Virtual Poster Session: Bone | Friday June 12, 2020 - 3:00-4:15pm EDT

https://vimeo.com/showcase/7175382

24| Mahsa Miss Zojaji- Queens University; Masters (In progress or completed)

"Quantifying Flexural Rigidity of a Bone Surrogate"

Surrogate bone materials are often used in testing when a natural bone is not available, or if more consistent results are required than what would be found in a natural material. One of the primary challenges of a surrogate material is the ability to accurately mimic the mechanical properties of natural long bone. In the current study, we used the bi-material bone surrogate functional testing data, developed in the previous study, to evaluate bending stiffness measurements and calculations. The aim of this study was to quantify differences in flexural rigidity assessments. Four-point bending tests were performed in a custom-designed four-point bending apparatus using an MTS Sintech 10/GL testing machine (MTS, Eden Prairie, MN). Flexural rigidity was determined by loading at a constant rate of 5 mm/min, for accurate flexural rigidity assessment a displacement sensor measured the specimen deflection at the mid-point and digital image correlation (DIC) to quantify deformation. Using Finite Element Analysis (FEA), four-point bending was simulated by applying transverse displacement to the bone surrogate by the upper load supports. The main conclusion was that crosshead deflection data are the sum of the specimen deflection, machine compliance and the local deflection of the load applicators compressing the bone at the contact points; therefore, the accuracy of long bone flexural rigidity was improved by accounting for testing compliances.

26| Jakub Szmit- Western University; Masters (In progress or completed)

"Impact of loose Fitting Radial Head Hemiarthroplasty Following Malalignment"

Background: Radial head (RH) hemiarthroplasty replaces the native RH with a metallic implant, with outcomes and contact mechanics (CM) remaining suboptimal. RH hemiarthroplasty is done using physical landmarks that are visually observed. Malalignment is common as optically a 5° variation is difficult to see. This studies purpose was to establish the effects of varus/valgus malalignment of both the native RH and following hemiarthroplasty. Examination into whether loose fitting mitigated effects of malalignment relative to fixed fitting was done. It was hypothesized that RH malalignment would result in suboptimal radiocapitellar CM, with negative effects being mitigated by loose fitting RH hemiarthroplasty implants relative to fixed fitting.
Methods: Cadaveric elbows (n=11) were disarticulated and sized by a surgeon for a RH implant. The radii and capitellum were potted and mounted into a custom testing device. A 50N compressive load was applied via an actuator, articulating the radius with the capitellum at 90° flexion. Joint contact area (CA) and contact pressure (CP) were measured using a Tekscan 5051 sensor for the native and hemiarthroplasty RH with a fixed fit and loose fit stem (1, 2 and 3mm over-reamed (OR)) at neutral and 5° varus/valgus.
Results: The native RH showed significant increase in CA between neutral and varus ($p=0.018$). In varus all loose fit implants saw significant increases in CA ($p<0.014$) relative to fixed. At varus OR3 had significantly lower average CP then OR1 and fixed fit ($p<0.048$). In valgus, OR2 had significantly lower average CP then fixed ($p=0.029$).
Significance: Malalignment of 5° did not impact the native RH significantly. Following RH hemiarthroplasty, loose-fitting over fixed fitting may mitigate the reduction of CA from varus/valgus malalignment. A loose fit of OR3 improved elbow CM relative to other fixation methods and may help to preserve the remaining native capitellar cartilage, mitigating the impact of malalignment.

27| Brian Kunath- Queens University; Masters (In progress or completed)

"Compressive Modulus of Trabecular Bone Surrogates in a Bioreactor"

