Experimental Trauma Surgery
Medical Faculty
Justus-Liebig University of Giessen (Germany)

2020 Proceedings of the
3rd International Conference
on Trauma Surgery Technology in Giessen

Multifunctional Trauma Surgery Implants

In cooperation with
Deutsche Forschungsgemeinschaft (DFG)

17 October 2020
Hosted online due to Corona situation
Funded by the Deutsche Forschungsgemeinschaft

University Medical Faculty
Giessen (Germany)

2020 Proceedings of the 3rd International Conference on Trauma Surgery Technology
Editors: WA Bosbach, B Yu, A Mieczakowski, C Heiss

Conference Organisation at JLU Giessen

M Ebeling, WA Bosbach, M Hofacker, KE Bosbach

Scientific Committee and Editors of the Proceedings

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3rd (virtual) conference: Multifunctional trauma surgery implants
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Preface

Dear Colleagues
Dear Speakers
Dear guests who logged in at zoom on 17 Oct

The **3rd** event of the **Giessen International Conference on Trauma Surgery Technology** on **October, the 17th 2020** was hosted on www.zoom.com in accordance with the worldwide corona situation. Dr Mieczakowski, Dr Yu, and Wolfram drafted in 2018 from Jan's apartment in Bremen the manuscript which was submitted to and **approved for funding by the Deutsche Forschungsgemeinschaft (DFG)**. At that time, we had no idea what substantial changes the conferencing concept would require. This is why we would like to thank again Michele. She first planned this year's event after the 2019 date and then in the spring of 2020 had to replan for the new situation.

The main topic for **2020** was **trauma surgery implants and their functionality**. The included figure (source: Dr Yu's introductory talk) shows some of the requirements for modern trauma implants. Resistance against wear and against the generation of debris particles, adapted fracture toughness and stiffness have to be considered to avoid implant failure. The three sessions this year specifically addressed these issues by 5 talks each. First, talks about **device functionality** were presented, followed by the second session on **surgical aspects of implants**, and the third which investigated optimised **surface properties**. As part of our ongoing collaboration, Bosco is overseeing our
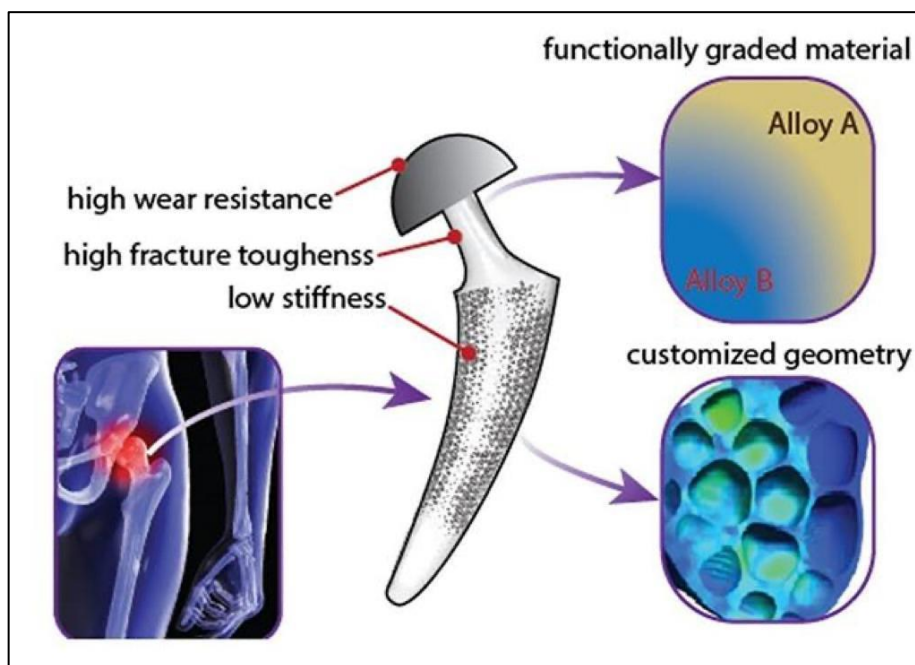

Figure: Sketch of a state-of-the art hip implant with highlighted functionalised sections: high resistance against wear in contact with acetabulum pelvis, high neck fracture toughness against traumatic implant failure, stem stiffness adapted to surrounding femoral bone tissue, achievable by graded alloys and by surface geometry designs (image source: Dr Yu's introductory talk).

joint investigations about the mechanical stiffness in human femur head samples and the influence of osteoporosis thereon. Results are being prepared for publication at the moment.

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Since the 2019 event, two more studies have been published by speakers where in both cases the Giessen event was able to make a contribution for discussion and exchange. The stimulation of an international **exchange of ideas and research results** has been the original reason for the DFG to fund our events. Joe's and Elisa's talks this year continue from those two studies and lead to the next steps of ongoing and future work. The 2020 event was again a platform for researchers and clinicians from different fields from different countries. Objective was again to stimulate **novel ideas for research work and follow-on funding proposals.**

We were positively surprised how well participants interacted in a virtual conference room and how many interesting discussions were started. We see this also as a chance for innovating our conferencing concept further and to use also in the post-corona future virtual formats.

The 3rd event attracted more participants from a greater number of countries than ever before. **Speakers this year came from North America, Europe, and the Far East**. At the time of the event's start on 17 Oct, local time for speakers ranged from

- 9 am in Ontario (Canada), to
- 3 pm in Frankfurt/Zurich, and
- 9 pm in Zhengzhou (China).

Amongst speakers, there were Giessen-regulars as well as Giessen-freshers.

The **closing talk** from Seper and Greg presented the first documented case of **osteosarcoma in a dinosaur** fibula (p 34-35). The dinosaurs did not innovate and eventually all died out as we know. **We as scientists** equally can get osteosarcoma and should see this probably as a wakeup call. We scientists enjoy structural conservatism so much in our habitats which we call research institutes.

For us, there is equally a risk that we go extinct unless we continuously innovate and try new ways. We should not shy away from evolutionary competition and, au contraire, rather should embrace with eagerness the best, novel ideas.

> **DOI of video recording:**
> /10.17863/CAM.60210

Preparations for the 4th event have started. We will see how soon we meet again. We plan to have again a face-to-face component.

