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3D-Printed mechanical twins to predict the risk of vertebral fracture with metastasis

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The most common cancers (breast, lung and prostate) often lead to the development of bone metastases, which are secondary tumours that migrate from the site of the main cancer to the bone. Vertebral metastases alter the structure and mechanical properties of the bone and can therefore increase the risk of fracture. These complications are difficult to anticipate using current clinical tools, such as the SINS score, and the numerical models that have been developed are not yet fully operational. The aim of the project is therefore to develop 3D-printed physical models of vertebrae, enabling the strength of vertebrae affected by metastases to be assessed on the basis of clinical images. The models are tested in compression using tomography in situ and compared with human vertebrae to refine the prediction of fracture risk.

Keywords: Biomechanics, Metastases, Vertebral Fracture, 3D Printing, Mechanical Twin, TPMS

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Bone-implant interface : from meso to sub-micro

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The bone-implant interphase is crucial for long-term implant stability. The compositional, structural, and mechanical properties of the interface evolve both temporally and spatially during healing. Despite their importance, these properties and their spatio-temporal evolution during osseointegration remain poorly understood. Given bone's complex hierarchical structure, the investigation of the sub-microstructure can help understand the resulting bone strength. The use of complementary approaches is needed and some will be presented, such as electron microscopy (SEM and FIB-SEM) to examine the tissue submicrostructure alongside with Quantitative Ultrasound (QUS) to identify ultrasonic signatures that reflect the bone-implant contact ratio.

Keywords: Bone, Implant, Experimental, High, Resolution Imaging, Mechanics

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Numerical Model for in-vitro Ultrasound Stimulation of Bone Cells

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The therapeutic potential of Low-Intensity Ultrasound (LIUS) for bone regeneration has been identified since the early 1950s, with clinical observations demonstrating its benefits (1). The FDA's approval in 1994 paved the way for its clinical use. Yet, the mechanisms underlying bone cells mechanotransduction triggered by LIUS remain poorly defined and the clinical use of LIUS is still controversial (2). Developing in vitro experimental setups associated with numerical simulations can contribute to a better understanding of ultrasound-cell interactions.
We developed an innovative in vitro experimental setup for LIUS stimulation of bone cell cultures (3). This setup includes an anti-reflection cover that ensures control of the acoustic dose delivered to the cells, avoiding disturbing phenomena such as multiple reflections and standing waves inside the Petri dish (60 mm diameter). The experimental set-up was replicated using a finite element model in COMSOL Multiphysics, allowing different sets of ultrasound parameters (frequency, incident sound pressure, stimulation duration) to be explored and experimentally inaccessible data such as the acoustic intensity delivered to the cells to be evaluated.

An initial series of experiments using a 1 MHz planar transducer (13 mm diameter) revealed a non-homogeneous acoustic intensity distribution, resulting in an insufficiently stimulated area. Some cells received peak intensities while others were unstimulated, potentially leading to misinterpretation of the biological response.

To address this issue, the use of an acoustic lens was investigated through Finite Element (FE) simulations, aiming to homogenize and enlarge the acoustic field. Despite testing various lens designs, none achieve the desired outcomes. Consequently, a custom 1 MHz divergent transducer (30 mm diameter) was developed (Imasonic, Voray-sur-l'Ognon, France). This requires a new FE model to account for the transducer's new characteristics. The model is validated through comparison of simulated and experimental acoustic intensity values, such as the spatial-average temporal-average intensity (ISATA). This approach will offers insights into the acoustic stimulation levels delivered to the cells and supports correlation with biological studies.

*Speaker

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Keywords: bone regeneration, ultrasound cell stimulation, acoustic intensity, experimental and numerical modeling

Pedicle screw implementation in vertebrae: when does the cortical bone is perforated?

