degeneration under excessive mechanical loads and potential AF repair or regeneration using adequate mechanical stimulation.
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308
MATRIX ELASTICITY-DEPENDENT DIFFERENTIATION OF ANNULUS FIBROUS-DERIVED STEM CELLS

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Background: Annulus fibrosus (AF) injuries commonly lead to substantial intervertebral disc (IVD) degeneration, the major cause of lower back pain which affects about 80% of the population. Recently, tissue engineering has evolved into a promising approach for AF regeneration. While a lot of attempts have been made during the last decade, constructing engineered AFs remains challenging due to the tremendous complexity of AF tissue at cellular, biochemical, microstructural, and biomechanical levels. It is known that the elasticity of matrix effectively directs the lineage specification of stem cells.
Methods: We synthesized a series of biodegradable poly(ether carbonate urethane)urea (PECUU) materials whose elasticity approximated that of native AF tissue. Fibrous PECUU scaffolds were fabricated by electrospinning technique and used for culturing AF-derived stem cells (AFSCs). The growth, gene expression, biochemical and biomechanical characteristics of AFSCs were studied. In particular, we explored the potential of AFSCs to achieve diversified differentiation of cells by varying the elasticity of substrate.
Results: By adjusting the molecular weight of polycarbonates, ratios of hard segment to soft segment, a series of polyurethanes were obtained with different elastic modulus (PECUU1, 13.4MPa; PECUU2, 6.4MPa; PECUU3, 5.1MPa; PECUU4, 2.5MPa), which is close to the elastic modulus of AF tissue. When AFSCs were cultured on electrospun PECUU fibrous scaffolds, the gene expression of collagen-I in them increased with the elasticity of scaffold material, whereas the expression of collagen-II and aggrecan genes showed an opposite trend. At protein level, the content of collagen-I gradually increased with substrate elasticity, while collagen-II and GAG contents decreased. In addition, the cell traction forces (CTFs) of AFSCs gradually decreased with scaffold elasticity. Such substrate elasticity-dependent changes of AFSCs were similar to the gradual transition in the gene, biochemical, and biomechanical characteristics of cells from inner to outer regions of native AF tissue.
Discussion and Conclusion: Together, findings from this study have, for the first time, implied that depending on the substrate elasticity, AFSCs may differentiate into various types of AF-like cells. Therefore, this study provides solid basis for the use of AFSCs, along with scaffolds of varying elasticity, for AF tissue engineering.
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336
HOW PATIENT-OPTIMISED DEVICE CONFIGURATION CAN PROVIDE FRACTURE SITE STIMULATION AND REDUCE AGE-RELATED SCREW LOOSENING RISK IN LOCKED PLATING

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Objective: When using locked plating for bone fracture fixation, screw loosening is reported as one of the most frequent complications and is commonly attributed to an incorrect choice of screw configuration. Choosing a patient-optimised screw configuration is not straightforward as there are many interdependent variables that affect device performance. The aim of the study was to develop a framework for device selection and configuration based on three key variables of interest: (1) interfragmentary motion (IFM); (2) strain concentrations around screws; and (3) stress levels within the plate.
Methods: Finite element models of a tibia with a comminuted diaphyseal fracture were developed incorporating cortical bone heterogeneity, orthotropy and geometrical nonlinearity. Strain concentrations around screws (SCS) were used as indicators of regions that may undergo loosening. Plate stress, SCS and IFM and were measured for a total of 10 different screw configurations and two different bone qualities (20 unique models). Axial and torsional load cases were considered.
Results: The study found that the material of the plate and the size of the bridging span influenced all three variables of interest. Screw spacing was found to be particularly influential in poorer bone quality. Leaving two empty holes between screws near the fracture reduced SCS by 49% in osteoporotic bone compared to 2.4% in healthy bone. Unlike bridging span, modifications to screw spacing had a negligible effect on IFM or plate stress levels. Under torsional loading, the importance of screw placement was similar for the two bone qualities.
Conclusion: Due to the large number of device variables and patient factors, the current guidelines regarding locking screw placement are somewhat unclear. This study provides valuable information regarding the configuration of locked plate devices for specific individuals. The results are presented in a decision making tree representing the first step towards comprehensive guidelines.
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348
STIFFNESS IN LIVING CARTILAGE INCREASES AFTER SELF-MATING ARTICULATION—A NANOINDENTATION STUDY