We shall see again, your scientific committee

Programme overview – adapted to 2020 Corona situation

Friday, 16 Oct 2020 - Cancelled due to Corona pandemic

~~*Evening get-together at the Giessen Old Brewery*~~

Day 1 - Saturday, 17 Oct 2020

- **Presentations with discussion rounds**

  03.00 pm, Frankfurt time (CEST)

  Log in via:
  https://zoom.us/j/92883591118?pwd=UGJKTUdkLzN2WGpEWU5tUEI5Tm51UT09
  Meeting-ID: 928 8359 1118
  Password: gießen2020

  Cancelled due to Corona pandemic
- ~~*Dinner party at the Giessen Boat House*~~

Day 2 - Sunday, 18 Oct 2020 - Cancelled due to Corona pandemic

- ~~*Interactive morning sessions:*~~
  - ~~*Osteosynthesis workshop (Dr Biehl)*~~
  - ~~*Visit to the University hospital's helipad*~~
  - ~~*Performance specifications in medical engineering (Dr Mieczakowski)*~~
- ~~*Lunch break*~~
- ~~*Departure by shuttle to Frankfurt airport*~~

Press statement (in German) by host institute Justus-Liebig University of Giessen

Implantate in der Unfallchirurgie

JLU richtet Internationale Tagung zur Traumachirurgie in diesem Jahr online aus

Nr. 152 • 6. Oktober 2020

Implantate sind aus den Therapieverfahren der modernen Unfallchirurgie nicht mehr wegzudenken. Sowohl alltägliche Kreuzbandrisse beim Sport als auch die komplexe Polytraumaversorgung Schwerstverletzter nach Verkehrsunfällen erfordern auf den Patienten zugeschnittene, passgenaue Systeme. Das Potential für gesteigerten Patientennutzen bei weiter Optimierung heutiger Implantate ist am 17. Oktober 2020 das Thema der 3. Veranstaltung der seit 2018 jährlich in Gießen durchgeführten Internationalen Tagung zur Traumachirurgie.

Die englischsprachigen Vorträge werden dezentral online gehalten und sind dabei öffentlich zugänglich. Das diesjährige Online-Format ersetzt aufgrund der Coronabeschränkungen die normalerweise in Gießen real stattfinde Veranstaltung. Vortragende kommen aus Europa, Nordamerika und Fernost. Wie schon in den Vorjahren finanziert die Deutsche Forschungsgemeinschaft das Event.

■ Weitere Informationen

https://www.uni-giessen.de/fbz/fb11/institute/klinik/chirurgie/uch/forschung/trauma-surgery-technology-conference-2020

■ Termin

Samstag, 17. Oktober 2020, 15 Uhr
Zugangsdaten Online-Event:
https://zoom.us/j/92883591118?pwd=UGJKTUdkLzN2WGpEWU5tUEI5Tm51UT09
Meeting-ID: 928 8359 1118
Password: gießen2020

■ Kontakt

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Experimentelle Unfallchirurgie

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Web link: https://www.uni-giessen.de/ueber-uns/pressestelle/pm/pm152-20implantateinderunfallchirurgieonlinetagung (issued on 06 Oct 2020)

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Detailed Programme with presented abstracts

Opening session – 03.00 pm, Frankfurt time (CEST)

- **Ebeling, Michele**

  Bosbach, Wolfram, University of Giessen

  Introduction about technical details and workshop structure

- **Group photo 2020 on zoom** (participation non mandatory, p 38)

Session 1 – Devices and device functionality, Chair: Bagherifard, Sara

- **Introductory talk:**

  Yu, Bosco, McMaster University

  Multifunctional Trauma Surgery Implants

- **Gonder, Nicole, Sarah, McMaster University**

  Development of Highly Tuneable Cellular Protective Bodywear using Rapid Prototyping and Additive Manufacturing, p 9-10

- **Mieczakowski, Anna, Ameliot Consulting, University of Cambridge**

  Investigation and Monitoring of Wound Microbes and their Bacterial Volatiles Through a New Sensor Technology, p 11-12

- **Deering, Joseph, McMaster University**

  Exploring design and surface modification strategies for porous metallic implants, p 13-15

- **Schwarz, Oliver, Fraunhofer IPA, Stuttgart**

  Learn from ants to build OP scissors, p 16

Session 2 – Surgery and bone, Chair: Heiss, Christian and Mieczakowski, Anna

- **Rier, Elyse, McMaster University**

  3D Point Cloud from CT Data to Assist Surgical Planning and 3D Printing, p 17-18

- **Aranguren van Egmond, Derek, University of Toronto**

  An investigation of the trabecular bone micro-architectures in osteoporotic human femoral heads using x-ray tomography, p 19-21

- **Schwarz, Oliver, Fraunhofer IPA, Stuttgart**

  Fish fins effect in anatomical forceps allows gentle gripping, p 22

- **Zheng, Kai, Zhengzhou University, Dalian Medical University**

  Medial Collateral Ligament Reconstruction Using Peroneus Longus Tendon Fixed by Interference Screw and Endobutton Fixation, p 23

- **Schwarz, Oliver, Fraunhofer IPA, Stuttgart**

  Extreme better usability of bone cutter after revision with biomimetic features, p 24

Session 3 – Tissue engineering scaffolds, Chair: Yu, Bosco

- **Mele, Elisa, University of Loughborough**

  Engineering materials for biomedical applications: from electrospinning to 3D printing, p 25

- **deVet, Taylor, McMaster University**

  Osteocyte electrical stimulation: Experimental design and culture media characterization, p 26-28

- **Senge, Jan Felix, University of Bremen**

  An approach towards novel roughness parameters for shot peened surfaces, p 29-31

- **Mora Sierra, Daniel Camilo, Politecnico di Milano**

  Numerical modelling of Ti6Al4V Additive manufactured lattice structures for bone implants, p 32-33

- **Closing talk:**

  Ekhtiari, Seper, McMaster University

  Osteosarcoma in a Dinosaur: A First-Time Diagnosis Confirmed through Comparison with a Human Specimen, p 34-35

Session 1 – Implants and functionality

Development of Highly Tuneable Cellular Protective Bodywear using Rapid Prototyping and Additive Manufacturing

Gonder Nicole Sarah, Tyedmers Walker Adam, Yu Bosco*

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Developing tuneable cellular lattices using domain misorientations for tiling of 3-dimensional surfaces for impact absorption and traumatic brain injury mitigation in protective headwear (helmets).

Introduction Traditional protective bodywear tends to be made from homogenous materials with minimal tuneable structures. Through additive manufacturing, we can explore structures that were previously difficult to produce and study. Modern cycling helmets commonly contain solid expanded polystyrene (EPS) with a solid internal architecture, with internal linings such as MIPS and WaveCel [1].

Cycling impacts involving rotational forces to the head can lead to concussion, and other forms of traumatic brain injuries. Linings in bicycle helmets offer potential reductions in rotational acceleration to the head [1], whereas the rigid EPS internal architecture can be improved using cellular geometry for impact absorption, light weighting, and reusability after impact.

Through this study, we are exploring new type of protective wear to protect from forces that are commonly unaccounted for in impacts.

Method and materials Cellular structures to accommodate curvature will be developed through an iterative method to rapid prototype using additive manufacturing. We will compare these to existing architectures in modern cycling helmets, and those seen in cellular architecture in nature.

