

[MEET THE EXPERT]

IMPLANTS

Materials and Surface Technology for Implants

Tuesday, 15 September 2026

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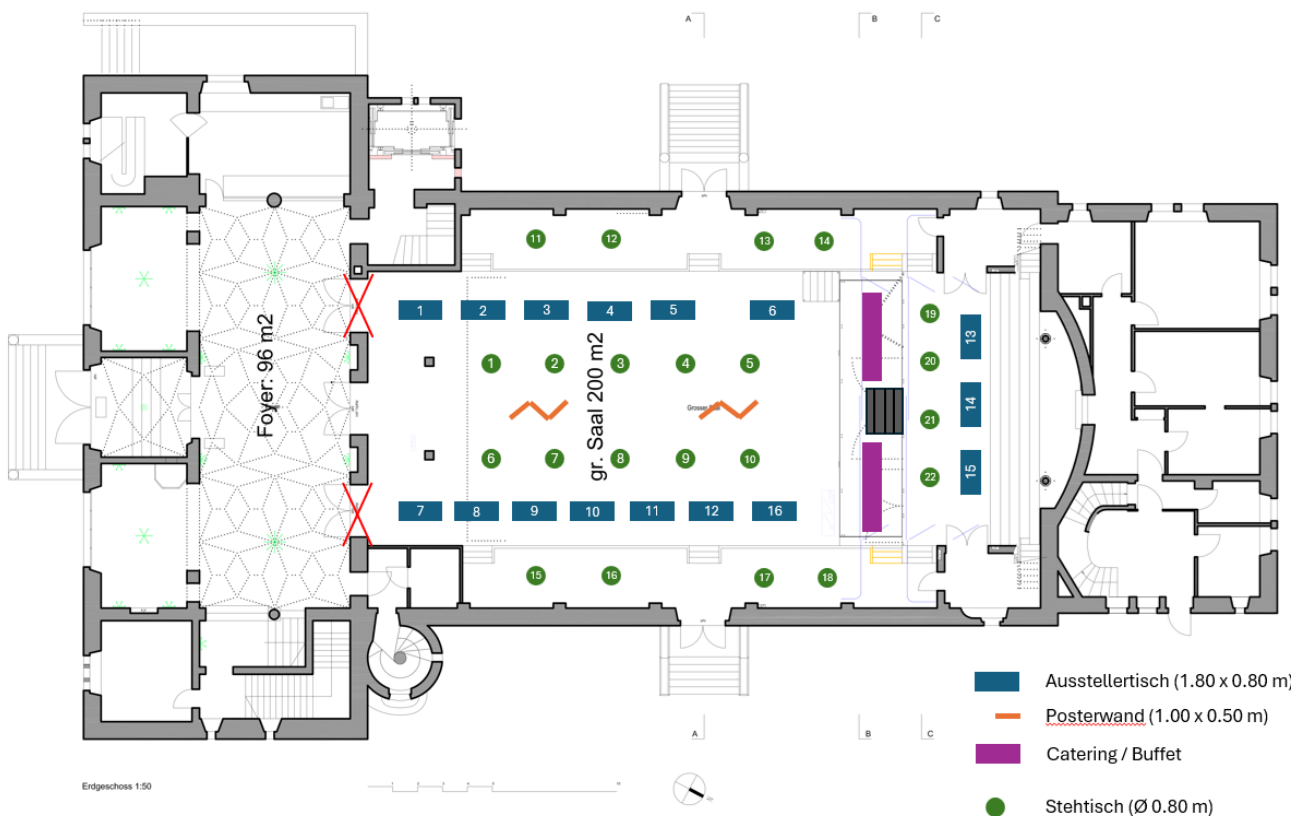
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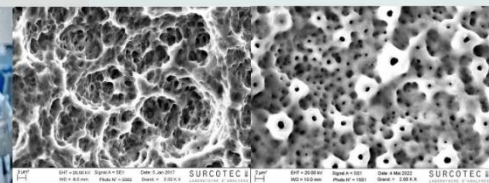


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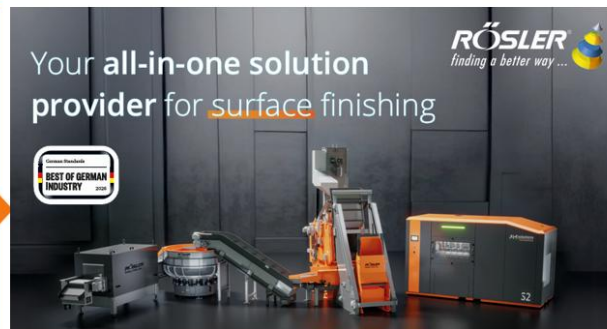


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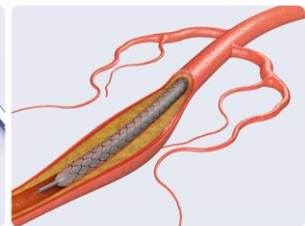
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Meeting Program Tuesday 15 September 2026

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09:00 **Welcome Message**

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09:35 Keynote: Adrien Rodrigues (Charmilles): *Digital five-axis Laser Blasting, an alternative to conventional blasting processes for orthopedic Implants* 10

09:55 Flash Presentations, Exhibitors, and Posters (1 min. each)

10:25 Break, Exhibition, and Posters

New Production Concepts

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11:20 Keynote: Michaela Maintz (Oral and Maxillofacial Surgery | 3D Print Lab – University Hospital Basel): *Point-of-Care Manufacturing of Patient-Specific Implants: From Biomechanical Design to Clinical Translation in Oral and Maxillofacial Surgery* 12

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14:10 Keynote: Pune Nina Paqué (Clinic of Reconstructive Dentistry, UZH): *Curcumin-mediated antimicrobial photodynamic toothpaste disrupts multispecies oral biofilms* 16

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14:40 Christopher Hartl (OFI - Austrian Research Institute for Chemistry and Technology): *Test strategies for the characterization of antimicrobial surfaces and materials: insight, overview and outlook* 18

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Materials and Surfaces

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17:05 Keynote: Arnaud Scherberich (Department of Biomedicine, University of Basel): *Translational and material aspects in the engineering of hypertrophic cartilage organoids for bone regeneration* 25

17:25 Roundup

From Industrial Scale to Patient-Specific Solutions: Insights from Dental Implantology

Raphael S. Wagner¹

¹*Straumann Group, Basel, CH*

INTRODUCTION: In dental implantology, production is increasingly characterized by two complementary models. Implants and standardized prosthetic components remain centrally manufactured, highly standardized medical devices requiring industrial scale, regulatory robustness, and consistent quality. In parallel, patient-specific prosthetic restorations, including crowns, bridges, and full-arch prostheses, are designed and manufactured through digitally connected workflows and integrated systems that seamlessly translate patient-specific data from planning and design into production at centralized facilities, local labs, or chairside. Dental care is further shaped by rising patient expectations, treatment efficiency, and the consolidation of dental professionals into larger practice networks. In a mature and cost-sensitive implant industry with substantial unmet clinical need, solution providers face a dual challenge: increasing scalability and cost efficiency while enabling more individualized, aesthetic, and close-to-the-patient solutions.

METHODS: The presentation provides an industry perspective based on trend, market, portfolio, and innovation sources, complemented by selected examples from CAD/CAM manufacturing, AI-enabled digital workflows, and emerging production methods for dental implant surface technology.

RESULTS: Three examples from ongoing innovation illustrate how digital technologies and new production methods enable scalable industrial manufacturing and patient-specific solutions. First, AI and analytics are becoming highly relevant not only in clinical planning, but also in industrial production, for example by structuring data around CNC programs, technical drawings, and three-dimensional part designs to support more efficient industrial production processes. Second, intraoral scanning, cloud platforms, AI-supported treatment planning, automated restorative design, and 3D printing are enabling integrated patient-specific workflows, including selected

chairside production solutions for temporary or potentially final prostheses. Third, ultra-short laser-based implant-surface structuring enables a transition from stochastic to more deterministic surface topographies designed with specific biological and mechanical intent.

DISCUSSION & CONCLUSIONS: The future of implant manufacturing will not be defined by one technology alone. Competitive advantage will come from connecting scalable industrial production with integrated digital, patient-specific workflows that create value for clinicians and patients. This requires manufacturing ecosystems in which centralized production, dental laboratory workflows and chairside solutions coexist, supported by data continuity, automation, robust quality systems and clinically relevant designs.

ACKNOWLEDGEMENTS: The author acknowledges colleagues from Straumann Group for discussions and insights that informed the industry perspective presented.