Background: Bone fractures caused by bone diseases, such as osteoporosis, are undertreated and underdiagnosed in Canada. Bone adaptation has been shown to be affected by mechanical loading and loading rate, however, precise ranges remain unclear.
Rationale: Previous studies have been performed to test the effect of load and loading rate using bioreactors, such as the ZETOS bioreactor. With modifications of the ZETOS bioreactor, a calibration method is required to ensure that consistent material stiffness is observed in and out of the bioreactor.
Purpose: The objective of this study was to investigate different rigid polymers' stiffness in and out of the bioreactor and to determine if the bioreactor has a significant effect on sample stiffness.
Methodology: Two trabecular bone surrogates, acetal copolymer and Ultem®, were pre-conditioned and compressed to 150 N at room temperature in and out of the bioreactor to compare the compressive modulus in each condition. System compliance was approximated and corrected for using ASTM standards.
Results: Compressive modulus results for both surrogates showed no significant difference between being tested in and out of the bioreactor ($p > 0.05$). However, the system compliance characterization caused over- and underestimates for the acetal and Ultem® polymers, respectively, due to non-linearity by less than 30%.
Significance: This study provides calibration steps for a system that aims to provide clinicians with the ability to prescribe patient specific physical activity as treatment for bone diseases and injuries.

43| Taylor J deVet- McMaster University; Masters (In progress or completed)

"Development of an Electrical Stimulation Environment for Osteocytes"

While the overall process of bone remodelling is well understood, the literature explaining the underlying mechanisms of activation and communication of the cells is not. It is hypothesized that osteocytes sense mechanical stimuli and generate a biochemical through electrical signals to control osteoblasts and osteoclasts.
Studies have shown that application of direct current increases osteogenesis indicating that bone cells are sensitive to electricity. This is evidence that osteocytes can be electrically stimulated in vitro to simulate stress generated potentials (SGPs) that occur in situ.
In order to investigate osteocytes in vivo, we have been working on a miniaturized electrical stimulation device for cell culture. Platinum electrodes are used to characterize the electrical properties of the cell culture media to try and maximize cellular stimulation while minimizing changes to the media. This also involves the development of an electrode array on the base of each cell culture well consisting of more platinum electrodes to probe the field strength across the stimulation field.
Once the culture media behaviour is better understood, osteoblast-like and osteocyte-like cells will be stimulated. It is hypothesized that the osteocytes will view the electrical stimuli like SGPs, and that they will send signalling molecules into the cell media, whereas the osteoblasts will migrate. The signalling molecules will be measured using molecular biology techniques (RT-PCR), and cell health will be monitored using a viability agent.
These experiments will give insight into the ability of osteocytes to sense their electrical environment, and if the signals that initiate bone remodelling are electrical. This will result in more insight into the mechanism of the cell to cell communication that occurs in bone remodelling which could be useful for electrical stimulation for fracture healing and rehabilitation.

61| Mahdi Rostami Haji Abadi- College of Kinesiology, University of Saskatchewan ; PhD (In progress or completed)

"Children with Autism Spectrum Disorder Sustain Bone Deficits during Growth"

Background: Poor bone development during childhood may explain an elevated risk of fracture in individuals with ASD. Boys with ASD sustained deficits in areal bone mineral density during growth when compared to typically developing children (TDC), but prospective comparisons of bone mass, structure and estimated strength development in children with ASD are limited.
Objectives: To compare radius and tibia bone mass, structure and estimated strength between children with ASD and TDC at baseline and after 1-year follow-up.
Methodology: We followed 13 children with ASD (12 boys) (mean age at baseline: 10.2, SD: 2.8 yrs) and 32 TDC (15 boys) (10.7, 1.7 yrs). We used our standard protocols to obtain radius and tibia peripheral quantitative computed tomography scans at the distal and shaft sites of the radius and tibia at baseline and after one year. We normalized follow-up bone outcomes to 1-year change. As there were no differences in confounding factors (age, maturity, body size) and no significant effect of sex, we used repeated measures MANOVA followed by pairwise comparison of bone outcomes at the baseline and after 1-year.
Results: There was a significant main effect of the group (Wilks' Lambda = 0.41, $F(14, 21) = 2.23$, $p=0.044$) but no interaction between group x time (Wilks' Lambda = 0.64, $F(14, 21) = 0.87$, $p>0.05$). Total area, cortical area, cortical content and estimated bone strength in radius and tibia shaft were 17-33% lower at baseline and after 1-year follow-up in children with ASD when compared to TDC. There were no between group differences at the distal sites.
Significance & Future Studies: These findings of sustained deficits in bone size and strength in children with ASD add to the evidence of sustained lower aBMD z-scores when compared to TDC. Future studies need to include younger children with ASD, identify factors underpinning bone deficits and develop therapies to optimize bone strength development in children with ASD.