Results and discussion We are currently investigating cellular structures by mimicking biological structures, and applying existing algorithms developed by our previous study to our current work. We are exploring the usage of various CAD software allowing us to develop highly tuneable cellular structures that can be additively manufactured into free-form helmets for miniature testing. During this conference, we will summarize the results of our work-in-progress.

Conclusions and future work Presently, we have developed numerous geometries and are beginning the testing phase using additive manufacturing with promising results from initial simulations. For this study, we have narrowed down our study to cycling helmets, but plan to expand to design other type of protective body wear on this in future studies (see example in reference [2]).

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Conflict of interest

The authors declare that there are no conflicts of interest.

Funding sources

Investigation and Monitoring of Wound Microbes and their Bacterial Volatiles through a New Sensor Technology

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Introduction Seven different species of microbes tend to be present in most wound infections, emitting volatile compounds through skin secretions, including predominately acetone, CO_2, ammonia and amine:

1.   Staphylococcus aureus – embedded closer to the wound surface;

2.   Pseudomonas aeruginosa – embedded deeper within the wound bed;

3.   Candida;

4.   Enterococcus;

5.   Aeromonas;

6.   Micrococcus;

7.   E. coli.

These bacterial volatiles can be detected from the wound dressing material, as well as directly from the wound's bed. However, detection of these species of bacteria usually requires sample and laboratory testing which is costly, inconvenient and time-consuming in the current medical practices for both patients and outpatients.

While 76 million of people worldwide suffer from acute and chronic wounds annually due to accidents, complications from diabetes, obesity and cardiovascular disease, currently medical practitioners (predominantly nurses) evaluate wound-status through a visual inspection based on experience (not on data), routinely changing dressings every 2 days, which in more severe cases requires anaesthetic and costly theatre time. 30% of wounds lack an accurate diagnosis due to treatment by non-specialist clinicians and 85% of dressings are changed too early, hampering healing [1]. Thus, a wound dressing equipped with a point-of-care, real-time sensor could significantly optimise and improve wound management and therapy.

Method and materials Together with a number of sensor development companies, an academic institution and a Hospitals Foundation Trust based in the UK, the author is involved in a project developing a new sensor technology for detecting in real-time the bacterial volatiles from the above-mentioned seven different genera of microbes in order to minimise infections by continually monitoring changes to the wound's bed and modifying treatment when any changes occur. Early diagnosis and management of wound infection is essential to avoid complications and this project offers a non-invasive method for diagnosing wound condition in real-time among both patients and outpatients, thus enabling appropriate treatment and reducing the risk of further complications. The project also aims to contribute to cost-effectiveness and improve the quality of life of the affected patients.

Ongoing work Despite that this work is currently underway, it already demonstrates the significant potential of the sensor technology for improving the quality of life for both patients and outpatients, given that, for example in the UK, 55% of outpatient cases are not being followed up and the outpatients' wounds being only seen when there is another medical problem. The sensor has a major potential to improve the time, pain management, speed and cost during healing of acute and chronic wounds, lowering the number of deaths as a result of undetected infections, antibiotics overuse, amputations, anaesthetic and theatre-use costs, by improving patient care in the hospital and the community, as well as speeding up clinicians' reactions to the imbalances in the wounds' bacterial volatiles' levels. Another benefit is that the sensor is planned to be inexpensive (£5-10 per use) to apply in dressings and the aim is to also provide it for use in non-clinical settings.

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Exploring design and surface modification strategies for porous metallic implants

Deering Joseph[1]*, D'Elia Andrew[1], Clifford Amanda[1,2], Zhitomirsky Igor[1,3], Grandfield Kathryn[1,3]

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This work investigates the design and application of coating technologies to influence osseointegration on the interior of porous metals built by additive manufacturing. A polymethylmethacrylate composite coating infiltrated the interior of a porous scaffold to increase Saos-2 cell metabolism, and early trials with solvent cast alginate show promise.

Introduction Recent developments in metal additive manufacturing processes have enabled the fabrication of complex implant geometries for orthopaedic and prosthodontic applications. In particular, the design of porous materials offers an innovative approach to improve functional bone-implant anchorage at a defect site [1] and mitigate bone resorption that may arise from stress-shielding [2]. During early-stage osseointegration, bone apposition occurs mostly in the outer layers of the porous material, with only minimal nucleation in the scaffold interior [3]. Surface modification strategies are needed to homogenize bone apposition throughout the scaffold and lead to improved implant stability.

Method and materials Scaffolds were designed in Autodesk Netfabb and fabricated from 304L stainless steel powder using selective laser melting (Figure 1) [4].
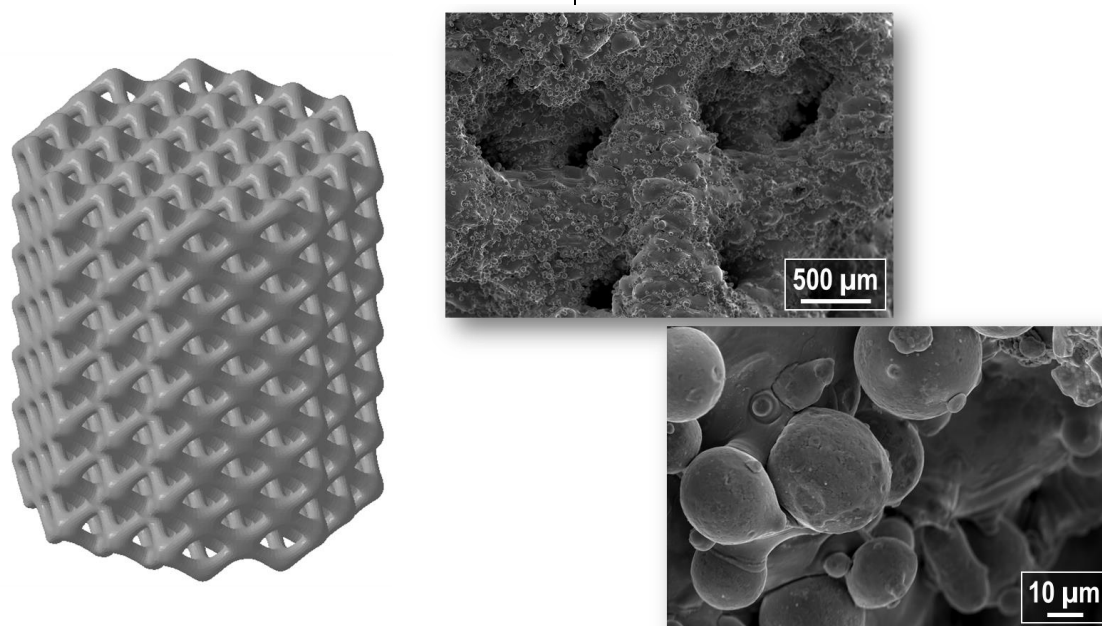

Figure 1: Porous scaffold design and micrographs showing surface topography and pore morphology of the scaffold

Polymethylmethacylate (PMMA) films with added alumina nanoparticles were deposited onto the scaffold by dip coating and subsequent solvent evaporation. Coating coverage was assessed by energy dispersive X-ray spectroscopy of the cross-section. Metabolic assays were used to assess Saos-2 cell viability and proliferation on solid cylinders, porous cylinders, and PMMA-composite coated porous cylinders. Early work on biomolecule functionalization by alginate solvent casting has also been conducted.