Digital five-axis Laser Blasting, an alternative to conventional blasting processes for orthopedic Implants

ADRIEN RODRIGUES¹

¹*Charmilles, part of United Machining Solutions group, Meyrin, CH*

INTRODUCTION:

Surface blasting is an important step in making orthopedic implants because it helps the implant bond well with bone over time. Traditional methods use abrasive blasting and involve many manual steps like masking, cleaning, and inspection. These processes are time-consuming, depend heavily on the operator, are hard to standardize, and lack good digital tracking.

This study introduces a fully digital five-axis laser process as an alternative. This new method can replace conventional blasting while simplifying the production workflow.

METHODS:

Instead of manually masking areas to protect them, the surfaces to be treated are defined directly in a digital machining program. This program is created offline and then automatically controls a five-axis machine, positioning and processing each implant with very high precision.

This digital approach removes many labor-intensive manual steps, reduces variability, and opens the possibility for fully automated implant production. Design changes can also be made quickly by updating the digital program and laser settings.

In addition to improving quality and consistency, this method allows more advanced designs, including complex or patient-specific surfaces, to be produced at controlled industrial costs. It represents a shift from manual processes to an automated, flexible, and data-driven manufacturing approach.

RESULTS:

The laser process successfully produced the required surface textures while eliminating several traditional steps such as masking, blasting, and multiple cleaning stages.



Fig. 1: Hip implant manufactured using a 5-axis laser machining strategy, integrating two distinct surface characteristics in a single operation without human intervention.

DISCUSSION & CONCLUSIONS:

Compared to conventional methods, this approach reduced the need for human intervention, improved consistency, and shortened production time. Even complex implant shapes could be processed automatically in a single step, delivering high precision, consistent quality, and excellent repeatability.

Towards in situ in vivo printing: robotic deposition on moving substrates using material extrusion

Loïc Mosser¹, Thibault Poignonec¹, Laurent Barbé¹, François Geiskopf¹, Pierre Renaud¹

¹University of Strasbourg, ICube laboratory, INSA Strasbourg INSERM, CNRS

INTRODUCTION: Additive manufacturing of viscous materials such as bioinks or silicones using multi-axis robotic deposition is an emerging technology in healthcare. It could enable the fabrication of patient-specific anatomical models and soft tissue structures directly on patients [1-2]. This work presents accordingly the foundations of a robotic printing platform designed for conformal deposition on non-planar and moving surfaces using paste-like materials for medical applications.

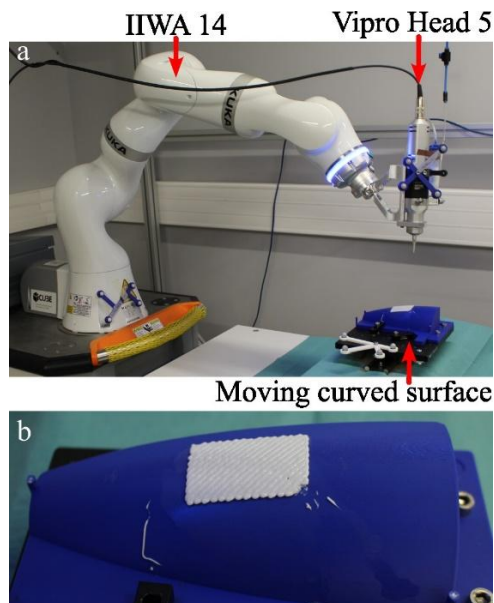


Fig. 1: Experimental setup for silicone extrusion onto a moving curved surface (top) and the resulting printed surface (bottom)

METHODS: The experimental setup (Fig. 1) is composed of an anthropomorphic robotic arm (IIWA 14, Kuka) with a material extrusion system (ViproHead 5, Viscotec) and a tracking system (Polaris Vega XT, NDI). The whole platform is based on ROS2 framework to interface these various systems and enable a precise synchronization of movements, scheduling, and material extrusion. The extrusion capability is assessed using one-component silicone sealant (A8 pro, Würth), that exhibits the characteristics of a high-viscosity threshold fluid.

ROS 2 enables motion planning via MoveIt, the planning framework of ROS2, and real-time control, ensuring accurate toolpath execution

and the possibility to compensate for physiological motions, essential for in situ in vivo printing. MoveIt's servoing tool is being used to enable online path planning for a moving path in space. The robot end-effector, where extrusion device is mounted, is tracked using the optical tracking system.

The platform is designed as a modular system whose components can be easily interchanged. It simplifies the integration of new hardware components. ROS2-based approach makes it portable and adaptable to different robotic manipulators and extrusion technologies.

RESULTS:

Our system for material extrusion enables the extrusion of silicone onto a curved surface. It is demonstrated that trajectory planning is respected to have the dispensing nozzle perpendicular to the surface along the whole trajectory with a printing speed of 5 mm/s. It was demonstrated that deposition is possible on a moving surface along one direction of a 30 mm motion moving at 10 mm/s. A tracking error (~2 mm) may occur due to the low refresh rate (20 Hz). A system with a higher rate would reduce this error.

DISCUSSION & CONCLUSIONS: This platform could support the direct fabrication on patients of customized dressings, skin substitutes, or other patient-specific structures. By combining robotic precision with adaptable biomaterials, it leverages additive manufacturing principles to advance personalized medicine and provides a scalable foundation for future medical and bioprinting applications.

ACKNOWLEDGEMENTS: This work has been partially supported by the French program Investissements d'avenir (ROBOTEX 2.0 ANR-10-EQPX-44-01, TIRREX ANR-21-ESRE-0015, RAMSAI ANR-22-CE10-0001)

REFERENCES:

- [1]: Li, Lan, et al. "Robotic in situ 3D bio-printing technology for repairing large segmental bone defects." *Journal of Advanced Research* 30 (2021): 75-84.
- [2]: Albrecht, Franziska B., et al. "Robot-based 6D bioprinting for soft tissue biomedical applications." *Engineering in life sciences* 24.7 (2024): e2300226.

Point-of-Care Manufacturing of Patient-Specific Implants: From Biomechanical Design to Clinical Translation in Oral and Maxillofacial Surgery

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²*Institut für Medizintechnik und Medizininformatik, Fachhochschule Nordwestschweiz, CH*

³*Dept. of Biomedical Engineering, University of Basel, CH*

INTRODUCTION: Conventional implants often require intraoperative bending and contouring, which can prolong surgery and may result in a compromise between anatomical fit and biomechanical stability. Patient-specific implants (PSIs) use medical imaging, digital planning, and additive manufacturing to match the patient's anatomy and the planned surgical procedure. This approach allows implant geometry, fixation, and mechanical performance to be considered before surgery. Figure 1 compares conventional implants with anatomically adapted and biomechanically optimized patient-specific designs.

METHODS: A fully digital workflow integrating virtual surgical planning, finite element analysis, topology optimization, hospital-based 3D printing, and robot-guided laser osteotomy was developed. Titanium, PEEK, and resorbable polymer implants were designed and biomechanically evaluated.

RESULTS: The workflow was applied to mandibular fracture fixation, bone augmentation, and fronto-orbital advancement. Topology-optimized implants improved biomechanical performance while reducing implant volume. Combining robot-guided laser osteotomy with point-of-care manufactured patient-specific implants achieved submillimeter surgical accuracy. Figure 2 demonstrates the digital fronto-orbital advancement workflow, from the intact skull and virtual surgical planning to the robot-guided transfer of the planned drilling and cutting pattern onto the skull, laser osteotomy, and stabilization with patient-specific implants.

DISCUSSION & CONCLUSIONS: Simulation-driven design, additive manufacturing, and robotic surgery enable a seamless digital workflow from virtual planning to patient-specific implantation, supporting the clinical translation of personalized cranio-

maxillofacial reconstruction. The additional time required for virtual surgical planning may be offset by shorter surgical times and improved accuracy, although these benefits were not quantified in the present work. Future studies should compare the workflow with conventional methods and quantify its clinical and economic benefits.

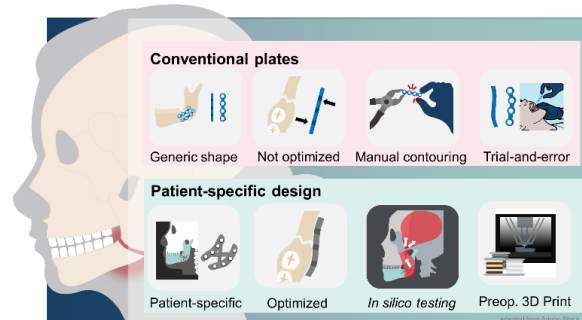


Fig. 1 : Conventional vs. patient-specific implant design (M. Maintz).

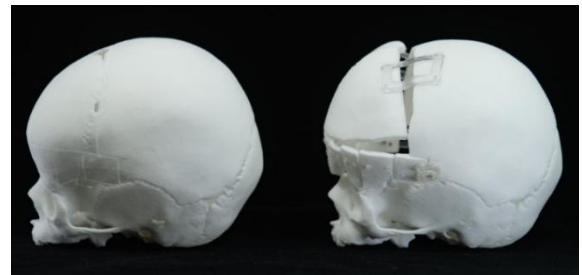


Fig. 2: Fronto-orbital advancement with patient-specific implants on 3D-printed model (M. Maintz).