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Introduction: While studies have demonstrated that osteoarthritis is linked to the softening of articular cartilage, the effect of tribological stress on cartilage mechanical properties is not well-understood. Nanoindentation has made mechanical characterizations of biological tissues at micro- and nano-scales possible. However, using nanoindentation on cartilage is challenging due to its heterogeneous, biphasic, and soft material properties. In this study, we developed a method to characterize articular cartilage explants using the Ti-950 Triboindenter by Hysitron®. Once we established a repeatable nanoindentation method, we compared mechanical properties of live cartilage explants before and after undergoing self-mating articulation in a joint motion simulator.
Methods: Cartilage explants were obtained from the patella-femoral groove of 24-week-old bovine and placed in DMEM/F12 media at 37°C. For method development, phosphate buffered saline was added to keep freeze-thawed explants hydrated during indentation with a 20um-indenter in order to optimize parameters including fluid levels and software settings. To test for reproducibility, we performed duplicates of five indents in five regions on the explant. A joint simulator that applies complex motion patterns on explants was utilized. Load (40N) and shear were applied to live explants for 3 hours (5400 cycles) using a modified hip-ball onto which a live cartilage strip is sutured, creating a cartilage-on-cartilage (CoC) interface with the explant. We performed a 3X3 array of 8um deep indents in the articulated and non-articulated regions of the explant before and after articulation ($n=18$ indents). In one explant, nanoindentation was performed one hour and three hours post-articulation to observe potential changes in mechanical properties over time ($n=9$ indents).
Results: In method development, we found that factors including fluid level and indent setpoint influence the Young's Modulus (E). For reproducibility, we used a paired t-test analysis and found no significant differences between duplicates ($E=367\pm7$kPa, $p=0.809$). For our pre- and post-CoC articulation stiffness comparisons, a one-way ANOVA analysis blocked by animal demonstrated that following articulation, E significantly increases in the articulated region ($p<0.001$) but not in the surrounding unworn region ($p=0.26$). In the non-articulated region, $E_{pre\text{-}test}=124\pm8$kPa and $E_{post\text{-}test}=137\pm8$kPa, whereas in the articulated region, $E_{pre\text{-}test}=105\pm30$kPa and $E_{post\text{-}test}=461\pm30$kPa. Additionally, 3hr-post-articulation indentation results indicated that in the articulated region, $E=127\pm5$kPa, demonstrating that with time, articular cartilage stiffness may return to its pre-articulation conditions.
Discussion and Conclusion: We found that the stiffness of live cartilage increases significantly following simulated articulation and that the variability increases in post-test measurements. This stiffness increase may be attributed to fluid flow out of the explant during articulation and a compaction of the cartilage tissue, leading to a higher modulus. Over time, the explant stiffness decreases to pre-test modulus levels, indicating that stiffness increase is a transient response to articulation. Limitations include: (1) post-test indent time after articulation and its influence on mechanical properties; and (2) animal variation. Observing how mechanical properties are affected by cartilage matrix wear and identifying biochemical differences that play a role in stiffness may be of interest in future studies.
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356
ASSESSMENT OF THE FRACTURE RISK OF PROXIMAL PORCINE FEMURS WITH SIMULATED LESIONS USING A FRACTURE PREDICTION METHOD BASED ON BEAM THEORY

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Introduction: Current methods of diagnosing bone diseases like avascular necrosis (AVN) are subjective and no reliable assessment of the fracture risk is available. AVN leads to an interruption of the blood supply, which results in the death of bone tissue and its collapse if left untreated. A fracture prediction tool is needed to help clinicians find the most suitable treatment. One route to finding the strength of bones, including the femur, can be the utilisation of structural mechanics, where bone is a structural member subjected to load. Ohzono et al. (1991) reported that collapse of the femoral head most often occurs when the lesion location is in the weight bearing area. Therefore lesions lateral to the fovea appear to be most critical. We hypothesized that the developed fracture prediction tool would be able to identify the fracture risk from these critical lesions. The aim of this study was to analyse porcine femurs affected by simulated AVN lesions to understand loading on subsequent failure of bone as well as the assessment of geometric and material parameters on fracture risk.

