated Vertebral Unit (TVU) under quasi-static and impact loading conditions have been carried out for aiding in the design of orthopaedic implants and countermeasures for vehicle occupant and pedestrian safety. TVU samples obtained from the lumbar spinal column of an adult human male cadaver were initially subjected to quasi-static compressive tests. Impact tests were then conducted on a similar TVU sample in a drop-weight testing device instrumented with a piezoelectric load cell and a high-speed data acquisition system. An explicit nonlinear finite element model of the TVU was developed for predicting the experimental quasi-static and impact dynamic responses. Using the validated modelling approach mentioned, insights have been generated on adjoining vertebral stresses due to disc arthroplasty, and single and multi-level disc fusions as well as posterior fusions with and without posterior instrumentation. The numerical study is further extended to another crucial orthopaedic domain i.e. the assessment of the performance of variants of TKR (Total Knee Replacement) implants under ISO-specified dynamic gait cycle. In the latter investigation, a detailed and realistic finite element model of a representative human knee complex was developed by capturing relevant tissues such as femoral and tibial bones, medial and lateral collateral ligaments, and the components of a typical TKR implant including femoral component, tibial tray and UHMWPE (Ultra High Molecular Weight Polyethylene) insert. Substantive contribution has been made in the current research work towards assessment of vehicle occupant and pedestrian safety by applying the previously mentioned advanced finite element modelling approaches for representing complex vehicle structures, anthropomorphic test devices (commonly called as “dummies”), and pedestrian leg-forms. To this end, keeping in mind computational efficiency and need for optimization, a truncated finite element modelling approach capable of predicting the occupant response for a passenger car subject to a full-frontal US-NCAP test has been developed. Using the modelling tools mentioned and a nonlinear explicit LS-DYNA solver, it has been shown that meeting pedestrian safety standards need not be an isolated exercise of designing the front bumper of a vehicle only but can be combined with meeting NCAP occupant safety requirements leading to weight reduction of the front structure of a vehicle with gages of parts such as front rails in addition to bumper parts being included as design variables. For the first time, with the help of a comparative study carried out with a Hybrid 3 dummy and detailed biomechanical models of human lower extremity, the susceptibility of knees with TKR implants to periprosthetic injuries during

frontal collisions has been demonstrated pointing out to a need for higher knee-protection countermeasures in vehicles.