ACKNOWLEDGEMENTS: The Authors thank the following funders: Werner Siemens Foundation, StiftungFHNW, and University Hospital Basel

REFERENCES: Maintz, M. V., Tourbier, C., et al. (2024). *3D Print. Med.*
Maintz, M. V., et al. (2024). *Int. J. Comput. Assist. Radiol. Surg.*

Access to Innovation: A Swiss Regulatory and Reimbursement Perspective

Nora Schweizer

J&J / Expert Group Market Access Swiss Medtech

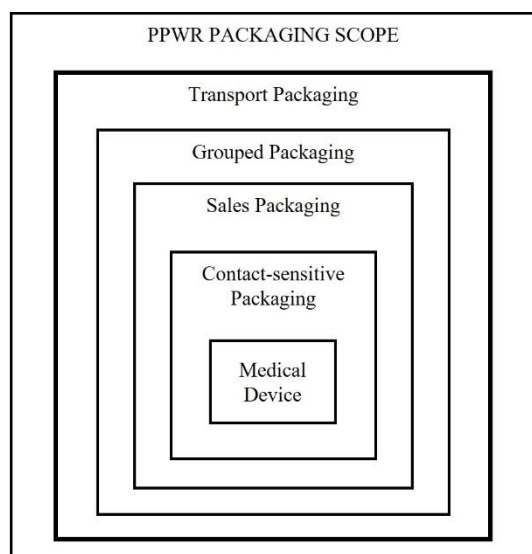
PPWR and Its Impact on Healthcare Industry

Tobias Bodenmüller¹

¹medmix, Haag, CH

INTRODUCTION: The EU Packaging and Packaging Waste Regulation (PPWR) introduces harmonized and directly applicable requirements for packaging placed on the EU market, including products supplied by non-EU companies. While healthcare applications are often considered to benefit from specific exemptions, the actual scope and implications require careful differentiation. This creates uncertainty regarding scope interpretation and practical implementation within the healthcare and medtech environment. Beyond regulatory compliance, PPWR may also act as a driver for packaging-related innovation.

METHODS: This contribution provides an overview of PPWR requirements relevant to healthcare applications, based on regulatory analysis and practical industry experience. It focuses on scope interpretation, the differentiation between medical devices and packaging, and the resulting implications for manufacturers, suppliers, and distributors. In addition, practical aspects such as role allocation, data requirements, and portfolio transparency are addressed.



Frequently assumed:
Medical device = packaging exemption

PPWR requires:
Assessment of each packaging level

Fig. 1: Perceived versus actual PPWR packaging scope in healthcare applications.

RESULTS: PPWR introduces a broad and evolving set of requirements that will impact packaging in healthcare to varying degrees, depending on application and classification. While certain contact-sensitive medical packaging may benefit from specific exemptions or transitional provisions, other packaging types remain within regulatory scope.

Independent of individual requirements, the regulation is expected to influence packaging design, material selection, and supply chain structures. At the same time, the healthcare sector is characterized by strict regulatory requirements and validated processes, making changes to packaging design and materials complex and resource-intensive. In addition, companies are increasingly required to address challenges related to data availability, system readiness, and the allocation of regulatory responsibilities across the value chain.

DISCUSSION & CONCLUSIONS: PPWR represents a fundamental shift for healthcare packaging, extending from regulatory compliance into operational implementation. Misinterpretation of scope and exemptions may lead to compliance risks, including potential restrictions in market access. As the first requirements become applicable in August 2026, PPWR is no longer a future topic but an immediate operational reality for industry. Early awareness, cross-functional alignment, and systematic portfolio assessment are essential to ensure readiness.

This presentation aims to provide a practical perspective on the relevance and implications of PPWR for healthcare and to outline initial steps toward implementation.

Antimicrobial PVD Coating for Medical Devices based on TiNAg

N. Manninen¹, C. Acikgoz¹, M. Drabik¹, B. Fischer¹

¹Oerlikon Surface Solutions AG, Balzers, LI

INTRODUCTION: Improvements in the cleaning and sterilization of surgical instruments and implants, together with enhanced perioperative procedures have led to a significant reduction in surgical site infections. Nonetheless any surgery provides a pathway for bacteria entering the human body and in specific procedures like colectomies or open fractures, the risk of infection is significant. Antimicrobial surface treatments can offer an attractive complementary strategy for infection prevention to actively avoid microbial colonization on surfaces of medical devices.

METHODS: Silver ions (Ag⁺) are known to show antimicrobial activity but incorporating silver into coatings, while enabling silver ions to be released, is a significant technical challenge. Physical Vapour Deposition (PVD) was used for creating surfaces that are releasing silver ions. The antimicrobial properties of the coating were evaluated according to ASTM E2180 with *P.aeruginosa* on uncoated Stainless-Steel coupons (X2CrNiMo17-12-2) and the same coupons were coated with TiN and TiNAg. The Certika Proliferation Test (following FDA requirements: >8 h net onset OD, 4 log step reduction) was performed with *S. epidermidis* (DSM18857; Initial inoculum: 5x10⁶ cell count/ml) and two different coatings (TiNAg & TiNAg with TiN top-layer). The samples were investigated as coated and after 50 autoclave cycles (steam sterilization at 121°C for 20 min).

RESULTS: While the stainless-steel coupons showed strong bacterial colonization of *P. aeruginosa*, coating the sample with TiN reduced the colonization and coating with TiNAg led to no visible colonization on the coupon surface.

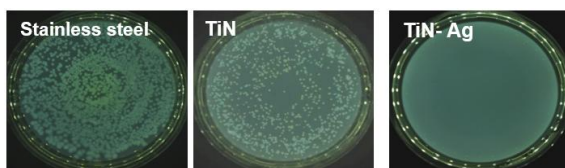


Fig. 1: *P.aeruginosa* colonization in ASTM E2180 with uncoated (left), TiN coated (middle) & TiNAg coated (right) coupon

In the Certika Proliferation Test all samples have passed the requirements for antimicrobial properties. The autoclaved samples have shown a reduced net onset time compared to their non-autoclaved counterparts and this reduction was less when the TiN top layer was applied.

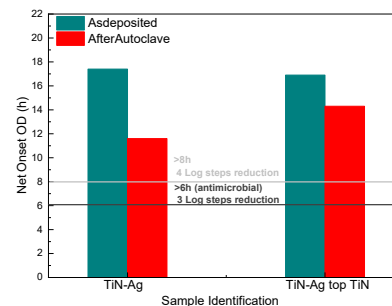


Fig. 2: Certika Proliferation Test as deposited and after 50 autoclave cycles with and without TiN top-layer

DISCUSSION & CONCLUSIONS: The results support the ability of the TiNAg coating, commercially available as BALIMED ARGENTA (Oerlikon Surface Solutions AG, 2025), to reduce bacterial growth on critical surfaces of medical devices. Embedding silver in TiN not only has the benefit of creating antimicrobial properties but comes with high surfaces hardness and wear resistance which is the reason TiN is already broadly used on medical devices today. Surface structuring methods can be a feasible alternative to releasing silver for antimicrobial properties but often target only a small subset of bacteria-types. The coating process avoids silver nanoparticles which are used in other coating methods and has passed biocompatibility tests after ISO 10993. All of this opens a big field of opportunities where such coating could be applied to reduce complications after surgery and reduce infection risks in general.

REFERENCES: Oerlikon Surface Solutions AG. (2025, November 20) *BALIMED ARGENTA: Antimicrobial TiN:Ag-Coating*. <https://www.oerlikon.com/balzers/global/en/portfolio/balzers-surface-solutions/pvd-and-pacvd-based-coating-solutions/balimed/balimed-argenta/>

Curcumin-mediated antimicrobial photodynamic toothpaste disrupts multispecies oral biofilms

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²*Division of Oral Microbiology and Immunology, Clinic of Conservative and Preventive Dentistry, Center for Dental Medicine, University of Zurich, CH,*

INTRODUCTION: Oral biofilms are the primary etiological factor of dental caries and periodontitis and remain difficult to control by mechanical cleaning alone [1]. Antimicrobial photodynamic therapy (aPDT) uses light activation of a photosensitizer to generate reactive oxygen species that disrupt microbial cells [2]. Curcumin is a natural photosensitizer with antimicrobial properties activated by blue light [3]. This study aimed to develop a curcumin-mediated antimicrobial photodynamic toothpaste and evaluate its efficacy against multispecies and saliva-derived oral biofilms.

