A COMPUTATIONAL ANALYSIS OF HIP IMPLANT FAILURE

Laureb Rao[1], Rounak Bhattacharya[2], Rajesh Malhotra[3,4], Deepak Gautam[3,5], Anoop Chawla[1,6], Kaushik Mukherjee[1,6]
[1]Transportation Research and Injury Prevention Centre, Indian Institute of Technology Delhi, New Delhi, India; [2]School of Interdisciplinary Research, Indian Institute of Technology Delhi, New Delhi, India; [3]Department of Orthopaedics, Jai Prakash Narayan Apex Trauma Centre, All India Institute of Medical Sciences, New Delhi, India; [4]Indraprastha Apollo Hospital, New Delhi, India; [5]BVP Medicover Hospitals, Navi Mumbai, India; [6]Department of Mechanical Engineering, Indian Institute of Technology Delhi, New Delhi, India.
Email: kmukherjee@iitd.ac.in

Summary
This study focuses on the failure of a cementless implant system. Two conditions were analyzed: one with complete osseointegration and another with inadequate osseointegration. Walking load condition was simulated in ANSYS APDL software. The location of maximum von Mises stress corresponds to the failure location of the implant. The von Mises stress increases from 194.5 MPa to 263.3 MPa in inadequate osseointegration compared to complete osteointegration.

Introduction
With the increasing rate of hip replacements every year, the need for more durable and long-lasting implants has become increasingly important. A cementless implant provides excellent stability and low rates of post-operative complications such as aseptic loosening [1]. Despite several advancements in the shape and surface texture of the implant for improved bone ingrowth, implant failure remains a leading cause of concern and leads to revision surgeries. The current study focuses on the failure of one such cementless implant system. A total hip implant system made by DePuy Synthes was used for the current study (Fig 1A). The current study suggests that the failure is attributed to inadequate osseointegration on the implant surface.

Methods
CAD model of the retracted implant was generated using a μ-computed tomography scan (μ CT-scan) on a Scanco Xtreme CT-II, Scanco Medical AG, Brüttisellen, Switzerland. The implant was positioned in a 4th generation saw bone (Model #3406 Saw Bones, A Pacific research laboratory, Vashon, WA, USA) femur model to simulate the total hip replacement surgery procedure Fig 1B. An FE model using second-order tetrahedral elements was generated for the bone and implant using Altair Hypermesh software (Altair Engineering Inc., Troy, Michigan, USA). Two conditions were analyzed: one with complete osseointegration in which the implant was completely bonded with the bone; the second with a gap of 1mm between the implant and bone surface up to the fracture surface to represent inadequate osseointegration. In the latter case, the implant-bone interface below the fracture plane was considered as bonded. Walking load condition [2] was simulated in ANSYS APDL software. Implant material properties were analyzed using energy-dispersive X-ray spectroscopy (EDS) technique Fig 2. The Young's modulus for cortical, cancellous, and implant was 16.8GPa, 0.155GPa, and 250GPa, respectively. Poisson's ratio for all components was uniformly considered as 0.3.

Results and Discussion
Von-mises stress distribution in the implant system for both the cases of complete and inadequate osseointegration are plotted in Fig 3. The location of maximum von Mises stress corresponds to the failure location of the implant. The von Mises stress increases from 194.5 MPa to 263.3 MPa in inadequate osseointegration compared to complete osteointegration.

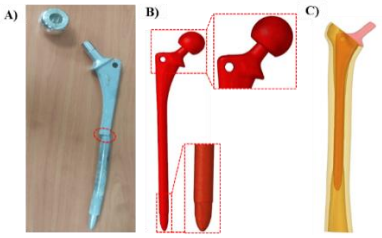

Figure 1: A) Fractured implant retracted from patient's, B) FE model Implant and, C)Implant bone assembly.

Element	Weight%	Atomic%
C K	16.60	46.28
O K	3.27	6.83
Si K	0.86	1.02
P K	0.31	0.33
Cr K	24.56	15.81
Co K	49.00	27.84
Mo L	5.41	1.89
Totals	100.00	

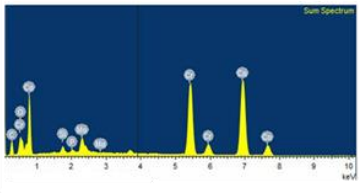

Figure 2: Material composition obtained from EDS

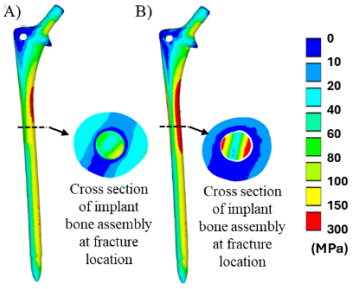

Figure 3: von-Mises stress distribution in A) complete osteointegration and B) inadequate osteointegration.

Conclusions
Higher von-mises stress was present near the fracture site of the implant. Increased von-mises stress in the case of inadequate osseointegration could be a possible reason for implant failure.

References
[1] Jin, S. (2021) *BMC Musculoskeletal Disorders*, 22(1).
[2] M.O. Heller et al. (2005), J Biomech 38.