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Intro: During the cannulation process, when the surgeon implants a pedicle screw with the vertebral pedicle, the perforation tool may slip on the pedicle cortical bone surface. This slipping depends on the angle of the surgical tool on the cortical bone according to the entry point used to insert the tool.
Methods: Several experiments were performed to determine the critical angle of slipping on the cortical bone as well as the parameters of insertion influencing the slipping. A simplistic model of the cortical wall was developed using three densities of bones simulating trabeculae bones (PCF5, PCF10, PCF20) and epoxy (CC) or an additional for simulating cortical bone. A MTS Acumen 3 A/T electrodynamic device was used to measure torques and forces while simulation three steps procedure simulating the surgeon perforation (constant rotational speed of 10◦ mm–1). In addition, cadaveric and porcine vertebrae (levels T9 to L4) were also perforated in a design of experiments that simulates perforation of the cortical bone randomly or not, according to the angle of the tools at the entry point. All samples (synthetic and vertebrae) were scanned before and after mechanical tests and the reproducibility of the protocol was tested on synthetic foam. Additionally, micro CT scan investigations of both the cadaver and swine models were performed on a subsample of the vertebrae.

Results: 68 vertebral pedicles (19/21 in human and 17/16 in swine, perforated/non perforated respectively) and 47 synthetic samples (18 PCF5, 14 PCF10 and 15 PCF20, 9 CC; 18 perforated) were tested. The reproducibility of the cannulation coefficient computation protocol resulted in an intraclass correlation coefficient of 0.979. The angular threshold for perforation prediction in synthetic data was found to be 17.5◦ (area under the Receiver Operating Characteristic curve: 89.5%) and 21.7â—¦ in vertebrae (AUC ROC: 100%). Torque measurement was found to be the best predictor of perforation. The correlation between bone density and cannulation coefficient was found to be significant ($p < 0.005$).

*Speaker

Conclusion: This work has provided insight into the possibility of using accurate synthetic material for bone experimental simulation). It will be continued with a focus on characterizing the motion and forces involved during the pedicle screw insertion procedure on synthetic vertebrae by several surgeons depending on their experience and practice.

Keywords: pedicle screw, bone surrogate, cortical, trabeculae

The duration of Type 2 Diabetes Mellitus is an important determinant of bone material properties: the DIABONE Study

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Background: Type 2 Diabetes Mellitus (T2DM) is a risk factor for fracture in some patients, despite normal or increased BMD. Thus, alteration in bone material properties have been proposed to explain this skeletal fragility.
Objective : To investigate the consequence of T2DM on bone material properties.

Material and Methods: After ethical approval, 19 T2DM patients (9 men 10 women, 71 $\pm$ 8 yrs, BMI: 32$\pm$ 4) were recruited and matched for sex, age and BMI with 19 controls (CTRL, 72 $\pm$ 6 yrs BMI: 32 $\pm$ 6). The median duration of diabetes was 11 yrs (range: 2-40 yrs), and patients were treated with metformin, sulphonylureas, DPP-4 inhibitors, GLP-1 agonists or insulin. Both groups of patients had a T-score $>$ -2 and underwent hip or knee arthroplasty. Bone strain Index (BSI) was obtained from DXA images. During surgery, iliac bone biopsies were collected for bone histomorphometry, non-enzymatic crosslink (pentosidine) analysis by HPLC, X-ray microradiography (degree of mineralization of bone, DMB).

Results: In T2DM patients, CTX and P1NP were significantly lower compared to CTRL ($p< 0.04$). While no significant difference in cortical (Ct) and cancellous (Cn) bone was observed by histomorphometry, the diabetic groups was characterized by a decrease of bone formation and bone resorption parameters. No difference in bone pentosidine concentration was found. Cancellous DMB was found significantly higher in diabetic than in CTRL group (p=0.0043). Interestingly, the duration of diabetes was significantly negatively correlated with bone remodeling activity (Cn-BFR/BS, r'=-0.762, p=0.004), and neck and femoral BSI (r'=-0.493 and -0.532, $p< 0.05$), but significantly positively correlated with Cn-pentosidine (r'=0.534, p=0.027), and with Ct and Cn DMB (r'=0.595 and 0.501, $p< 0.05$).

Conclusion: In T2DM patients, the duration of diabetes appears to be a main determinant of modifications of bone material properties.