METHODS: An optimized toothpaste formulation (TP) containing curcumin (TPA, 2 mg/mL) was evaluated against multispecies biofilms (*Streptococcus mutans*, *Streptococcus oralis*, *Actinomyces oris*, *Veillonella dispar*, *Fusobacterium nucleatum*, and *Candida albicans*) and saliva-derived biofilms established from pooled saliva of three healthy donors on hydroxyapatite discs. Multispecies biofilms received three treatments (17, 24, and 40 h), whereas saliva-derived biofilms were treated once after 24 h. Biofilms were exposed to the formulation for 1 min and irradiated with blue light (445 nm, 10 s). Biofilm viability was determined by CFU analysis. Biocompatibility was assessed using an MTT assay.

RESULTS: In the multispecies biofilm model, the irradiated curcumin-containing toothpaste (TPA+) produced approximately 3–4 log reductions in viable microorganisms compared with non-irradiated treatments and more than 5 log reductions compared with PBS controls (Figure 1A). The curcumin solution (SolA+) also reduced biofilm viability, although to a lesser extent than TPA+. No substantial reductions were observed for PBS or the toothpaste carrier without curcumin (TPO).

In saliva-derived biofilms, TPA+ resulted in approximately 3–4 log reductions in viable microorganisms compared with PBS controls

and approximately 2.7 log reductions compared with non-irradiated TPA-treated biofilms (Figure 1B). Irradiation alone did not significantly affect microbial recovery. Overall, the curcumin formulations maintained high fibroblast cell viability (approx. 80–90%).

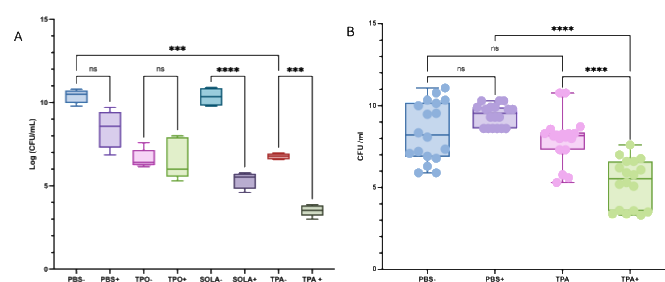


Fig. 1. Curcumin-mediated photodynamic toothpaste reduces multispecies (A) and saliva-derived (B) oral biofilms. Groups: PBS served as control, toothpaste carrier with (TPA) and without curcumin (TPO), curcumin solution (SolA) with (+) and without (-) light.

DISCUSSION & CONCLUSIONS:

Curcumin-mediated antimicrobial photodynamic toothpaste significantly reduced multispecies and saliva-derived oral biofilms while maintaining biocompatibility in human oral epithelial cells. These findings support its major potential as a preventive oral hygiene strategy.

ACKNOWLEDGEMENTS: Special thanks to P. Guazzo (Dentaltek AG) and Prof. C. Adlhart (ZHAW) for providing the optimized curcumin powder, and Medena AG for incorporating it into the toothpaste formulation.

REFERENCES:

1. WHO. *Global Oral Health Status Report*. 2022.
2. Cieplik F, et al. *Crit Rev Microbiol*. 2018;44:571–589.
3. Paschoal MA, et al. *Lasers Med Sci*. 2015;30:1177–1184.
4. Nikinmaa S, et al. *PLoS ONE*. 2020;15.

Aerosolized Bacteria Model of Operating Room Contamination of Orthopaedic Implants

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INTRODUCTION: One source of microbial contamination of tissue-contacting biomedical devices is the surgical operating room (OR), where viable bacteria in the atmosphere can sediment onto a device surface intraoperatively [1]. Increased infection control has reduced sedimentation rates to $\sim 10^3$ – 10^4 CFU/m²·h. But a strong clinical consensus remains that OR contamination is linked to device infection. That said, there is no clear method to evaluate device-modification technologies meant to mitigate the effects of such contamination [2]. We have been developing an aerosolizing system able to spray small quantities of bacteria onto a surface in a manner that mimics OR contamination [3,4]. This system applies short bursts of pressurized gas to aerosolize bacteria-containing liquids and contaminate surfaces with areal densities of bacteria on the order of 10^2 CFU/cm².

METHODS: 15mL of an *S. aureus* (ATCC 25923) overnight suspension was diluted to 10^2 , 10^3 , and 10^4 CFU/mL using spectrophotometry at 600nm. Titanium sputter-coated PEEK 8-hole RatFix plates were positioned on tryptic soy agar plates, inoculated with a 100 ms aerosol burst of bacterial suspension, and then dried at room temperature for 30 minutes. Male Sprague-Dawley rats were anesthetized, and the lateral femur was accessed via a craniolateral incision. The contaminated plates were secured to the lateral aspect of the femur with four 0.7mm titanium screws. The surgical site was closed in layers. The animals were treated perioperatively with meloxicam (2mg/kg) and buprenorphine (0.06mg/kg) subcutaneously. Seven days after inoculation, the rats were euthanized, and the soft-tissue envelope and implants were collected aseptically for microbial quantification using Petrifilms for colony counts. **RESULTS:** The rats appeared grossly infected, with swelling, pockets of purulent material, and dehiscence at the higher inoculum concentrations. The recovered CFU/mL from the femoral plates was not statistically different between inoculum concentrations (Fig.1). The trends suggest increased variability in the response to the lower

inoculum concentrations, with 10^4 CFU/mL yielding more reliable and expected recovery.

DISCUSSION & CONCLUSIONS: The described model produces microbial contamination equivalent to operating room conditions and allows adjustment to achieve specific contamination levels required to cause infection. This is key for using this apparatus in

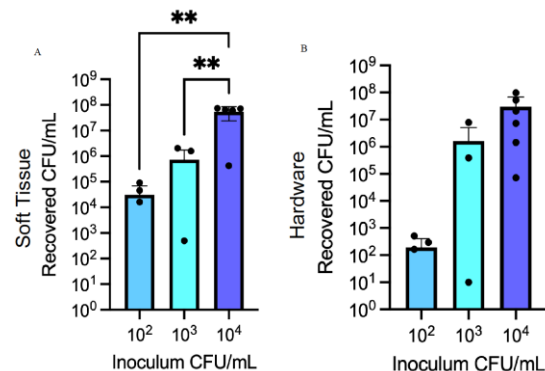


Fig. 1. Colony counts recovered from A) the soft tissue envelope and B) implanted hardware collected 8 days post-implantation. Plates were contaminated via a spray apparatus using inoculum at three spray concentrations. Significantly more contamination was recovered from the soft tissue when inoculated with 10^3 and 10^4 CFU/spray compared to 10^2 CFU/spray. A similar trend was observed in the hardware, but significance was not reached.

future studies testing antimicrobial implant materials in animal models where the goal is to create a consistent and reproducible infection model to test anti-infective strategies of implants while avoiding sepsis, a condition these materials are not designed to combat. *In vitro* results show that the apparatus reproducibly creates a variety of specified contamination levels, providing a reliable model of operating room contamination. *In vivo* testing also indicates that the spray apparatus may be used at the specified spray concentrations to create a reliable rat infection model that then can be scaled to larger animal models of device infection.

ACKNOWLEDGEMENTS: NSF: 2219014; NIH: AR076941, AR082038, GM146268.

REFERENCES: 1. Gehrke et al., The Journal of Arthroplasty, 2019. 2. Stavakis et al., Sci. World J. 2013. 3. Zhao et al., Adv. Mat. Interfaces. 2022. 4. Zhao et al., J Biomed Mater Res. 2022

Test strategies for the characterization of antimicrobial surfaces and materials: insight, overview and outlook

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INTRODUCTION: Healthcare facilities face growing hygiene challenges from nosocomial infections, antibiotic resistance, and outbreaks. Innovative antimicrobial materials and coatings can complement conventional disinfection. Using a case study, this presentation highlights the complexity of evaluating such surface treatments, including antimicrobial efficacy, durability under real-life conditions as well as regulatory, material-related, and bio-compatibility challenges in developing smart antimicrobial surfaces.

METHODS: The antimicrobial properties of the product were evaluated following the standard series ISO 22196 and ISO 21702 for antibacterial and antiviral activity respective. The samples were tested for 24 h contact time with *E. coli* and *S. aureus* (for antibacterial activity) and for 2 h as well as 24 h for MS2 and phi6 bacteriophages (for antiviral activity).

The effect of antimicrobial agents on the safety of the product was evaluated following the standard series ISO 10993 for biocompatibility. Hence, the chemical properties of the antimicrobial agents were assessed. Furthermore, for skin contacting devices, cytotoxicity, skin irritation and skin sensitization need to be addressed. Within this study, the effect on sensitization was observed using an in-vitro test according to OECD 442D.

RESULTS: The product demonstrated very high efficacy against *E. coli*, *S. aureus* and phi6; in contrast, hardly any significant effect was measured against MS2 (Table 1). For phi6, the effect was observed even with a reduced contact time of 2 hours.

