Mechanical Engineering and the Ageing Population: Proposal for Post-Graduate Training

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Abstract

Background to the effects of ageing of the world's population is presented. Attention is drawn to the World Health Organisation's concern over elderly people and the need for new training. The role of mechanical engineers in providing solutions to problems faced by clinicians in treating elderly patients is described. Proposals for post-graduate training are then discussed. This will take the form of a post-graduate Master of Science degree related primarily to orthopaedics. The modules to be introduced are discussed. The arrangements for a research thesis based on the effects of these modules are included.

Introduction

People are living longer, but their bodies are finding it difficult to cope with the effects of old age. Falls occur, bones fracture, arthritis sets in, the back aches. With an ageing population and ever-rising costs in patient care after trauma there is an increased demand on health services to which engineering solutions are required as well as post-graduate training. The World Health Organisation has already recognised the need for enhanced and growing care patterns for the elderly, and has declared this the "decade of bone and tissue".

In the University of Edinburgh, post-graduate research training in mechanical engineering has given rise to deeper understanding of the way in which mechanical engineering can enhance the quality of life of the elderly.

The next section illustrates some key findings in which mechanical engineers have collaborated with clinicians, mainly orthopaedic surgeons.

Post-Graduate Research: Mechanical Engineering and Orthopaedics for Aging.

Figure 1 shows a decrease in fracture energy of the human cortical bone with increase in age. A corresponding rise in porosity is shown in figure 2. The increase is more marked for people aged over 70 years, and even more noticeable for women.

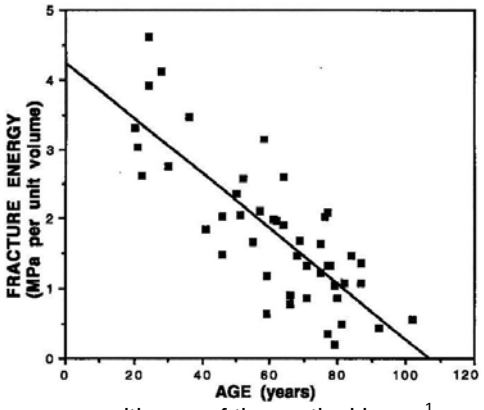

Figure 1: Decrease in fracture energy with age of the cortical bone.[1]

These experimental observations mean that bone is more likely to fracture for older people; Table 1 presents the main causes of bone fracture. Note that simple falls, that are likely to occur for older people, are a major cause of fracture, after road accidents. Wrist fractures are common, especially for women, as noted from Figure 2.

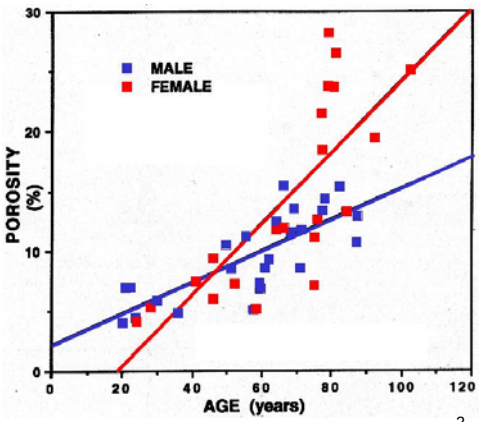

Figure 2: Rise in porosity of bone with age in both males and females.[2]

Causes of Bone Fracture	
Percentage of Fractures	Cause
57.7	Road traffic
19.0	Simple fall
9.7	Fall from height
6.2	Direct blow
4.5	Sports accidents
1.9	Fall down stairs
1.0	Caused by sharp object

Table 1: Causes of bone fracture[4]

Hip fractures are also very frequent in older people. In Scotland alone (with a population of 5 million), there is on average 6500 hip fractures each year, in England (with a population of about 55 million), 33,000 total hip replacements are performed every year, with 80% occurring in women aged over 70 years.[4] The cost of this to the National Health Service (UK) amounts to £30 million. World-wide, incidence of hip fracture exceeds 1.7 million. Mechanical engineers are involved in the use of computer-aided design and manufacture of hip replacements, Figure 3, and the search for new alloys including titanium, and coatings for the prosthesis that will prolong their duration within the body.[5] An example of the criteria which is required to be met with prostheses coatings include: a) Low Toxicity b)High biocompatibility c)Resistance to corrosion by body fluid d) Prevention of bone loosening at implant contact point.

The effects of osteo- and rheumatoid arthritis in the knee and other places of the body in older people give rise to total knee arthroplasty (TKA). The average age of patients requiring TKA is 68 years. The key to long term biological stability is good initial mechanical stability, by press-fit or use of cement.

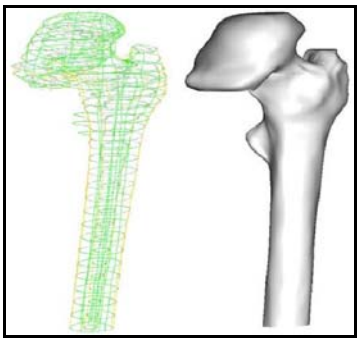

Figure 3: Computer Aided Design of proximal femur for repair of fracture.