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Keywords: Type 2 Diabetes, Degree of mineralization, human bone biopsies, pentosidine

Development of Minimally Invasive Dental Implants for Medically Compromised Patients: From Preclinical Evaluation to Clinical Application

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Introduction: Innovative surgical protocols and advanced dental implant designs can reduce the need for complex bone grafts and minimize bleeding and infection risks, crucial for medically compromised patients. These individuals are more prone to implant failure, which highlights the importance of developing minimally invasive implant systems tailored to their specific needs. Such systems should incorporate noncorrosive, biofunctional surfaces that support effective integration with both alveolar bone and periimplant soft tissues. These innovations aim to simplify surgical procedures, improve healing, and enhance overall patient comfort and clinical outcomes.
Objectives: This study aimed to compare the topographical and biological properties of the minimally invasive MagiCore ® implant (MC ®, InnosBioSurg, IBS) with those of the gold-standard NobelParallel system (NB, Nobel Biocare). Additionally, in vivo animal models were used to evaluate the histological responses to both implants. A novel βtitanium alloy was also developed, designed to provide enhanced biocompatibility, reduced stiffness, and improved corrosion resistance.

Me**thods/approach:** *In vitro* studies were conducted using human gingival fibroblasts as a soft-tissue model and human osteoblasts as a bone-tissue model. *In vivo* studies were performed using a canine model to evaluate the peri-implant tissues.

Result: The results demonstrated that gingival cells could successfully adhere to the smooth neck of the MagiCore implant (MC ®), with the bone initially present around the collar gradually replaced by soft tissue. As reported in the literature, the broader epithelio-conjunctival attachment observed with this type of implant may act as a barrier to bacterial infiltration and is indicative of long-term peri-implant tissue stability. In the in vivo study, a reduced thickness of keratinized tissue was initially observed around MC ® at T0, likely due to the removal of keratinized tissue during the surgical procedure using the Magic drill trephine. However, following tissue maturation at T16, this trend reversed, and a significantly thicker keratinized tissue was noted around MC ®. These findings were supported by histological analysis, which revealed

*Speaker

an increase in soft tissue height around MC ® from T0 to T16, whereas a significant reduction in soft tissue height was seen around the reference implant, NobelParallel (NB). These results suggest that the combination of a minimally invasive procedure and a one-piece smooth-neck implant promotes the formation of a dense epithelial barrier and thicker keratinized gingiva, potentially helping to prevent peri-implantitis. This hypothesis is reinforced by in vitro findings showing enhanced adhesion and proliferation of human gingival fibroblasts on MC ® compared to NB as evidenced through scanning electronic microscopy (SEM) and confocal imaging.

Conclusion: These findings provide valuable insight into the biological responses associated with minimally invasive implant designs and highlight their clinical potential across a range of implantology applications. Moreover, the incorporation of non-corrosive, biocompatible β-titanium alloys may reduce the inflammatory risks linked to particle release during implantation, thereby enhancing long-term stability and decreasing the likelihood of implant failure.

Keywords: Minimally invasive dental implant, Biocompatibility, Soft tissue healing, Bone, Human gingival fibroblasts, Osteoblast, like cells, Surface characterization, β, titanium alloy, peri, implant tissue response.

Evaluation of a new modular system for personalised corrective surgery

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Corrective surgery of angular limb deformities in veterinary surgery requires accurate identification of the deformity and surgical technique for optimal recovery (1). Patient-specific instruments are widely used in human surgery and have recently been introduced in veterinary surgery (2). These methods significantly improve surgery accuracy, reduce operating time and accelerate recovery (2). However, their high cost, due to significant design preparation and production expenses, limits their use in clinical practice.
To optimize the manufacturing process, combined modular bone plates have been proposed in the literature (3). The assembly system is the critical part and can alter the mechanical behaviour and the fatigue strength. In a previous study, we demonstrated that similar mechanical properties and fatigue life can be maintained compared to standard plates. However, the study focused on the mechanical characterization of the modular system only using the ASTM F382-24 standard to analyse the impact of the assembly system, without considering the clinical environment.

The aim of this study is to evaluate the feasibility of using such a system under biomechanical considerations. The combined system will be screwed on a synthetic tube and subjected to compressive loading. Experimental and numerical analyses will be carried out to evaluate its performance.