Table 1. Measured antimicrobial reduction R on the sample surface after 2 h / 24 h contact.

Test strain	Contact time [h]	R [log]	R [%]
<i>E. coli</i>	24	6.6	99.99997
<i>S. aureus</i>	24	6.1	99.99993
phi6	2	4.4	99.996
phi6	24	5.0	99.998
MS2	2	0.0	0.0
MS2	24	0.5	65.7

Three elements were detected in the antimicrobial agent. These elements were As, Ba, Cu (Table2). When estimating the use of 1 mL of the antimicrobial agent within the sample, the concentration of these elements detected is far lower than the permitted daily intake. All Margins of Safety (MOS = permitted daily intake / expected exposure) were higher than 1.

Table 2. Detected elements in the antimicrobial agent.

Element	Conc. within anti-microbial agent [µg/L]	PDE* (oral) [µg/day]	MOS** when applying 1mL within sample
As	118.2	15	126
Ba	10.02	1400	139 000
Cu	137.8	3000	21 000

* PDE (Permitted daily intake), derived from ICH Q3D

** MOS (margin of safety)

Furthermore, to investigate the safety related to sensitizing reactions, an in-vitro test was performed. This test showed, that the Nrf2-pathway (a marker for sensitizing reactions) was not activated compared to the controls. Hence, a risk for sensitizing reactions was considered to be low.

DISCUSSION & CONCLUSIONS: The product with its incorporated antimicrobial agent displayed clear antimicrobial activity for various test strains, while potentially adverse effects to users were considered to be at a low risk.

The case study demonstrates the importance of a holistic test battery design, in order to address not only the actual functionality of modified materials but also to ensure safe use beyond its intended purpose.

REFERENCES:

International Organization for Standardization. (2011, 2018, 2019). *ISO 22196:2011, ISO 10993-1:2018, ISO 21702:2019*. ISO.
Organisation for Economic Co-operation and Development (2018). *OECD Guideline for the Testing of Chemicals, Test No. 442D*. OECD.

A look into the surgeon's toolbox: antibacterial coatings

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INTRODUCTION: There is a broad consensus among orthopaedic and trauma surgeons, as well as infection specialists, that antibacterial coatings represent an important tool for both the prevention and management of fracture-related infections. Nonetheless, the choice of commercially available implants fitted with an antibacterial coating remains limited. Intramedullary nails with resorbable, antibiotic eluting coatings have been commercially available for over a decade. Although multiple case series have shown evidence of efficacy of antimicrobial orthopaedic implants, randomized controlled trials are still lacking and their uptake in everyday clinical practice has been slow. More recently, nails with galvanic noble metal coatings were introduced, with encouraging clinical results. The most widely used coatings with the longest clinical track record are silver coated joint replacement endoprostheses, which have been successfully employed in revision surgeries and in patients undergoing tumor-related procedures. Silver coated plates are on the verge of market introduction and will represent the first of their kind to be broadly available. Overall, adherent antibacterial coatings are showing beneficial outcomes in terms of safety and efficacy. Health-technology assessments show cost effectiveness, demonstrating that in higher risk patient populations, the additional cost of using a coated implant is significantly less than the cost of treating an infection. Regulatory hurdles remain high, especially in the USA, where, to be best of our knowledge, coated implants have not been approved yet. Driven by the clear clinical need, we anticipate a dynamic near future in this field, with progress moving toward establishing coated implants as the standard of care for appropriate patient populations and expanding the range of available coating solutions. Such developments will ultimately benefit patients, surgeons, and the overall healthcare system.

METHODS: Commercially available implants with an antibacterial coating were identified through internet search and a literature review. The authors acknowledge that the list of

commercially available coated implants may not be complete.

RESULTS: Despite positive results documented in literature, clinical adoption of antibacterial coated implants and of other local delivery technologies remains cautious. It is noteworthy, that only few antibacterial coatings have reached commercial maturity, despite long and widespread research ongoing in the field. None of the coating technologies listed below is commercially available in the USA.

Table 1: Overview of commercially available adherent antibacterial coatings.

Manufacturer	Product / Technology
DePuy	ETN PROtect – Resorbable
Synthes	Gentamicin coating
Zimmer	Zimmer Natural Nail
Biomet	Bactiguard galvanic noble metal coating
Zimmer	THR Prosthesis with plasma
Biomet	electrolytic iodine coating – Japan only
Synicem	IM Nails, PMMA – Gentamicin coating
aap Implants	Loqteq plates, plasma electrolytic Ag coating
Implantcast	MUTARS endoprosthesis, galvanic Ag coating
Kyocera Medical	On-demand implants thermal spray HA-Iodine coating – Japan only
Aesculap AG	Revision implants with Biogate HyProtect Ag coating, clinical development

DISCUSSION & CONCLUSIONS: Long development cycles and hurdles to regulatory approval still limit the availability of antibacterial coated implants. Initial clinical data points towards a positive risk and cost – benefit ratio, with overall reduced infection rates in patients treated with coated implants. With more positive efficacy data becoming available, adoption will increase and market pull is expected to lead to increased efforts by manufacturers to make more technologies available to surgeons.

Materials-Based Antimicrobial Solutions and Testing

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INTRODUCTION: Biomaterial-associated infections remain a major clinical challenge due to biofilm formation and increasing antimicrobial resistance. While numerous antimicrobial materials have been developed, many fail to translate clinically because their performance is primarily evaluated under simplified laboratory conditions. This presentation highlights recent advances in antimicrobial biomaterials and discusses strategies for clinically relevant evaluation.

METHODS: Representative antimicrobial platforms, including living materials, surface-functionalized coatings, and responsive drug delivery systems, will be presented. Advanced testing approaches incorporating biofilms, dynamic flow, and physiologically relevant infection models will be discussed to better mimic the biomaterials microenvironment.

RESULTS: Material stiffness and environmental conditions significantly influence bacterial behavior and biofilm formation[1, 2], often exceeding the effects observed under standard laboratory assays. The droplet biofilm model enables more reproducible high-throughput evaluation compared to the conventional microplates and Calgary Biofilm Assay[3], while the ex vivo skin model captures clinically relevant host–biofilm interactions that cannot be reproduced in conventional culture systems[4].

DISCUSSION & CONCLUSIONS: Successful translation of antimicrobial biomaterials requires evaluation under clinically relevant conditions that integrate host–material–microbe interactions. Combining materials science, microbiology, and advanced infection models will facilitate the development of next-generation antimicrobial solutions with improved clinical performance and help address the growing challenge of antimicrobial resistance.

ACKNOWLEDGEMENTS: These works were financially supported by the Swiss National

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REFERENCES:

1. Valentin, J.D.P., et al., *Substrate viscosity plays an important role in bacterial adhesion under fluid flow*. Journal of Colloid and Interface Science, 2019. **552**: p. 247–257.
2. Straub, H., et al., *A microfluidic platform for in situ investigation of biofilm formation and its treatment under controlled conditions*. Journal of Nanobiotechnology, 2020. **18**(1).
3. Zhang, S., et al., *A simple, reproducible, and rapid droplet culture method for the formation and characterization of microbial biofilms*. <https://doi.org/10.5281/zenodo.16952295>, 2026.
4. Tao, S.Y., et al., *Bio-Responsive Hydrogel for Targeted on-Demand Release of a Phage Cocktail for Treatment of Infection*. Advanced Functional Materials, 2026. **36**(2).

Biodegradable Magnesium Implants: Current Developments and Future Challenges

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INTRODUCTION: Magnesium-based implants combine load-bearing mechanical properties with complete absorption by the body: they provide temporary stability during healing, progressively degrade, cause minimal CT and MRI artefacts and eliminate secondary removal surgeries. First used surgically over a century ago but long abandoned because of uncontrolled degradation rates [1], magnesium (Mg) has now returned to the clinic, with over 800 publications on Mg-based bioabsorbable metals in the last five years (of which around 260 present preclinical in vivo data and around 30 present clinical data), 25 clinical device studies on clinicaltrials.gov, and a growing family of CE-marked and FDA-cleared devices over the past decade. This keynote reviews how the field has progressed to this point and which challenges remain.

METHODS: The state of the field is reviewed along the translational chain from materials science to clinical application. Key strategies are compared: impurity control and ultra-high-purity (UHP) processing, lean alloy design (e.g. Mg–Zn–Ca) as well as rare-earth-containing alloys (e.g. WE43), surface modification, and stepwise accumulation of safety and efficacy evidence – in vitro degradation and mechanical testing, small- and large-animal studies, cadaveric testing and the non-clinical programme required for regulatory approval.