Back pain is a further common occurrence in the elderly. As indicated in Figure 4, the foot of the vertebrae is the sacrum; clinicians hypothesise that its surface roughness contributes to the onset of back pain. Mechanical engineers are involved in measurement of sacrum surface roughness in order to throw further light on this cause of back pain.[6]

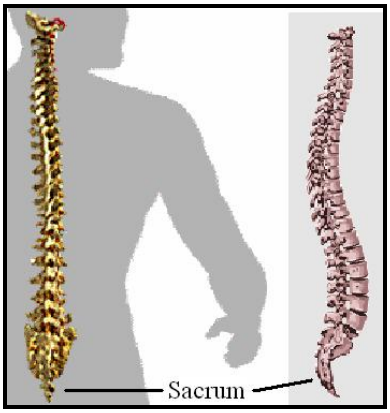

Figure 4: The Sacrum bone at the foot of the vertebrae.

Finally, many older people live in sheltered housing and nursing homes. Mechanical engineers are involved in using "smart" technology including "intelligent" flooring to provide them with privacy and dignity within their house. Table 2 summarises advances in assessment of flooring, for the prevention of fractures in residential care.[7]

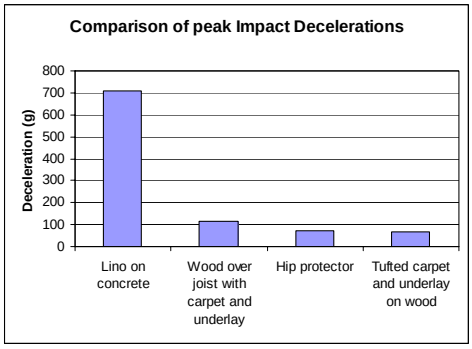

Table 2: Impact decelerations with differing flooring types.

In summary, these researches have given rise to proposals for a post-graduate Master of Science course to provide graduates and working professionals with a broad training in orthopaedic engineering. The course takes account of the training needed to deal with the aging population.

Post-graduate Training: Mechanical Engineering in Orthopaedic Engineering.

During the first and second semesters, students will attend examined instructional classes. Then working with a clinician, they will complete a research project, reporting by submission of a thesis. An informal component of the programme will consist of visits to local clinical centres and attendance at research seminars presented by visiting experts from the UK and overseas.

The proposed course structure consists of a full-time option lasting for 12 months, or a diploma for 9 months. Provision is to be included for distance learning to suit the needs especially of registrars and other full-time professionals. Candidates will also choose one conversion module, and five from six optional modules. Please find the proposed module listing below.

1. Conversion Modules:
    a. Fundamentals of Engineering for Clinicians or
    b. Biomedical and Health Science for Engineers. Consultation with clinicians confirms that they would value reinforcement of their scientific and engineering appreciation of basic principles, for example, 3 or 4 point bend tests in bone mechanics, strength of

materials. Engineering candidates require insight into the mechanics of the human body.

2. Optional Modules:
    a. Instrumentation. Orthopaedics concerns the skeletal frame of the human, and the different functions of the components such as bone, tendon, muscle, tissue and ligament interaction. To carry out scientific observation of these actions, application of sensors to measure force, acceleration of different components, and understanding of electromechanical instrumentation is required.
    b. Computational and Experimental Methods. As a consequence of the above instrumentation, data have been gathered and finally analysed. This module therefore deals with aspects of mechanical manipulation of raw signal data.
    c. Finite Element Analysis (FEA). Present research between engineering and orthopaedic surgery has underlined the value of FEA in understanding the interaction between mechanical forces on human structures.
    d. Applied Human Movement. The instrumentation and analysis of the individual components discussed above are essential tools needed for understanding human movement. This module will deal with how deficiencies in movement, due to old age, disease or trauma differ from healthy conditions.
    e. Tissue Mechanics. As a consequence of the above aspects of ageing, disease and trauma, insight is required into the microstructural, microscopic and cellular composition of human tissue. In this module relevant topics including the composition of human bone, cartilage, ligaments, tendons, and muscle, the mechanics of healing, injury and fixation will be considered.
    f. Prosthetics Technology. An outcome of the preceding modules is grounding and preparation in mechanical engineering solutions to tissue that is ageing, injured and diseased. In many cases these solutions will take the form of implants and artificial prostheses. This module addresses the topics which relate the requirements of the surgeon in serving the needs of the patient to the work of the mechanical engineer in providing the materials used in prosthesis, their design and manufacture, including rapid prototyping.

Research Thesis

While studying these modules, students also undertake preparations for their chosen professional project in the third and final semester. This is expected to be linked to a current research area. Typical recent projects include a) load-displacement measurement of a radial fracture, b) design of instrumentation for testing mechanical stimuli on human cells and tissue.

Conclusions

With the world's ageing population, there is a rising need for post-graduate training in mechanical engineering linked to surgery. This need requires close cooperation between the engineer and clinician. The training has to include conversion courses that provide clinicians and engineers firstly with the foundation on which their post-graduate education has to be based. Then they have to become acquainted with key computational and experimental methods, and the bases of human movement and tissue mechanics, that underpin the effects of ageing. They should know about the technology of prostheses that are fitted by the surgeon, especially to elderly patients.

References

1. McCalden, R.W., McGeough, J.A., Barker, M.B., Court-Brown, C.M., Journal of Bone and Joint Surgery, 1993 Vol 75-A, pp1193-1205.
2. idid.
3. Cardone, L, PhD Thesis, University of Edinburgh, 2006.
4. Cardone, L, Private Communication, 2004.
5. Skalski, K., Warsaw University of Technology, Private Communication.
6. Gardner, D. L., McGeough, J.A., Private Communication, 2004.
7. Simpson, H., et al, Paper in proof, 2005.