Due to the complexity of direct comparisons with data from the literature, the mechanical properties of the proposed system were compared to a reference plate with identical dimensions. The plates were fixed on synthetic tubes (Sawbones4th generation, Vashon, WA, USA). Quasi-static compression tests (ElectroPuls E1000) were first conducted on six plates from each group (reference and prototype). Digital Image Correlation (DIC) was performed using two cameras (Nova R4-4K) to measure axial displacement and deflection. The experimental displacement was then compared with numerical displacements obtained from SolidWorks Simulation. Then cyclic tests were conducted on five combined systems. Each test was conducted to reach 180000 cycles with a maximal force of 200N (60% of the 30Kg dog body weight). The number of cycles was recorded at failure if it occurs before the end of the cyclic test.

*Speaker

In conclusion, the proposed method provides an evaluation of the new system and a comparison with numerical simulations, which may subsequently be used to evaluate different configurations or sizes.

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Keywords: osteosynthesis plate, numerical simulations, experimental tests, veterinary surgery

MASTICATORY MUSCLE RESPONSES DURING MAXIMUM INCISAL CLENCHING

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INTRODUCTION

Temporomandibular disorders (TMDs) cause pain and dysfunction in the temporomandibular joint (TMJ). The TMJ reaction force during occlusion is an indicative parameter for associated TMDs. In this study, a framework of patient-specific musculoskeletal model of TMJ to estimate the muscle forces for clenching activity has been presented.

METHODS

The Computed Tomography (CT) images of a healthy subject were used to reconstruct the mandible, skull, and hyoid geometries using Mimics. A musculoskeletal model of the human jaw was developed using the OpenSim Creator (Fig. 1a-1c). The bilateral TMJs were modeled as one six-degrees of freedom joints between the mandible and the skull. The TMJ actuator muscles (including Masseter, Temporalis, Pterygoid, and Hyoid muscle groups) were modeled as Hill-type muscle-tendon units (1).

The simulation was performed using OpenSim software. Maximum incisor clenching load was applied to the central and lateral incisors of the mandible (Fig 1d, Table 1) (2). Static optimization was used to estimate the muscle forces by minimizing the sum of squares of the muscle activations. The muscle forces were constrained by the upper limits of each muscle's maximum isometric muscle force (3). TMJ reaction forces were predicted from muscle forces using the Joint Reaction tool in OpenSim.

Keywords: Temporomandibular joint, Temporomandibular disorders, Musculoskeletal modelling, Patient, specific musculoskeletal model

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Spatial Heterogeneity of Cochlear Bone Microctructure Supports Auditory Function

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Cochlear bone plays a vital role in auditory function and maintains its material properties throughout life despite the absence of osteoclast- and osteoblast-driven remodeling in the cochlea. This suggests that osteocytes may regulate bone quality in the cochlea. Recent studies indicate that the cochlear bony labyrinth exhibits a gradient in material properties from the inner to outer cortical regions, contributing to the cochlea's rigidity and its role in sound transmission. However, the underlying structural differences between the inner and outer regions remain poorly understood.
To explore this spatial heterogeneity, we performed high-resolution Synchrotron Radiation micro-Computed Tomography on cochleae from C57BL/6 mice. Our data confirmed that the inner cochlear bone exhibits significantly higher tissue mineral density (TMD) than the outer regions across all cochlear turns, which likely translates to increased stiffness and mechanical support in the inner bone. In addition, TMD was highest in the basal region compared to the middle and apical regions.

We also analyzed osteocyte lacunar morphology and found marked differences between inner and outer bone regions. The outer cochlea exhibited osteocyte lacunae with significantly higher aspect ratios (e.g., more elongated) than those in the inner cochlea, which were smaller and more spherical. This pattern resembles that observed in cortical bone and may reflect increased matrix turnover activity in the outer regions. In addition, lacunar volume also varied along the cochlear length, with the basal region showing smaller lacunae than the apical and middle regions.
Together, these findings suggest that cochlear bone is regionally specialized, not only along its length but also across its radial thickness, with the inner and outer bone compartments showing distinct mineralization profiles and osteocyte morphology. This structural heterogeneity may reflect localized osteocytic regulation of matrix quality without classical remodeling.