Results and discussion Scanning electron microscopy confirmed deposition of the PMMA-composite coating on the scaffold interior. Distinct alumina particles were visible in the PMMA films on both the exterior of the scaffold and, as shown in Figure 2, around the periphery of interior struts in the scaffold. Energy dispersive X-ray spectroscopy showed that films deposited on struts have a higher intensity of alumina and carbon than the remainder of the sectioned midplane, which is rich in elements characteristic of the stainless steel scaffold (iron, chromium, nickel, etc.) [5]. The alumina nanoparticles add topography at a smaller length scale than residual surface particles from selective laser melting. In vitro assays with osteoblast-like cells proved that the composite-coated porous scaffolds promoted significantly higher cellular metabolism compared to solid stainless steel cylinders after seven days of culture [5].

Conclusions and future work Coatings serve as an effective means to modify the interior of porous metallic implant structures for osteogenic applications. These coating technologies can be used for targeted delivery of bioactive agents or other functionalized biomolecules to the scaffold interior. Future work will focus on modifying coatings to integrate sustained protein release and induction of therapeutic pseudohypoxia on the scaffold interior to improve osseointegration.
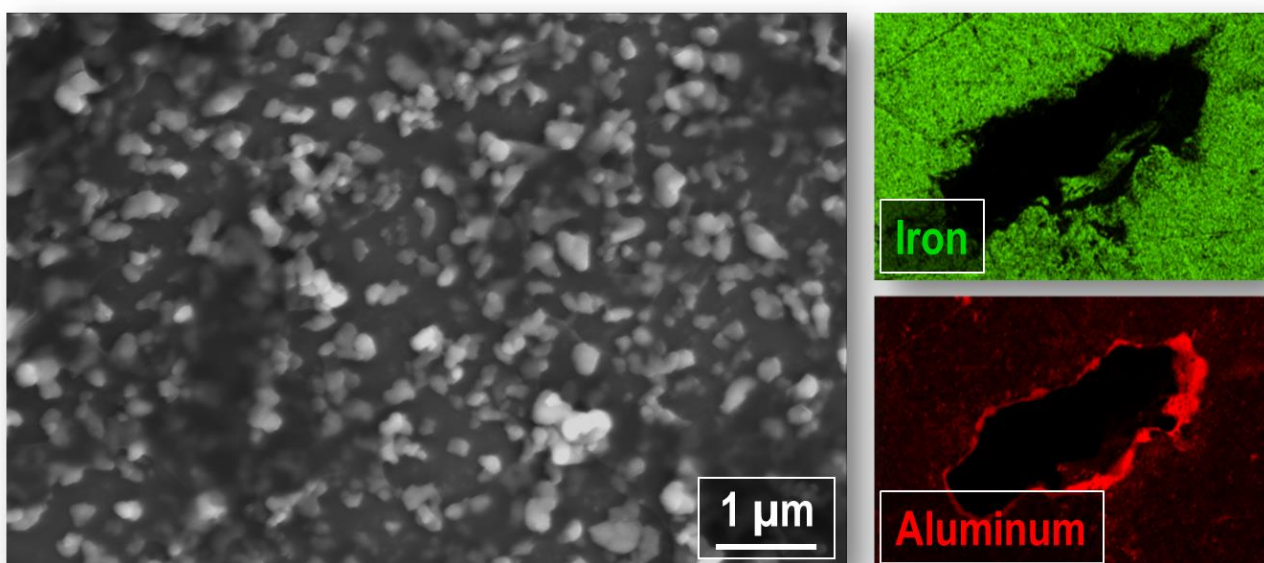

Figure 2: Micrographs of PMMA-alumina composite coating on the interior of a porous metallic scaffold. Characteristic X-rays for coating components are more intense around pore periphery.

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Conflict of interest

The authors declare that there are no conflicts of interest.

Funding sources

Learn from ants to build OP scissors

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In endoscopic operations in human surgery, precision and efficiency combined with high reliability are crucial. Scientific progress in this field is largely determined by the development of new instruments and depends on their development. In the course of this progress, fungus breeding ants and their special way of cutting leaves will serve as a biomimetic example.

Leaf-cutting ants are the most successful of their kind, which is not the last of other effective, efficient and precise leaf-cutting techniques. The filigree cuts of these ants allow them to make an arc in a field that is also filigree. In human surgery, and especially in minimally invasive procedures, precision and efficiency combined with high reliability are very important.

The asynchronous cutting of the ant is a special aspect of this technique. The two lower jaws thus fulfil completely different tasks. Remarkable here is the method of simultaneous knife and scissors cutting, which combines the advantages of both techniques. This special feature was taken up and adapted. The result is scissors that could cut more effectively, especially where little force can be applied due to the small size (neurosurgery) or where endoscopically compact tissue has to be removed.

Conflict of interest

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Funding sources

Session 2 – Surgery and bone

3D Point Cloud from CT Data to Assist Surgical Planning and 3D Printing

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The overall goal of our work is to develop a platform that allows users to easily visualize and manipulate CT data with the intent to facilitate surgical planning and potential rapid prototyping of biomedical implants.

Introduction: Surgeons can visualize the anatomy of defects by processing computed tomography (CT) data using software such as MIMICS (Materialise) to create 3D models of the area of interest [1]. These models can aid in preoperative planning and design of implants [1]. Although software tools are available to create 3D models or STL files, they can be expensive or require technical expertise. The overall purpose of this project is to create an independent software platform that would allow surgeons to manipulate segments of a CT scan and enable generation of STL files for surgical planning or additive manufacturing.

Method and materials: An anonymized CT data set of DICOM images of a skull (Discovery CT7, helical mode, GE Medical Systems) were used to develop the tool. The algorithm to extract a 3D point from CT data was first developed in MATLAB and then ported to Python. Image files were uploaded into MATLAB and Python and converted from grayscale to Hounsfield Unit (HU) using rescale slope and rescale intercept from the DICOM header. Images were binarized to isolate bone from surrounding tissue (threshold = 350 HU) based on [2]. Binarized images were subjected to a Canny edge detector to identify surfaces of the skull. Points were converted into spatial coordinates to create a point cloud. In-plane spatial coordinates (x,y) were obtained based on the edge location in each slice and pixel spacing of the CT images. Longitudinal coordinates (z) were summation of spacing between slices and the slice thickness for each slice.