RESULTS: Microgalvanic corrosion, driven by cathodic intermetallic phases and trace impurities, dominates degradation behaviour: The solubility of Fe in Mg is below 5 ppm; above this limit, Fe-rich particles precipitate and drive severe degradation, whereas UHP alloys with about 1 ppm Fe show strongly reduced degradation and hydrogen evolution [2]. Cathodic intermetallic phases likewise accelerate degradation [3]. Surface modifications, such as plasma electrolytic oxidation (PEO), further improve degradation kinetics and early osseointegration. Pooled large-animal and clinical data show near-linear implant resorption over roughly 130–150 weeks, which primarily depends on alloy purity and composition, and only weakly on implant

geometry, species or anatomical location (Fig. 1). Clinically, Mg devices have progressed from the first CE-marked compression screws (2013) and coronary scaffolds (2016) to FDA-cleared fracture screws (2023) [4]. Membranes, plates and pins have arrived in clinics as well; ongoing developments are extending the technology to further indications in trauma and sports medicine.

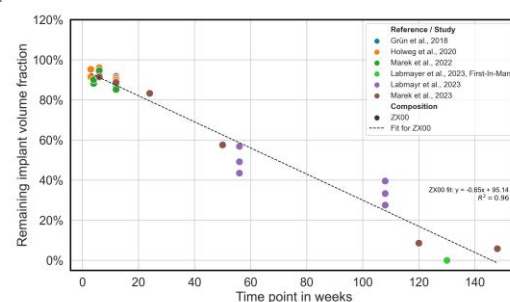


Fig. 1: In vivo degradation of Mg–Zn–Ca implants: pooled published large-animal and clinical data show near-linear resorption.

DISCUSSION & CONCLUSIONS: A century after the first surgical attempts, absorbable magnesium implants have become a clinical reality. The remaining challenges lie less in the material than in translation: establishing predictive in vitro–in vivo degradation correlations, harmonised test standards and regulatory expectations for absorbable metals, GMP-scale manufacturing and market access. Through impurity control, lean alloy design and accumulation of systematic evidence, Mg implants are positioned to mature and become a standard practice of care, providing temporary stability before resorbing and leaving only healed, pristine tissue behind.

ACKNOWLEDGEMENTS: The author would like to thank all academic, clinical and industrial collaborators.

REFERENCES: [1] F. Witte, *Acta Biomater.* 6 (2010) 1680. [2] J. Hofstetter et al., *Acta Biomater.* 23 (2015) 347. [3] A. Atrous et al., *Mater. Sci. Eng. B* 176 (2011) 1609. [4] P. Holweg et al., *Bone Joint Res.* 9 (2020) 477.

Trace iron in body fluids: a hidden driver of magnesium implant degradation

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INTRODUCTION: Bioresorbable magnesium-based implants hold great promise for temporary orthopaedic applications, yet their unpredictable in vivo degradation remains a central obstacle to clinical adoption. Current development strategies focus predominantly on alloy purity, driven by the well-established principle that iron impurities within the bulk Mg matrix act as potent corrosion accelerators via microgalvanic coupling [1,2]. This material-centric approach overlooks a critical question: can trace iron naturally present in body fluids deposit onto high-purity magnesium surfaces and drive corrosion independently of bulk material purity?

METHODS: To decouple bulk impurity effects from solution-derived iron deposition, we combined hydrogen evolution measurements, liquid- and Laser ablation (LA) based solid-phase trace elemental analysis (ICP-MS and LA-ICP-MS), electrochemical quartz crystal microbalance (eQCM), and X-ray photoelectron spectroscopy (XPS). High-purity Mg (with bulk Fe contents < 10 ppm) well below established impurity threshold (< 180 ppm [2]) was immersed in physiologically inspired solutions designed to maintain biologically relevant iron concentration (mM range) present in the form of citrate complex. This combination of techniques allowed separating simultaneous chemical and electrochemical interfacial processes that remain unresolvable by conventional electrochemical measurements alone.

RESULTS: Iron speciation was found to critically determine the fate of solution-derived Fe at the Mg interface. Under physiologically relevant conditions, iron citrate-complex species were electrochemically reduced and electrodeposited at the corroding Mg interface, forming localized cathodic sites that were absent under iron-free conditions. This process markedly increased the Mg dissolution kinetics (confirmed by a factor 2.5 increase of hydrogen evolution), as shown in Fig. 1 and resulted in strongly heterogeneous corrosion morphology, even for high-purity Mg with bulk Fe contents well below established impurity thresholds. No detectable Mg was present initially (at t = 0 h).

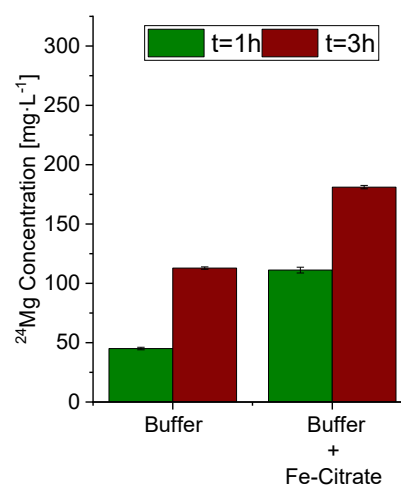


Fig. 1: Time-dependent evolution of dissolved ²⁴Mg concentrations in the liquid phase, measured by ICP-MS, following the immersion of HP-Mg in Buffer or Buffer + Fe-containing solution. Mg concentration at 3 h is significantly higher in Fe-citrate solution than in Buffer alone (two-sample t-test, n = 3, p < 0.001).

DISCUSSION & CONCLUSIONS: These findings identify the coordination chemistry of the peri-implant environment as a previously unrecognised modulator of Mg bioresorbability. The results demonstrate that degradation of high-purity Mg is not solely governed by bulk alloy composition but is also strongly influenced by the speciation of trace metals in surrounding body fluids. This highlights the need for in vitro testing protocols that more accurately replicate complex body-fluid composition, and for implant design strategies that consider solution-derived metal deposition as a possible driver of Mg degradation.

ACKNOWLEDGEMENTS: This work was financially supported by the MAGnostic project, funded by the Swiss National Science Foundation (SNSF, Grant No. 310030E_205609).

REFERENCES: [1] McCafferty E. Introduction to corrosion science. Springer, New York, USA; 2010.

[2] Liu M, et al. Corros Sci. 2009;51:602–619. doi:10.1016/j.corsci.2008.12.015.

Micrometer-Scale Surface Heterogeneity Shapes Biocorrosion of CoCrMo Implant Alloys

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INTRODUCTION: Despite decades of clinical use, CoCrMo implant alloys are still predominantly evaluated using macroscopic approaches for biocorrosion assessment, which provide limited insight into the influence of local material heterogeneity on surface reactivity. In this work, clinically relevant high-carbon CoCrMo alloys are revisited to unravel how microstructural and surface oxide heterogeneity jointly govern the electrochemical activity at the material–bioliquid interface.

METHODS: A correlative multimodal and site-specific characterization approach was used to link local electrochemical activity with the bulk microstructure and passive film chemistry. High-carbon CoCrMo (HC-CCM) implant alloy specimens were investigated as model surfaces, with a carbon content of 0.22 wt% in line with ISO 5832-12. AFM-based Kelvin probe force microscopy (KPFM) was combined with scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS) on identical regions of interest to associate local surface potential variations with the underlying microstructure, carbide distribution, and phase boundaries. Complementary Auger electron spectroscopy was used to probe local surface oxide chemistry and its evolution upon immersion in bioliquid-relevant environments, including physiological and crevice-like conditions relevant to modular implants.

RESULTS: Pronounced micrometer-scale surface heterogeneity was found in HC-CCM. Correlative KPFM/SEM-EDS revealed two carbide populations with distinct electrochemical signatures: larger Cr-rich (~2–4 µm) and smaller Mo-rich (<1 µm) carbides, with cathodic surface potential offsets of ~60 and ~30 mV relative to the metallic matrix, respectively (Fig. 1). These localized potential differences define a non-uniform electrochemical landscape across the implant surface. Spatially resolved Auger analysis of the passive oxide, which defines the immediate solid–liquid interface, revealed that carbide-associated regions exhibited a systematically different

passive oxide composition from the surrounding matrix, and that this site-dependent oxide chemistry evolved upon immersion, highlighting the dynamic nature of the passive film under bioliquid-relevant conditions. Carbide–matrix interfaces were further identified as preferential sites for phase-boundary activation and local oxide breakdown during crevice-relevant acidic exposure. Crucially, these localized reactivity patterns were not detected by conventional macroscopic electrochemical protocols, consistent with the small area fraction of carbide-associated domains.