Keywords: cochlea, bone remodeling, osteocyte, mineralization, synchrotron microCT

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A Numerical investigation of the Bone-implant Interface using Quantitative Ultrasound

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The success rate of endosseous implants depends on their long-term stability, which relies on the osseointegration process, i.e. the creation of a bone-implant interface (BII). Such stability is determined by both the quantity and the biomechanical properties (structure, composition and material properties) of bone tissues surrounding the implant surface. It is now acknowledged that osseointegration can be assessed using quantitative ultrasound (QUS), based on the analysis of ultrasound waves reflected at the interface between these two media. Experimentally, the technique has proven to reflect the Bone Implant Contact (BIC) ratio, but remains limited by its poor lateral resolution in the MHz range. In addition, the complex interactions of ultrasound with the bone-implant interface make local assessment of osseointegration challenging.

The aim of this study is to numerically reproduce the propagation and interactions of ultrasound with a BII of a standardized, coin-shaped titanium implant model and eventually apply it to realistic three-dimensional bone distributions obtained by neutron microtomography (voxel size 7.5 μm) after 12 weeks of healing in rabbit cortical bone. The numerical model developed combines a semi-analytical approach based on Green's functions for ultrasonic wave propagation and focusing (13 MHz) with the finite-difference time-domain (FDTD) method for solving elastodynamic equations (SimSonic).

In comparison with a non-osseointegrated implant (prior to surgical insertion), this model shows that the average maximum amplitude of echoes received over the entire BII consistently decreases with the proportion of bone tissue in immediate contact with the implant (coefficient of determination R^2=0.91, $p<$ 0.001) which aligns with experimental results. Furthermore, the local decrease in echo amplitudes received at the interface shows good agreement with the spatial distribution of mineralized tissue derived from the imaging data, enabling discrimination between areas of high mineralized tissue concentration and non-osseointegrated regions of the BII.
The proposed numerical approach confirms the sensitivity of ultrasound waves to the quantity and spatial distribution of bone tissue in the vicinity of the implant, based on data derived from a high-resolution 3D imaging method. In the future, the application of advanced signal

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processing methods should enable a better understanding of the acoustic responses resulting from the complex interaction of waves with the BII.

Keywords: FDTD simulations, Osseointegration, Bone, implant interface, Quantitative Ultrasound

Evaluation of metastatic vertebral fracture prediction using personalized biomechanical models on patient data

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Cancer represents a major health and economic burden, accounting for 10% of total healthcare costs in France, with bone metastases occurring in up to 70% of patients with advanced breast, prostate, or lung cancer. Among these, the spine is the most frequent metastatic site, with the thoracic and lumbar regions particularly affected.
The risk of vertebral fracture in such patients is not only a source of morbidity, including pain and neurological deficit, but also a major driver of medical overcost due to emergency interventions and hospitalizations. Currently, clinical tools like the SINS score are used to guide surgical decision-making in metastatic spine disease. However, these tools are limited by subjective variables and inter-operator variability, especially in intermediate cases.

The integration of biomechanical modeling, particularly patient-specific finite element (FE) analysis based on CT imaging, represents a promising approach to quantitatively assess fracture risk and personalize treatment decisions. This preliminary study aimed to assess the reproducibility and robustness of a vertebral FE model developed in Lyon, based on CT-derived segmentations of vertebral bodies in patients with metastatic spine lesions.

Our objective was to quantify intervariability as well as the agreement between manual and automatic segmentations in predicting vertebral strength under uniaxial compression. We segmented 29 vertebrae (both healthy and metastatic) from 12 patients of the MEKANOS cohort. Manual segmentation of vertebral bodies was performed using 3D Slicer (v5.6.2) by one expert and two non-expert operators, following a standardized protocol. A deep learning-based automatic segmentation was also performed.