Results and discussion: From visual inspection, the shape and the curvature of the surface of the skull was maintained in both point clouds. Dimensions of the point clouds obtained are summarized in Table 1. The variation between the number of points and the dimensions of the point clouds was likely caused by the variations in the Canny edge detector functions used in the two platforms. These dimensions are reasonable for an adult human skull considering that the CT images used did not contain a portion of the skull. The point clouds were both successfully saved as

matrices containing the surface points representing the skull. This representation reduces the size of the data from a stack of DICOM files to a simple Nx3 matrix of doubles where N is the number of points in the point cloud.

Conclusions and future work: In next steps, the current algorithm will be modified to be compatible with data files for CT machines from other manufacturers. The 3D point cloud will be sampled based on curvature to reduce the size and will be converted into a 3D STL model. This model will act as the base for a program which will provide users a method to manipulate and extract 3D portions of the skull to create patient-specific implantable devices.

Table 1: Dimensions of obtained point clouds

	Number of Points	Height (z) [mm]	Length (x) [mm]	Width (y) [mm]
Matlab	307,250	238	139	152
Python	282,938	238	140	152

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The authors declare that there are no conflicts of interest.

Funding sources

An investigation of the trabecular bone micro-architectures in osteoporotic human femoral heads using x-ray tomography

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An image analysis method has been developed to investigate micro-CT scans of the trabecular bone micro-architectures in human femur heads. Preliminary results show that the spatial distribution of pore structures within human trabecular bone is similar to stochastic pore arrangements observed in animal bones, plant cells, and other porous materials found in nature. They also suggest that the degree of randomness in the structures is not correlated to the degree of bone loss and mechanical resilience of the femoral neck. However, prior observations have demonstrate that porosity, trabecular morphology, and the fracture toughness of bone are indeed all correlated. More investigation is needed to provide a conclusive statement.

Introduction and scope of study Cellular structures are a type of micro-architecture that is ubiquitous in nature. They can be found in plant cells (e.g. bamboo, wood), as well as the trabecular bones of animals (e.g. bird bones, femoral heads in mammals) [1]. Cellular structures have superior stiffness-to-weight and strength-to-weight ratios compared to their solid (fully dense) counterparts. For this reason, engineers have long mimicked nature in developing human-made cellular solids (also known as lattice materials) for use in structural applications. However, the current scientific understanding of mechanical behaviour (especially fracture mechanics) in cellular structures has been more focused on periodic (identical tessellations of a single cell shape) cellular structures, as opposed to the stochastic (or "random") structures found in nature [2-3].

The goal of the current study is to gain insight about the spatial distribution of trabeculae and how their randomness might relate to mechanics, especially in the case of femoral neck fracture in the hip bones of human patients that are suffering from osteoporosis.

Method and materials

The first two authors of the current proceeding (D. Aranguren van Egmond and B. Yu) have previously developed a forthcoming image analysis method to examine the micro-architectures of engineered and natural

cellular solids in a quantitative way. In this study, we will adapt this quantitative method to analyse the micro-CT scans of the trabecular bone structure in multiple specimens of osteoporotic human femoral heads. The results from this study will then be compared with other cellular structures observed in nature. For that purpose, femur head samples were scanned by micro-CT. Image post-processing followed.

Results and discussion Based on preliminary analysis of the CT scans, the relative porosity of the femur head was clearly observed to increase with greater proximity to the fracture site. This suggests that osteoporosis, bone porosity, and the fracture toughness of bone are all correlated, in line with traditional bone density analyses.

There did not appear to be a significant change in the metric of microstructural "randomness" of the trabecular bone relative to the measurement location's distance from the fracture site. It was observed that the degree of randomness of trabecular structures is in agreement with other typical cellular structures found in nature. This agreement suggests some degree of preferential intent in the distribution of pores as originally documented in Wolff's law already in 1892 [4].

Conclusions and future work Our preliminary results in the current investigation confirm that bone porosity can be a major governing factor of the fracture toughness of trabecular bone, leading to a greater likelihood of bone fracture. Meanwhile, the effect of microstructural "randomness" remains inconclusive. There remain several challenges ahead in this form of quantitative image analysis. First, a representative sample set (potentially multi-centre) needs to confirm the above findings. Second, bone samples are not free from mechanical damages during surgical procedures. Overcoming these challenges will provide useful new insights and indicators as to why, and perhaps how, femoral neck fracture occurs, further elucidating the influencing mechanism of osteoporosis.

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Conflict of interest

The authors declare that there are no conflicts of interest.

Ethics approval

Ethics approval from Giessen University Medical Faculty, christoph.biehl@chiru.med.uni-giessen.de

Fish fins effect in anatomical forceps allows gentle gripping

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Objects sometimes get damaged by anatomical forceps or slip out of their grip. Therefore, a forceps based on the Fish fins effect was developed. This effect was discovered 20 years ago when fishing and was used in biomimetic robot grippers from Festo. The jaws of the forceps adapt to the shape of the object that is handled with it while standard anatomical forceps force objects to adapt to their shape. Due to this unique property, less and more uniform pressure is applied on the object. Furthermore, it is possible to apply targeted pressure on objects by using the tips of the Fish fins effect -forceps. This offers the usual properties that users expect from forceps. Soft tissues can be handled with these forceps as well. This biomimetic instrument was chosen In the Devicemed magazine, in the "Research" section, foreceps were ranked second among the best developments in Medical technology selected in 2018.

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Medial Collateral Ligament Reconstruction Using Peroneus Longus Tendon Fixed by Interference Screw and Endobutton Fixation

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Introduction To perform an evaluation of clinical effects in medial collateral ligament (MCL) reconstruction using peroneus longus tendon fixed by interference screw and an Endobutton fixation device.

Planned methods We plan to select suitable patients to be treated with MCL reconstruction by our method. We are going to quantify knee joint biomechanics as follows: by the Lysholm knee score, the IKDC score, the range of motion, the distance of medial knee space in 0° and 30° stress x-rays, the difference of distance between medial and lateral knee space in 0 ° and 30° stress x-rays, and by gait analysis at the last follow-up.