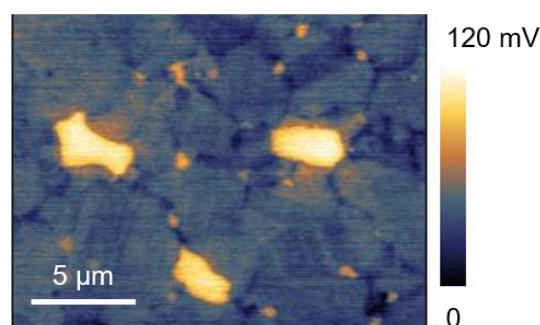


Fig. 1: Micrometer-scale surface-potential heterogeneity of HC-CCM mapped by KPFM.

DISCUSSION & CONCLUSIONS: The findings show long-term performance of HC-CCM implants is governed by localized micrometer-scale processes that remain hidden in conventional macroscopic assessments. The passive oxide should therefore not be treated as a uniform protective layer, but rather as a chemically heterogeneous and dynamically evolving interface that links metallic microstructure to electrochemical behavior at the solid–bioliquid interface. These results call for a reconsideration of how multi-phase implant materials are evaluated, emphasizing spatially resolved analysis of surface reactivity and composition as necessary complements to macroscopic material assessment for clinically relevant performance prediction.

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Bioinspired Hydration Coatings to Reduce Friction and Wear in Hip Resurfacing Arthroplasty

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INTRODUCTION: Compared with total hip replacement, surface replacement arthroplasty preserves bone, reduces dislocation risk and better restores gait [1,2]. However, its large ceramic articulating surface is prone to lubricant film breakdown, causing particle-induced inflammation and potential implant failure.

To improve the tribological performance, highly hydrated polyelectrolyte multilayer (PEM) coatings based on poly-L-lysine, polyglutamic acid and hyaluronic acid (HA) were developed and covalently bound to the ceramic implant.

METHODS: Hydration was characterized by polarization-modulated infrared reflection-absorption spectroscopy (PM-IRRAS). Coating integrity and the coefficients of friction (CoF) were assessed by rotating pin-on-disc analysis (NTR3, Anton Paar; 4 mm track; 2 mm sapphire ball; lubricant: artificial synovia) in two consecutive steps on identical tracks: (1) increasing normal load from 1 to 11 mN in 1 mN increments at 20 mm/s for 20 cycles per condition; and (2) decreasing velocity from 40 to 0.625 mm/s at 10 mN, with 100 to 5 cycles to maintain a constant sampling time per condition and generate a Stribeck curve. After testing, coating integrity and possible defects were examined by white-light interferometry (WLI), scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS).

RESULTS: The PM-IRRAS analyses confirmed very strong hydration of the PEM layers (see Fig. 1A). The substitution of PGA by HA in five double layers has a positive effect on hydration. Further analyses of the binding state of surface-associated water showed that the excellent friction properties (see Fig. 1B) of the PEM are attributable to increased surface associated water, discussed as “non-freezing-water” and “bound-freezing-water” within the PEM layers. Analysis of the coatings following the PoD measurements revealed no delamination and confirmed the stability of the layers even under physiologically relevant load conditions (see Figs. 1C and D).

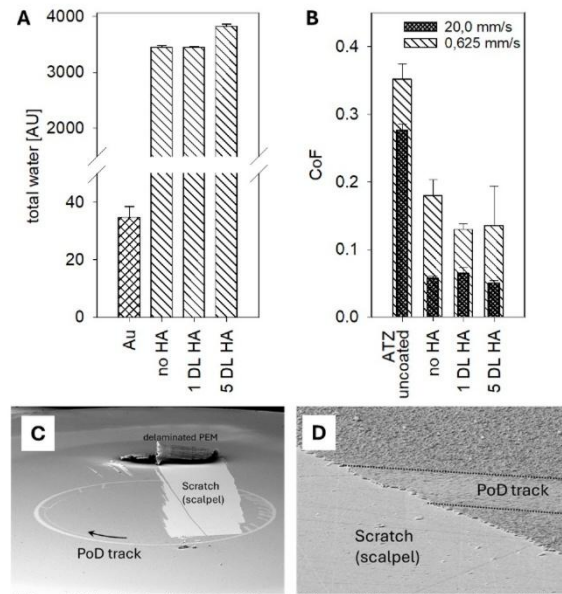


Fig. 1: A) PM-IRRAS analysis of PEM layer hydration; B) coefficient of friction measured by PoD; C, D) SEM images confirming coating integrity after PoD testing. The scalpel scratch was applied after PoD testing and confirmed that the PEM layer was compressed but not damaged.

DISCUSSION & CONCLUSIONS: The results demonstrated covalent immobilization of the PEM without delamination under shear loading in PoD. All coatings reduced the coefficient of friction down to 0.05. HA-containing PEM architectures showed performance even under “quasi-static” conditions (at low PoD speeds of 0.625 mm/s), where lubricant film breakdown is most critical. These findings identify PEM-based coatings as a promising strategy using the biological principle of interface hydration to improve the durability and reliability of hip surface replacements.

ACKNOWLEDGEMENTS: The authors acknowledge funding from the Federal Ministry of Research, Technology and Space (BMFTR) grant no. 13XP5209C.

REFERENCES: [1] Hutt JRB, Lavigne M, Vendittoli PA (2014) *Total Hip Arthroplasty versus Hip Resurfacing* Orthop Muscul Syst 3: 173. 10.4172/2161-0533.1000173 [2] Gerhardt DMJM, Ter Mors TG, Hannink G, van Susante JLC. (2019). *Resurfacing hip arthroplasty better preserves a normal gait (...)*. Acta Orthopaedica, 90(3), 231–236. 10.1080/17453674.2019.1594096

Translational and material aspects in the engineering of hypertrophic cartilage organoids for bone regeneration

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INTRODUCTION: Bone tissue is the second most transplanted tissue after blood transfusion with over two million procedures performed annually worldwide. Autologous bone graft—bone harvested from the patient own’s body—remains the gold standard for the treatment of critical size bone defects, tumour resection and congenital bone deformities. However, the severe donor site morbidity and limited tissue availability associated with autologous bone grafting has prompted for development of tissue engineering (TE) approaches to generate clinical alternatives. While most of the bone TE strategies are based on an intramembranous ossification (IMO) pathway, a change in paradigm was recently proposed with new “developmental engineering” approaches focusing on recapitulating endochondral ossification (ECO).

METHODS: During ECO—the major ossification pathway for the development and repair of long bones and bones of the hand and feet—mesenchymal stromal cells (MSCs) first condense and form an intermediate avascular cartilage tissue which upon vascularization remodels into a bone organ. Several research groups, including my own, have sought and succeeded in generating cartilage or hypertrophic cartilage tissues—now termed cartilage organoids—from various cell sources in vitro that faithfully recapitulated ECO in vivo. Our group has shown that, despite their non-skeletal origin, human adipose derived stromal cells (ASCs) were capable of generating bone organs when adequately primed in vitro. However, despite an intense research focus on bone and cartilage organoids in the last 15 years, these organoids have not yet been used in the clinic to treat bone defects mainly due to the rather limited size of their resulting bone organs.

RESULTS: This lecture will summarize our 10 years of results in the development of bone organs, from studying the biology for ensuring reproducible chondrogenesis by ASCs, to the development of bio-fabrication techniques to generate upscaled and customized grafts,

especially paediatric phalangeal ones (figure 1), the GMP-fication of the processes and the development of specific, albumin-based protein biomaterials to support their translation to the patients, first in the form of a clinical trial.

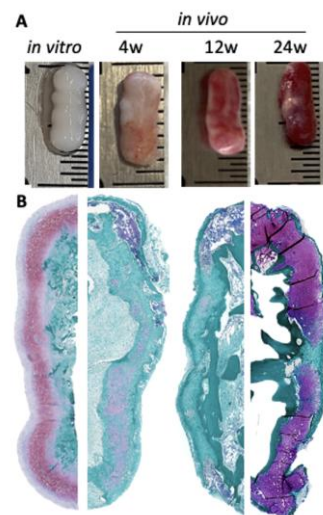


Fig. 1: A: In vitro generation of a hypertrophic cartilage in the shape and size of a paediatric phalanx. B: Upon ectopic in vivo implantation, gradual remodelling into a fully mature bone organ after 4, 12 and 24 weeks.

DISCUSSION & CONCLUSIONS: The accumulated preclinical and manufacturing data support progression toward a first-in-human study and will be used to treat children suffering from symbrachydactyly as a first in human study.

ACKNOWLEDGEMENTS: This work was supported by the Propatient Forschungsförderung Universitätsspital Basel (pp 23-06, “Fingerknochen” and the “Fondation Louis de Lassence”, the Innovation Focus “Regenerative Surgery” program at the University Hospital Basel and by the program INTERREG Upper Rhine from the Region Grand Est, Land Baden-Württemberg, Land Rheinland-Pfalz, Cantons Baselstadt, Basellandschaft, Swiss Confederation and the ERDF (ALBUCOL project). We also thank the Flow Cytometry, Microscopy and Histology Core Facilities of the Department of Biomedicine (University of Basel), for assistance and support.