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Importantly, the segmentation protocol included removal of posterior elements (cutting at the narrowest section of the pedicle) and exclusion of osteophytes to avoid bias in force vector calculation.Segmented volumes were imported into the Lyon FE model to compute the maximum rupture load. Initial results showed an average predicted load of 3442N for the expert, 3413N for the AI-based segmentation, 3580N and 3704N for the two non-expert operators.

The difference between the expert and AI was $< 2\%$, but two outliers revealed segmentation failures due to pedicle or boundary misinterpretations, pushing the difference to 5.2%. Systematic discrepancies between expert and non-expert segmentations were observed, attributed to residual pedicles being erroneously included by non-experts, leading to overestimation of surface area and thus mechanical strength.

This preliminary validation allowed us to define the first phase of our project: a detailed sensitivity study involving intra- and inter-observer variability and AI performance, all segmenting at the mid-pedicle level. Once reproducibility is confirmed, the second phase will involve applying the validated pipeline to the full MEKANOS cohort to compare predictions from the Lyon and Paris FE models.The third phase will extend the analysis to 50 patients from the IMMUNOS cohort with CT scans at baseline and 6 months, comparing predicted fracture risk with clinical outcomes and SINS score.
Our goal is to propose a robust, standardized, and clinically validated tool to help anticipate vertebral fracture risk, reduce unnecessary surgeries, and improve the therapeutic strategy for patient in metastatic spinal disease.

Keywords: Metastatic spine disease, Finite element modeling, Fracture risk prediction, CT, based segmentation

Finite element analysis of the radiocarpal joint to evaluate the risk of loosening of two radial implants

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Patients suffering from conditions such as osteoarthritis of the wrist gradually lose mobility and experience increasing pain. If this becomes too troublesome, surgery is required. One possible treatment is total or partial wrist arthroplasty. This involves replacing the damaged joint surfaces with an implant.

As with all orthopedic implants, there is a medium-term risk of loosening. This is due to the phenomenon of stress shielding. This is a modification of the stress distribution in the bone due to the presence of the implant, which is often much more rigid than the bone. A few years after implantation, a reduction in bone density around the implant is observed, and its migration can be observed(1).

The aim of this study was to compare the impact of two radial wrist implants on load transmission to the radius. A fourth-generation implant (ReMotion ®) and an innovative implant with an intramedullary stem (Prosthelast ®) will be compared. The first is one of the most widely used implant, while the second is an innovative design with good initial clinical results. Indeed, a densification of cortical bone around the implant is observed a few months after implantation(2).

Three numerical models have been developed on ABAQUS (Dassault Systèmes, France). They enable stresses to be assessed in the distal radius without implant, with the Prosthelast ® implant, and with the ReMotion ® implant. The model of the non-implanted radius was obtained by scanning a cadaveric forearm. DICOM files were processed on 3D Slicer software. The forearm was then implanted with the Prosthelast ® prosthesis by a senior surgeon and rescanned to obtain the second model. The model incorporating the ReMotion ® implant was constructed using the two previous models and Fusion 360 CAD software (Autodesk, USA). In all models, the proximal of the radius was fixed, and a compressive load of was applied along the longitudinal axis. The load was transmitted via the scaphoid and lunate in a neutral wrist position in all cases(3).

Results demonstrated that both implants altered engineering strain distribution in the distal radius (Figure 1). On the palmar face, under the ulnar notch, absolute maximum principal strain values were approximately for the non-implanted radius, for the Prosthelast ® implant,

*Speaker

and for the ReMotion ® implant. In a more proximal region, deformation ranged from for the non-implanted radius (Prosthelast ®) and (ReMotion ®). Although both implants influenced strain distribution, the Prosthelast ® implant had a lesser impact compared to the ReMotion ® implant.

Keywords: Radiocarpal joint, Finite element analysis, Arthroplasty

How Does Spinal Cord Injury Affect the Bone Mechanical Properties of Mice Femurs?

