Development of new treatment strategies and improved clavicle plate designs for acromioclavicular dislocations and clavicular fractures using principles of stratified design and manufacture and enhanced 3D software based reconstruction techniques

The proposed project is an interdisciplinary project between engineering, computer science and medical science. The project aims to develop new device designs using advanced manufacturing processes for a system that will enable the manufacture of functionally stratified titanium medical devices such as clavicle implants.

Clavicular fractures account for 2.6 % of all fractures [1]. Of these, nearly 80 % occur in middle third of the bone, 15 % in distal thirds and 5 % in medial thirds [1]. Diagnosis of clavicular fractures may be done using X-rays, CT scans, MRI and ultrasound techniques. Traditional treatments vary from using supports such as slings, straps and braces to surgical techniques such as plate and screw fixation and intramedullary fixation. In many cases, slings will not help fully heal. In such cases, surgery with one of the other two treatment methods is required. Usually, titanium or steel plates are used in the case of plate and screw fixation. While intramedullary fixation involves less surgical dissection and soft tissue stripping and less prominent physical abnormity, there are often cases of pin migration and poor rotation control of the shoulder. On the other hand, plate and screw fixation provides the advantage of resisting bending and torsional forces during elevation but results in increased exposure and soft tissue stripping and potential damage to supraclavicular nerves, higher infection rate and risk of refracture after plate removal. 2D plates currently being used are difficult to secure because of the complex 3D shape of the clavicle [2]. A correctly shaped plate can therefore reduce the risk of complications. Furthermore, in current designs, there is a potential for developing osteolysis and fracture around the implant [3] and pain elimination was not fully achieved in most patients post surgery [4].

To overcome the issues associated with the current state of the art in claviculoplasty, this project will seek to develop new fixation strategies and functionally stratified clavicle plate designs. New fixation strategies will be centered around creating new thin plate structures in the form of a mesh to hold the split clavicle bone in place with minimal use of screws and possible incorporation of growth factors in the mesh that will enhance self repair. The designs will be functionally stratified by taking into account patient variability in age, types of dislocations and fractures, race, gender, prior medical history etc. which will be accounted for by analysing medical images of clavicle fracture cases using machine learning techniques. A detailed taxonomic classification from this analysis will be embedded into a software design tool which will enable selection of appropriate fixation techniques for clinical cases. Enhanced 3D reconstruction techniques will be developed within this project which will take medical images of fractures as inputs and process them to come up with the reconstructed contoured clavicle plate designs. Appropriate manufacturing processes will then be linked to the clavicle plate design from the new prototyping methods available within the research group such as Single Point Incremental Forming (SPIF) and Two Point Incremental Forming (TPIF), and additive manufacturing strategies such as selective laser sintering and stereolithography (SLA). The new 3D contoured plate designs for a set of test cases will be manufactured with the selected manufacturing strategies and sent for further clinical evaluation. Design iterations will be incorporated post feedback from collaborating hospitals.

References

[1] SA Bhat, KA Bhat, S Gupta, MS Lone, A Bhat, N Ali. Changing trends in the management of adult clavicular fractures: A prospective study. International Journal of Advanced Research (2014). Vol. 2, Issue 6, pp. 843-849

[2] JW Shen, PJ Tong, HB Qu. A three-dimensional reconstruction plate for displaced midshaft fractures of the clavicle. The Journal of Bone and Joint Surgery (2008). Vol. 90-B, No. 11, pp. 1495-1497

[3] R Nadarajah, J Mahaluxmivala, A Amin, DW Goodier. Clavicular hook-plate: complications of retaining the implant. Injury - International Journal of the Care of the Injured (2005). Vol. 36. pp. 681-683

[4] N Rosenberg, L Neumann, AW Wallace Functional outcome of surgical treatment of symptomatic nonunion and malunion of midshaft clavicle fractures Journal of Shoulder and Elbow Surgery (2007) Volume 16, Issue 5, pp. 510–513

Supervisors

Faculty of Engineering: Dr. Amar Kumar Behera, Research Fellow, Materials, Mechanics and Structures
Faculty of Science: Dr. Bai Li, Associate Professor, Computer Science
Dr. Hengan Ou, Associate Professor, Associate Professor, Faculty of Engineering

Collaborators

*Nottingham University Hospitals Trust: Prof W Wallace, Professor of Orthopaedic and Accident Surgery
Dr. Hengan Ou, Associate Professor, Associate Professor, Faculty of Engineering

---

*Contacts were made with Prof. Wallace, Apollo Hospitals, India, Fortis Memorial Research Institute and a number of orthopaedic surgeons already. Confirmation of collaboration and use of research output is awaited in some cases.