Methods: A computational tool was created which predicted the stress and strain of the bone structure under loading and its susceptibility to geometric and material properties. Beam theory was used to calculate the maximum loading force at which the bone was likely to fracture. The forces acting on the upper femur were simplified and merged to a single static joint contact force pointing to the centre of the femoral head. Geometric and material properties such as Young's modulus were derived from non-invasive three dimensional computed tomography images (QCT) using a material model. Fifteen porcine femurs were compression tested until failure, where apart from the control samples each femur had an artificial lesion at one of two different positions within the femoral head, lateral and medial to the fovea. The predicted fracture load and location was compared with experimental results.

Results: The predicted fracture load and site correlated well with the experimental data. When analysing fracture at the neck, the predicted fracture loads for the lesion affected femurs were lower throughout. Lesions within the subchondral area had a huge impact on the stability. This trend has been seen in the computational as well as in the experimental data. The predicted fracture load was up to 50% lower within the femoral heads which had a lesion lateral to the fovea. Experimentally as well as computationally there was no difference between the control samples and the heads affected by a lesion medial to the fovea.

Discussion: This in-vitro study demonstrated that fracture prediction based on beam theory is a viable tool to predict fracture. The tool correctly identified the femoral neck and points at the head as fracture sites. The lesion position plays an important role and lesions lateral to the fovea in the weight bearing area are more severe. Slippage of the epiphyseal plate decreased the stability of the porcine femurs indeterminably and made an exact calculation of the fracture load more difficult.

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371

STAND UP AND SIT DOWN ASSISTANCE PROVIDED BY CUHK-EXO EXOSKELETON

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Introduction: The number of people with mobility disorder caused by stroke, spinal cord injury or other related diseases is increasing [1]. To improve the quality of life of these people, devices that can assist them to regain the ability of mobility are in great demand. Stand up and sit down (STS) motion is the first step for paralyzed patients to regain the ability to walk around from their wheelchairs, which is significantly important. In addition, STS training is important for paralyzed patients because it can activate their circulatory and respiratory systems, alleviate spasticity, and increase the bone mineral density of their lower body.

Subjects and Methods: A lower extremity exoskeleton (CUHK-EXO) was developed to assist paralyzed patients with performing essential daily life motions, such as STS, walking, walking upstairs and downstairs. The whole system of the CUHK-EXO was designed with the considerations of ergonomics, user-friendly interface, safety and comfort. Kinematics model of the human-exoskeleton system (HES) was established, and the center of pressure (COP) on the ground and center of gravity (COG) of the whole system calculated. A reference motion pattern of the STS motion was also designed based on discussion with clinical doctors with regard to stability and comfort. In addition, a preliminary test was conducted with optical motion analysis system to obtain reference trajectories of hip and knee joints of the CUHK-EXO. Based on the change in COP position, an algorithm of reference trajectories online modification of the exoskeleton according to the wearer's own effort in the STS motion was proposed and implemented in the control of CUHK-EXO. The effectiveness of the whole system was evaluated by STS testing. Due to safety considerations, before clinical testing, the STS test was first conducted with a healthy subject simulating paralyzed patients.

Results: Based on STS testing, ground reaction forces (GRFs) applied to the HES feet and crutches were obtained. With the measured GRFs, the HES actual COP position was calculated, and the COP deviation between the actual COP and predefined reference COP was obtained. With the COP deviation, the modification angle φ for the exoskeleton knee joints was generated, and the predefined reference trajectory of the knee joint was updated online.