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With over 18,000 new cases annually, it is estimated that at least 250,000 people in the United States suffer from spinal cord injuries (SCI). Each of these patients incurs costs of over $1 million while seeking treatment for their symptoms over the course of their lifetimes. Compared to the general population, individuals living with SCI are twice as likely to experience a bone fracture injury. Previous studies have linked risk of bone fracture to alterations in bone biomechanical properties. However, the risk of bone fracture for people living with SCI and its connection to bone biomechanical properties is not well established. Studying this relationship will allow clinicians to improve patient outcomes in SCI patients and improve their quality of life. To tackle this challenge, this project will quantify the changes in the morphological and mechanical properties of mice femur bones due to SCIs. We hypothesize that SCI will alter mechanical properties in mice femurs leading to higher elasticity (measured by a higher young's modulus) and less toughness (measured by decreased work to fracture). We believe these changes will be accompanied by reductions in the thickness of the cortical bone. To test these hypotheses, we will use 6 non-SCI mouse femurs as a control group and 6 mouse femurs post-SCI. We will perform microCT imaging and 3-point bending tests to quantify the morphological and mechanical changes between these two groups.

Keywords: SCI, Spinal Cord Injury, Mechanical Properties, Mice Femurs, Mouse Femurs, 3 Point Bending, Young's Modulus, Elasticity, Biomechanics, MicroCT

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Mechanical characterisation of femoral cancellous bone samples with metastases

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Introduction

Bone metastases, frequently arising from breast or lung cancer, often affect the femur and can lead to severe skeletal complications such as pathological fractures and spinal cord compression**1,2**. While CT imaging is used to assess metastatic bone lesions, it provides primarily qualitative data. Finite element models based on quantitative imaging have been proposed**3** to predict fracture risk, but they often rely on mechanical properties derived from density of healthy bone. However, metastatic lesions can alter the microarchitecture of cancellous bone, potentially affecting its mechanical behaviour at the structural level. The aim of this study is to determine the local properties of the metastasis within the femoral cancellous bone in order to implement them in a finite element model.

Methods

The bone samples (N=13) used in this study were collected at the Hospices Civils de Lyon and originated from prophylactic surgeries or femoral prosthetic replacements. The specimens were stored at -80◦C. The morning before testing, they are thawed by placing them in the refrigerator at +4◦C. Samples are analysed by a clinician to identify metastatic areas. For each sample, 3 cylindrical samples are taken (healthy zone, metastatic zone, transition zone) in the Main Trabecular Direction (MTD), determined from a scan (Skyscan 1076). The samples are cut using a bench drill (PROMAC 210Z), a Meunier modification of Bordier trephine (diameter D=7.5mm) and a low speed saw (ISOMET BUEHLER) to cut samples so that their maximum length Lmax satisfies Lmax=2*D. Samples undergo a mechanical testing protocol based on uniaxial compression combined with tomodensitometric imaging (micro-CT, Skyscan 1174). Scans are taken at different compression levels (0N, 10N, 40N, 90N, 140N, 200N), and performed at 0.6 to 0.8 degree rotations for 180 degrees (50 kV to 800 μA; 0.5mm aluminium filter), with a nominal isotropic voxel size of 18μm before loading and 33 μm, followed by analysis with CTAn software. Elastic modulus (E) is calculated from the stress-strain curves.

Discussion

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Three pre-tests were carried out on a human femoral head specimen obtained from a prosthetic replacement due to fracture, enabling the protocol to be finalised and validated. We obtained E(MPa) =116.27+/-21.95, bone volume fraction (%) = 37+/-8, trabecular separation (μm) = 734+/-278, trabecular thickness (μm) = 335+/-76, trabecular number (1/mm) = 1.16+/-0.34, and degree of anisotropy = 0.49+/-0.05.

The mechanical characterisation of the three regions (metastatic, healthy, and transition) is expected to highlight potential differences and irregularities. Particular attention will be paid to the relationship between mechanical properties and microarchitectural features.

Conclusion

This study aims to enhance the understanding of how mechanical and structural parameters evolve across metastatic, transition, and healthy bone regions, offering new insights into the local impact of bone metastases on cancellous bone integrity. Integrating these findings into finite element models could improve their accuracy. In the long term, this work aims to contribute to better-informed therapeutic decision-making for patients with metastatic bone disease.

References

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Keywords: Mechanical properties, metastatic bone, microarchitecture, micro CT

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