Expected Results and Outlook We expect that in medial side which will be treated by surgical intervention the data will differ significantly comparing status preoperatively and postoperatively. Our operation method would gain tendon easily and could provide perfect medial stability of the knee, fewer complications. These long-term assessments would need further follow-up.
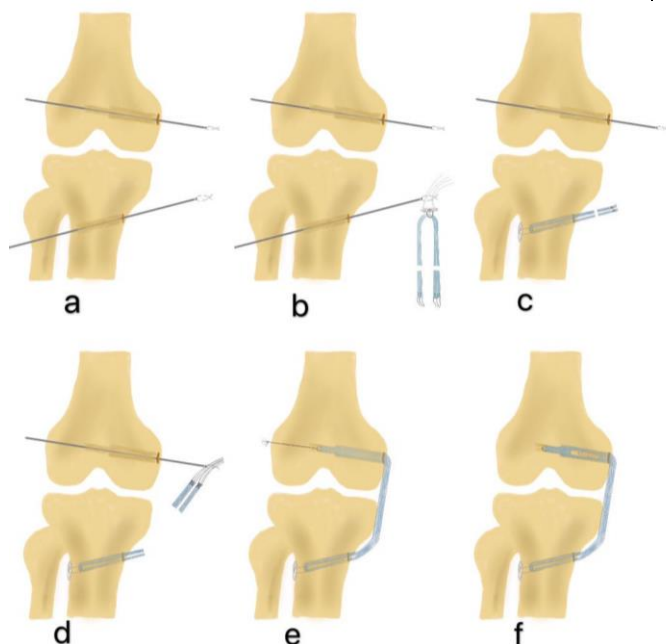

Figure:
a. Femoral canal 4.5mm, medial bone canal 7mm, tibial canal 4.5mm;

b. Endobutton with tendon through the tibial canal;

c. Turn over and fix Endobutton on the bone;

d. Guide the tendon;

e. Tendon cross the femoral canal;

f. Interference screw fix on the femoral.

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Extreme better usability of bone cutter after revision with biomimetic features

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A "swallowing" bone punch modelled on the dentition of the snake Anaconda was developed, which sterilely holds the resectate inside the instrument after the forceps have been closed. The next bone piece can be resected immediately. The resectates are in the cartridge in the order in which they were removed and can be used for biopsies or removed and implanted again at the end of the operation. The punch or cartridge can hold 40 resectates, which means that the punch can remain in the operated area for a long time without being emptied constantly. The cutting mechanism has been modified from the carnivorous dentition of the feline (Feliformia). This saves approx. 50% of the force required for cutting and the cuts have clean cutting edges in contrast to the traditional punch cutting mechanism. It could be shown that biomimetics enables an effective transfer into medical technology.

Session 3 – Tissue engineering scaffolds

Engineering materials for biomedical applications: from electrospinning to 3D printing

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One of the main requirements that scaffolds for tissue engineering should possess is a porous structure with interconnected porosity that promotes cells and nutrients infiltration, and yet has mechanical strength to support *in vivo* loading. Three main approaches have been proposed so far to achieve this goal: manufacture natural or synthetic biomaterials, decellularise tissues and stimulate cells to generate their own matrix. My research focuses on the first approach and this seminar is an overview of the technologies currently used in my group to manufacture biomaterials with multiscale porosity [1-4]: electrospinning, phase separation and 3D printing. The resulting scaffolds possess a hierarchical structure where layers of nanofibres act as a biomimetic interface for cell attachment and proliferation, while porous 3D structures provide mechanical support.

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Osteocyte electrical stimulation: Experimental design and culture media characterization

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Introduction Osteocyte lineage and morphology are well understood, but their behaviour within the tissue is widely debated [1]. The accepted hypothesis is that osteocytes can sense mechanical strain within the bone matrix and control the response of osteoblasts and osteoclasts accordingly [1]. Research indicates that the bone matrix experiences changes in electrical charge when stressed through streaming potentials in the canaliculi and piezoelectricity of the collagen-hydroxyapatite junctions [2], [3]. The application of external electrical stimulation (ES) has been shown to increase bone formation which indicates that the cells are electrically sensitive [3]–[5]. This is currently under-researched for osteocytes, which are presumed to be the ones sensing the stimulus. The goal of our work is to develop an experimental platform to further our understanding of how osteocytes respond to electrical stimulation.

Method and materials To apply ES to osteocytes in vitro we have been developing a device to fit into 12 and 24-well cell culture plates. To avoid electrode-electrolyte interactions, we use platinum electrodes for their inert properties. These electrodes were placed in each culture well, parallel to each other, suspended above the bottom of the well. When cells are introduced, they will not have anything impeding their ability to move and grow. A DC stimulus was applied with magnitudes between 100 and 800 µAmps using a constant current supply. The resistance of two media types, Dulbecco's modified eagles medium and McCoy's medium, were monitored over time to track their electrical response behaviour.

Results and discussion ES of culture media caused visible changes in the media, as well as electrical properties over time. The resistance of the media increases rapidly upon application of the electrical stimulus and plateaus between 60 and 120 minutes of stimulation. The pH of the media also changes, with the media around the cathode becoming basic and media at the anode, acidic. This pH gradient disperses over time, corresponding to the resistance plateau. The resistance of the media is directly linked to the amount of current going through the media, with the relationship following a power curve. No relationship between voltage and current or voltage and resistance was found for the media.

Conclusions and future work These experiments have shown us which conditions allow for more stable behaviour of the cell culture media with the application of ES. This

should give us more insight into whether outcomes from ES cells are coming from the stimulation or the electrochemical reactions that are present in the media due to the ES. This will be a first step into generating a controlled ES environment for bone cells in culture.

The future of this work may also include the introduction of a set of measuring electrodes in each well to see how much stimulation is reaching the cells at the bottom of each well. This information will allow us to strengthen conclusions on what aspect of the stimulation is causing behaviour in the cells.
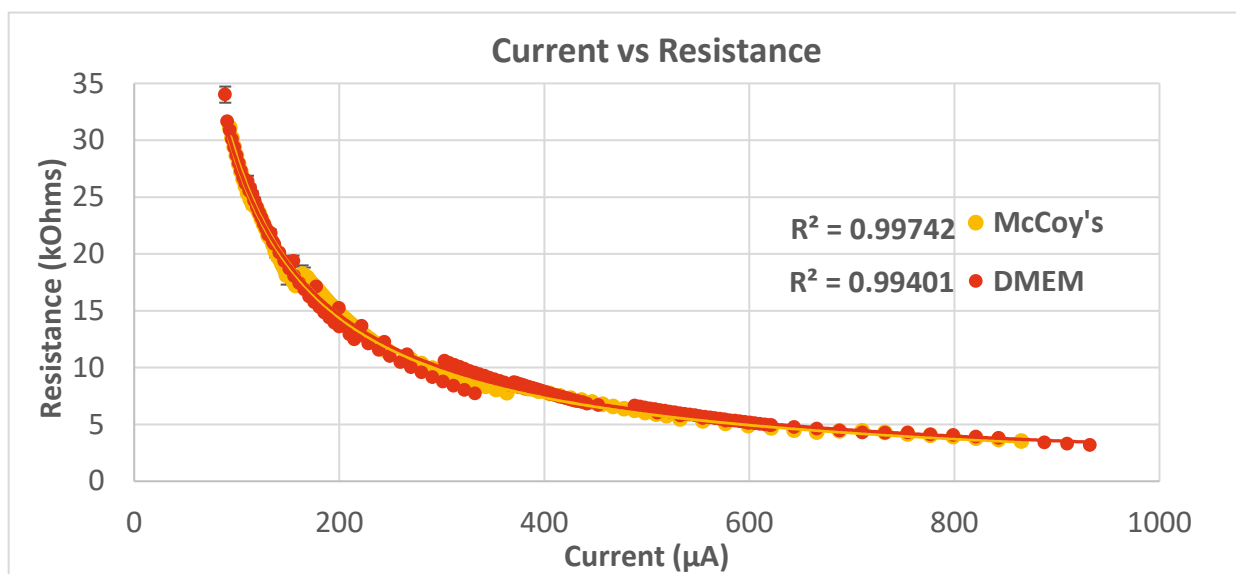