Discussion and Conclusion: With the testing results, we found that if the COP deviation of the HES exceeds the threshold, then we get into an area where the system has the possibility of becoming unstable. The modification angle φ was c-alculated and added to the predefined reference trajectory of the knee joint. Then, the COP deviation returned to within the threshold to ensure the stability and comfort of the wearer during STS assistance. Thus, we can conclude that the CUHK-EXO can provide stable and comfortable STS assistance for paralyzed patients according to their motion intention and motion conditions.

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489

HUMERAL COMPONENT VERSION IN REVERSE SHOULDER ARTHROPLASTY AFFECTS IMPINGEMENT IN ACTIVITIES OF DAILY LIVING

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Introduction: Impingement, the major functional setback of reverse shoulder arthroplasty (RSA), has been correlated with both implant design and surgical techniques. Studies have suggested the favorable effect of humeral component retroversion on reducing scapular impingement (contact of the humeral cup with the scapular inferior border) and increasing external rotation and abduction range of motion (ROM). However, limited data exist to show how humeral version affects impingement in activities of daily living (ADLs) and whether other impingement sites (besides the glenoid inferior border) may affect the functional outcome. We investigated the effect of humeral component version on the mechanism of impingement during ADLs.

Materials and Methods: A single surgeon performed virtual RSA on 30 arthritic shoulders that were reconstructed from pre-operative CT scans. For each subject, the humeral component was placed into 5 versions (-40°, -20°, 0°, 20°, and 40°; (+) anteversion, ($-$) retroversion), while maintaining the height and 45° neck/shaft humeral resection. Incidence of both intra-articular impingement (contact of the scapula's inferior border with the humeral prosthesis) and extra-articular impingement (acromion and/or coracoid contact to the humerus) was measured for a kinematic dataset that included 10 ADLs and 3 standard ROM (abduction, forward flexion, scaption) activities determined from 10 healthy subjects. The risk of impingement during the ADLs was assessed as the collective frequency of impingement across a cycle of motion. Frequent impingement sites on the scapula were also identified. For the standard activities, average ROM for each humeral version was calculated.

Results: For the ADLs, 0° retroversion showed the least amount of impingement. In contrast, 40° retroversion resulted in the largest ROM for the standard activities ($94.5\pm20.6^\circ$ in abduction, $108.3\pm8.6^\circ$ in forward flexion, and $89.1\pm13.0^\circ$ in scaption). The most frequent site of impingement changed with the degree of version; retroverted fixation increased the extra-articular impingement, where the anteverted alignment increased the contact between the inferior scapula border and the humeral cup.

Discussion: Our results showed that humeral version can significantly affect the impingement in RSA. Maximizing ROM in standard activities may not reduce the risk of impingement during ADLs. Our data indicate that 0° of humeral version should be preferred to reduce the overall impingement. However, the results are based on a small number of ADLs, and future studies should expand on a larger kinematic data set. It has also been shown that retroversion can increase tension on teres minor, which can result in increased active external rotation post-operatively.

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512

A NOVEL SCREW HEAD DESIGN OF PEDICLE SCREW FOR REDUCING THE CORRECTION LOSS IN PATIENTS WITH THORACOLUMBAR VERTEBRAL FRACTURES: A BIOMECHANICAL STUDY

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Background: Correction loss is a common phenomenon in patients with thoracolumbar vertebral fractures (TLVF) who undergo posterior pedicle screw fixation. The incidence varies with the kinds of fixation instrumentation used. There is higher incidence in polyaxial pedicle screws (PAPS) group than in fixed-axis pedicle screws (FAPS). Monoplanar pedicle screws (MPPS), which is mobile in the axial plane but fixed in the sagittal plane, may be a better fixation instrumentation for TLVF.

Subjects and Methods: 30 porcine spinal units (L2–L4) were used for the static and dynamic tests, which were randomized into 6 groups (A1, A2, A3, B1, B2 and B3). Static test was performed in A1, A2, and A3. In this test, FAPS, MPPS and PAPS were performed in A1, A2 and A3 respectively. The ultimate load was noted after tested. Additionally, dynamic test was performed in B1, B2 and B3, used FAPS, MPPS and PAPS respectively. Correction loss (head-shank angle (HSA) shift and anterior vertebral body height (AVBH) shift) was obtained and analyzed in each mode.