68| Daniel y Dapaah- University of Waterloo; PhD (In progress or completed)

"Impact of loading rate on micro-damage formation during bone fracture"

A greater mechanistic understanding of the bone fracture process is needed in order to develop better predictive tools for skeletal fragility and fracture. Bone, a natural nanocomposite, engages different mechanisms to delay or slow down crack growth. One of such mechanisms is the micro-damage process zone(MDPZ), a cloud of fine diffuse microcracks that forms ahead of a crack, dissipating energy, blunting the stress field, and thereby delaying crack growth(Willett et al., 2017). However, little is known on how loading rate affects MDPZ formation. Therefore, in this study, the MDPZ size formed was compared between quasi-static and impact rate tests in human cortical bone. Paired single edged notch bend cortical bone specimens were prepared from the diaphysis of five cadaveric human femurs. From each pair, one underwent a 3-point bend quasi-static rate fracture test(0.083mm/s) while the other underwent an equivalent but impact rate test(40mm/s). For all tests, a high-speed camera attached to a microscope captured images around the crack tip. Using digital image correlation, the strain fields around the crack tip were computed, from which the MDPZ was estimated. With the peak load as a reference, the MDPZ size and the J-integral fracture toughness(Jmax) were measured. The quasi-static rate specimens formed significantly larger MDPZ sizes(1.25 ± 0.24mm2, $p=0.025$) but at lower peak loads with greater deflections($26.74N\pm3.1N$,$p=0.058$) as compared to the impact equivalents: (0.71 ± 0.13mm2) and ($34.55\pm5.64N$) respectively. There was also a strong correlation between MDPZ size and Jmax for all specimens ($R2=0.9246$, $p<0.001$). The results show that higher loading rate limits MDPZ formation. This may be because microdamage formation is controlled by a rate dependent mechanism linked to viscoelasticity/plasticity (Chintapalli et al.,2014). Furthermore, the strong correlation between MDPZ size and J-integral reinforces the idea that MDPZ formation is an important toughening mechanism.

70| Khaled M. Hijazi- Western University; PhD (In progress or completed)

"Optimizing Porous Titanium Constructs for Mandibular Reconstruction"

Background: Solid constructs made from titanium 6-aluminium 4-vanadium (Ti6Al4V) alloy are often used for mandibular reconstruction surgery. However, non-union of the mandible and other complications have been reported post-implantation. A possible solution is to use porous intraosseous implants that permit the ingrowth of blood vessels and bone while minimizing stress shielding.
Objective: To optimize the design of porous Ti6Al4V constructs for mandibular reconstruction.
Methods: Computer-aided design models were prepared as either rectangular prisms or dumbbell-shaped constructs, with pores for the entire rectangular prism or between the solid dumbbell grips. Each construct was built with a uniform strut thickness that varied between 150 and 650 µm, with the cross-sectional shape of the struts being either square or circular. Solid construct models were used as controls. Finite element analysis was used to perform flexural, tensile, and compressive loading simulations, providing estimates of the mechanical properties of the models.
Results: Elastic moduli derived from the mechanical simulations showed second-order polynomial increases with increasing strut thickness. Constructs with circular struts yielded elastic moduli lower than those of square struts of equal maximum thickness. Constructs with circular struts of thicknesses ranging between 250 and 370 µm, had elastic modulus values matching those of mandibular cortical bone. The corresponding pore sizes of 630-700 µm fell within the range reported by others to be optimal for bone ingrowth.
Significance: We are continuing to optimize the design of porous Ti6Al4V constructs for intraosseous mandibular devices. It is anticipated that these devices will permit vascularization and bone ingrowth. Furthermore, matching the elastic modulus of the construct to that of mandibular bone is expected to minimize stress shielding. These implants should be useful for applications in maxillofacial and orthopaedic surgery.