Figure: Current vs Resistance trend of DMEM and McCoy's Cell Culture Media

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An approach towards novel roughness parameters for shot peened surfaces

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Introduction Surface topography and roughness evaluation plays an important role in many problems such as friction, contact deformation or coat adhesion [1]. Different roughness parameters like the arithmetic average height/deviation (S_a), skewness (S_{sk}) and kurtosis (S_{ku}) are used to describe the topography of a surface and are of particular importance if we want to understand the changes during different stages of a shot peening treatment [2]. Standard roughness parameters struggle to exhibit differences between surface samples of the same material with different coverage percentages above fifty percent. As a remedy of this shortcoming, we consider methods from computational topology, namely persistence diagrams (PD) from persistent homology [3] to capture meaningful geometric features of the surface and use that to construct new surface roughness parameters better able to distinguish surface samples.

Methods and Materials Our dataset consists of 3D representations of the deformed surface after multiple impacts of a numerical finite element simulation of ARMCO pure iron (99.89%) using the numerical model developed in [4] and done in the Abaqus software by Dassault Systems. Input parameters such as Almen index and shot size were fixed and we track the evolution of the surface geometry by the number of impacts. From the number of impacts we calculate the coverage percentage of the specific surface samples. The dataset we present consists of several impact sequences each containing several samples for fixed coverage percentages ranging up to 100 percent. For each of these we consider the sublevel-set filtration of cubical complexes build on the out of plane displacement of the surface samples and calculate their persistence homology using the GUDHI software [5]. For the evaluation of the performance of using persistence-based parameters we considered different vectorization methods for the persistence diagrams like persistence entropy and landscapes [6], [7]. For a pipeline of the persistence-based approach, see Figure 1.

Results Incorporating a persistence-based parameter proves helpful in distinguishing different shot peened surfaces in comparison to the standard roughness parameters. , this can be extended into several directions as a different function for creating the filtration results in a different characteristic of the persistence-based descriptor. The goal of the subsequent analysis was to see how well

persistence-based methods can be used to distinguish between samples of different coverage values, as well as, clustering samples with the same coverage percentage together. While the set of standard parameters we considered had similar values for coverage percentages above fifty percent, the persistence entropy shows clear differences.

A linear regression was done to predict coverage percentages by using standard roughness parameters such as S_a, S_{sk}, and S_{ku} as the independent variable. For comparison we do the same regression using persistence-based parameters as input. The best result is observed for persistence entropy which outperforms all other roughness parameters significantly on the considered dataset in terms of error and prediction and shows a clear linear relationship.

Conclusion and future work The analysis and comparison of the persistence-based methods for surface roughness with the standard roughness parameters clearly shows the suitability for shot peened surfaces and its improvements upon standard roughness parameters. a more extensive analysis needs to be made to for different kinds of numerical simulation with a wider variety of input parameters such as coverages exceeding 100 percent as well as a comparison to more diverse roughness parameters to give better general statements about performance and usefulness for applications like recognition of surface patterns which influence bacterial adhesion.

Furthermore, an extension of persistence diagrams to incorporate finer details of the surface by accounting for contributions of size the connected components encounter during the calculation of the persistent homology might be useful..
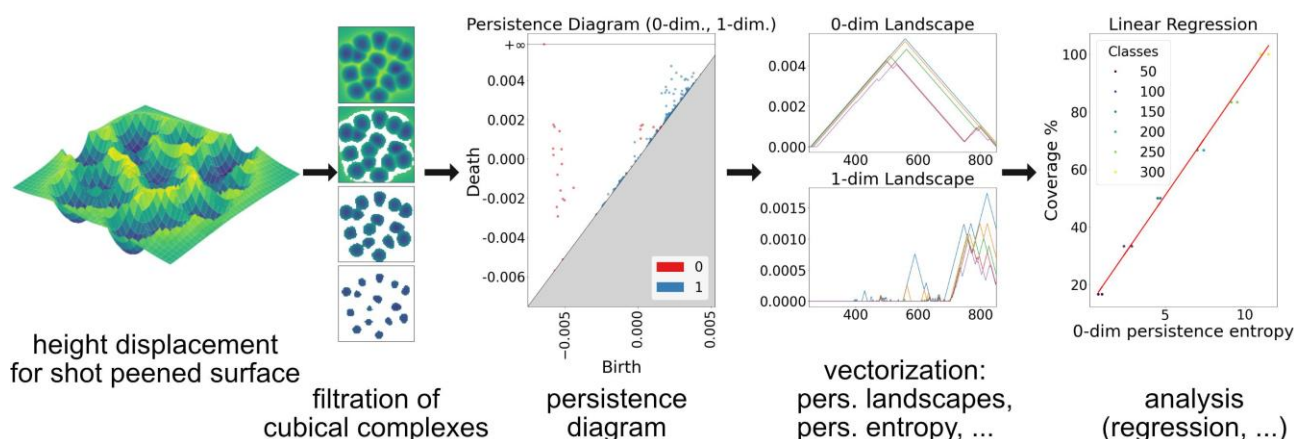

Figure 3 Persistence Homology pipeline for a shot peened surface. Calculate the persistence homology for the lower-start filtration for the sublevel-set filtration of the height function. Use different vectorizations of the PD for the analysis.

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Numerical modelling of Ti6Al4V additive manufactured lattice structures for bone implants

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In this study, a numerical model is developed and validated for the prediction of deformation and mechanical properties of lattice structures. Most promising ones are identified by comparing the mechanical properties to those of human bone tissue.

Introduction A significant requirement for a bone implant is to mimic the stiffness of host bony tissue since the mismatch creates stress shielding in implanted bones, which is one of the root causes of the reduced lifespan of commercial bone implants. In this work continuous functionally graded porous scaffolds (FGPSs) made of Titanium alloy Ti–6Al–4V are studied. The structures are based on different unit-cell topologies at different overall porosities. Lattice structures' topology is modulated by means of different gradient strategies to be mechanically compatible with surrounding bones, while offering an adequate mechanical resistance.

Method and materials A numerical model was developed in Abaqus by Dassault Systems in order to study the mechanical behavior and deformation mechanisms of the above-mentioned porous structures. CAD models of the structures were developed using Autodesk Inventor Professional and then imported into the FE software. An elastic plastic model was implemented to simulate the failure of the additively manufactured scaffolds under compression. Analytical rigid shells with were created to replicate the upper and lower compression plates of a testing machine.

Results and discussion The model was validated by means of experimental data provided in the literature. Stress–strain curves were extracted from simulations' results, and elastic modulus, yield strength, and peak stress were estimated according to standards. Estimated mechanical properties are compared to those of human bone in order to underline the most promising structures. Mechanical properties of structures based on pillar octahedral unit cell were found to be, for a specific porosity, lower than corresponding structures based on cubic unit cell. Only the elastic modulus of pillar octahedral structures having 85% porosity were close to the upper limit found on the literature for trabecular bone. On the other hand, remaining structures for both pillar octahedral and cubic unit-cell-based structures had elastic modulus within the range of cortical bone. The main advantage seen with FGPSs compared to uniform structures is that although elastic modulus remains similar for specific porosities, the other mechanical properties are still high enough to ensure mechanical integrity of the structures.

Conclusions and future work The numerical model developed provides an important tools

to design open porous lattice structures. The results obtained provide a solid background to further more inclusive and accurate numerical models. The next step is to experimentally study the structures analysed here to understand in more detail the accuracy and possible improvements of the current model.
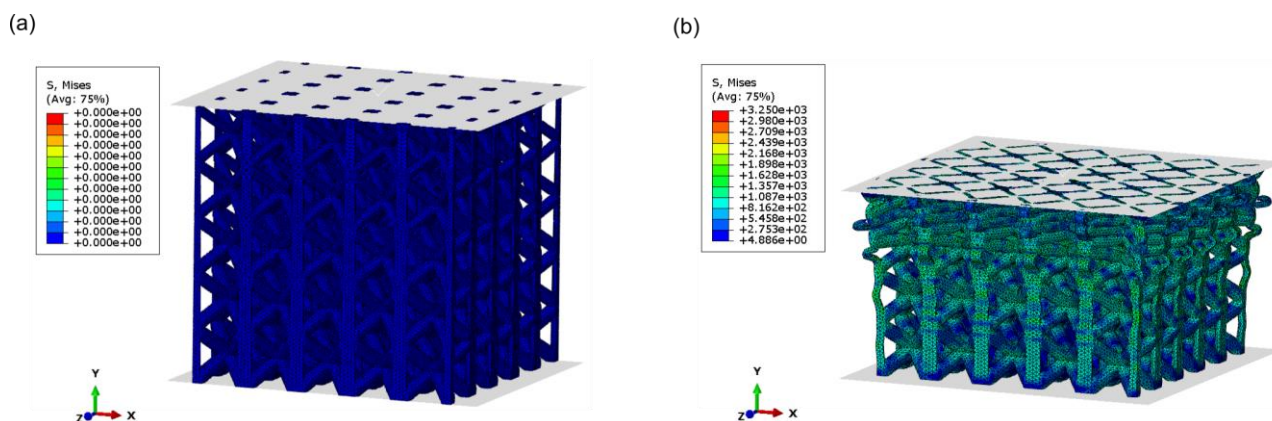

Figure 4: Stress distribution on a FGPS (a) prior and (b) after compression.

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Closing talk

Osteosarcoma in a Dinosaur: A First-Time Diagnosis Confirmed through Comparison with a Human Specimen

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Introduction Osteosarcoma is one of the most devastating diseases in orthopaedic oncology, most commonly affecting young patients in their second decade of life. It has been hypothesized that given its osteoblastic nature and timing, there may be a relationship between osteosarcoma development and growth velocity. Osteosarcoma has also been previously described in extant animals such as birds, reptiles, crocodiles, and amphibians. To date, however, no bony malignancies have been reported in dinosaurs. Here we describe a radiographically and histologically diagnosed case of osteosarcoma in a pathological fibula from a horned dinosaur (Centrosaurus apertus). The diagnosis was confirmed through direct comparison with a confirmed case of human osteosarcoma in a fibula.

Method and materials The specimen consists of the distal half of an adult Centrosaurus apertus fibula collected from a bonebed in the Dinosaur Park Formation, Alberta, Canada (Campanian). With ethics approval, the specimen was compared to a specimen of a proximal human fibula with a confirmed osteosarcoma. Both specimens underwent micro computed tomography (micro-CT) as well as microscopic histological examination by a pathologist and radiologist specializing in musculoskeletal oncology.

Results and discussion Gross examination of the dinosaur specimen reveals a tumour that takes up the proximal half of the

specimen, located about 150mm from the normal, distal end of the bone. The mass measures 155mmx92mmx61mm. The compact bone covering the tumour is quite thin in some places, suggestive of neocortex formation. In addition, unusual foramina consistent with malignant angiogenesis are clearly visible. The High Resolution X-Ray Computed Tomography (HRXCT) scan of the dinosaur specimen reveals a Codman triangle and proximo-distal invasion of the tumour throughout the cortex. The histological examination demonstrated a lack of zonation with bone maturation that would be seen if the lesion were a fracture callus, and evidence that the tumour extends throughout the cortex of the bone (confirmed on histological and radiological examination). Furthermore, the bone formation is irregular and inconsistent with Wolff's Law. In addition, there was evidence of extensive and multifocal penetration and destruction of the cortex by architecturally abnormal neoplastic bone with islands of normal bone visible. These findings were consistent with the proximal human fibula specimen from a patient with a confirmed diagnosis of osteosarcoma, which revealed similar findings on magnetic resonance imaging (MRI), micro-CT, and histology.

Conclusions and future work The gross, radiographic, and histologic appearance of the dinosaur fibula were identical to the human osteosarcoma, despite the lack of preserved soft tissue structures in the former. We conclude with a similar degree of certitude as would be possible in a patient in clinical practice, that this dinosaur bone demonstrates an osteosarcoma and thus represents the first histologically confirmed case of cancer in a dinosaur. Our findings confirm that dinosaurs suffered from primary bone cancer, and suggest that the exceptionally fast-growing bones of dinosaurs may be particularly prone to the development of osteosarcoma - in the same manner that this tumour commonly occurs in humans.

Conflict of interest

The authors declare that there are no conflicts of interest.

2020 Group photo – 17 Oct 2020

2019 Group photo – 12 Oct 2019

2018 Group photo – 17 Nov 2018

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