Poster Session

Batch variability of albumin-based scaffolds for cartilage tissue engineering

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Micro- and Nanomechanics of BSA-Loaded PLGA Microspheres

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Laser-Induced Oxide Heterogeneity on Titanium: Implications for Implant Surface Function

- 3 Y. Streit¹, U. Taylan², M. Urbanczyk³, C. Cancellieri¹, M. Rottmar³, K. Maniura³, P. Hoffmann², P. Schmutz¹, M. Cihova¹
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A Computational Framework for Parameter-Specific Design Evaluation of Ultrasonically Assisted Subcortical Fixation Implants

- 4 I. Ilic^{1,2}, J. Mayer¹, A. Kumar², L. Rhem², M. Bambach², M. Afrasiabi²
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Medical Device Integrated Hybrid Manufacturing

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Interesting applications of pin-on-disc in biotribology

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Antimicrobial Cationic Surfaces for 3D-Printed Immediate Denture Base Resins

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Needle-like Hydroxyapatite Particles as Immunological Modulator for Enhanced Osteoinduction

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Two fix-and-replace techniques for acetabular T-type fractures: primary stability under cyclic loading, measured optically

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Batch variability of albumin-based scaffolds for cartilage tissue engineering

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INTRODUCTION: Porous scaffolds intended for biological and tissue-engineering applications must combine reproducible manufacturing, long-term structural stability, and a 3D-morphology that supports cellular infiltration. In particular, pore size distribution, interconnectivity and accessibility at cell-relevant length scales are critical parameters. This study evaluates a biocompatible and biodegradable porous scaffold made by a salt-assisted production process based on egg white albumin self-assembly [1] with respect to batch reproducibility, shelf-life stability, and biologically favourable micro- and macro-architecture.

METHODS: The specimens (Fig. 1a) were imaged using contrast-enhanced (phosphotungstic acid) μ CT (SkyScan 1172, NV). Scaffolds from two independent production lots (B1 and B2) were analysed to assess batch reproducibility. Pore size distributions were quantified at three defined storage time points in 25 % v/v ethanol to evaluate shelf-life stability. Scaffold microarchitecture was examined by SEM (JSM-IT800, Jeol) (Fig. 1b). Pore accessibility was analysed for characteristic cell-relevant length scales of 50 μ m and 100 μ m over time (Fig. 2a), supported by visualized accessibility illustrations (Fig. 2b,c) and three-dimensional volume renderings of the entire scaffold geometry and the pore network (Fig. 1c,d).

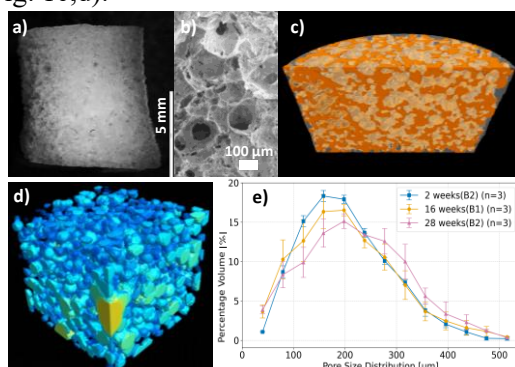


Fig. 1: a) Light microscopic and b) SEM image. c) Volume rendering and d) pore network of scaffold. e) Pore size distributions.

RESULTS: Quantitative pore size analysis demonstrated a high degree of overlap between batches, indicating excellent batch-to-batch reproducibility (Fig. 1e). Importantly, pore size distributions remained stable across all investigated time points, confirming shelf-life stability of 7 months without detectable structural degradation. SEM imaging revealed a fine morphology with thin pore walls and well-defined interconnections (Fig. 1b). Pore accessibility analyses showed that a large fraction of the pore network was accessible at both 50 μ m (~90%) and 100 μ m (~50-65%) thresholds at all time points (Fig. 2a). Three-dimensional analysis confirmed a continuous, highly interconnected pore micro-architecture throughout the scaffold volume, with cell-relevant pathways extending across the entire structure (Fig. 1d, 2b,c).

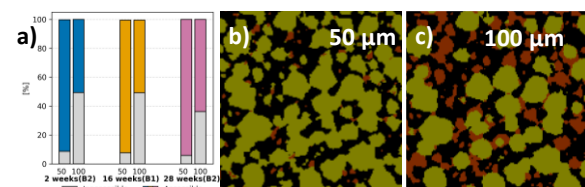


Fig. 2: a) Pore accessibility. b, c) Red areas: inaccessible for the corresponding threshold.

DISCUSSION & CONCLUSIONS: The preserved accessibility of cell-relevant pore sizes and the uniform, biologically favourable micro-architecture indicate that the scaffold is well suited for cellular infiltration, nutrient transport, and long-term biological use. Together, these properties support its potential as a reliable, off-the-shelf platform for tissue engineering and regenerative medicine applications.

ACKNOWLEDGEMENTS: The ALBUCOL project is supported by the Region Grand Est, Land Baden-Württemberg, Land Rheinland-Pfalz, Cantons Baselstadt, Basellandschaft, Swiss Confederation and by the program INTERREG Upper Rhine from the ERDF (European Regional Development Fund).

REFERENCES: [1] Bertsch et al. *Mat. Today Bio*, 38 (2026) 103193.

Micro- and Nanomechanics of BSA-Loaded PLGA Microspheres

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INTRODUCTION: The scalable production of porous poly(lactic-co-glycolic acid) (PLGA) microspheres loaded with bovine serum albumin (BSA) as a model drug was successfully demonstrated in batch mode (up to 20 g/batch) and continuous mode (up to 16.2 kg/day). As controlled and reproducible manufacturing is a prerequisite for clinical translation, a detailed understanding of the microstructure as well as the micro- and nano-mechanical properties of the particles is essential.

METHODS: PLGA microspheres (Resomer RG 502H) were fabricated using a double emulsion solvent evaporation process. Morphological and structural analyses were conducted using optical microscopy and scanning electron microscopy (SEM) (Fig. 1). Mechanical behaviour of particle aggregates was characterized by strain-controlled in-situ compressive testing inside a SEM (TM3030Plus, Hitachi) equipped with a micromechanical stage (Deben, UK), enabling simultaneous imaging and stress-strain acquisition (Fig. 2a-e). Nanoscale mechanical properties of individual particle surfaces were assessed by atomic force microscopy (AFM) using stiffness mapping (Fig. 2f).

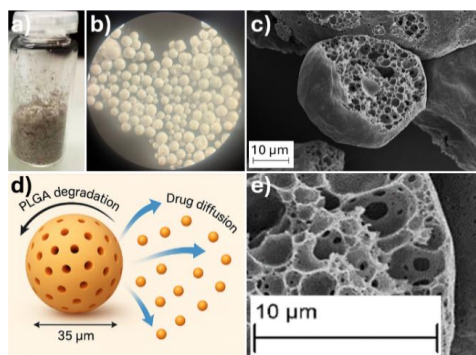


Fig. 1 (a) Photo, (b) optical microscopy, (c,e) SEM image of PLGA microspheres. (d) Scheme of the prolonged drug release process.

RESULTS: The produced microspheres exhibit a spherical morphology with a highly porous and interconnected internal structure. In-situ compression tests revealed an effective compression modulus of approximately

200 MPa for small particle aggregates. AFM measurements yielded a mean surface stiffness of 314 MPa for individual microspheres. Quantitative image analysis showed an internal porosity ranging from 30.6% to 48.9%.

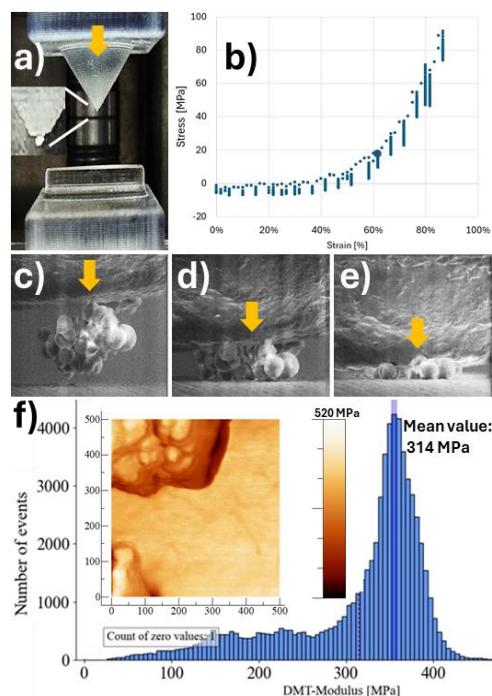


Fig. 2 (a-e) In-situ compression test of particle aggregate and (f) AFM stiffness mapping on 500x500 nm² area.

DISCUSSION & CONCLUSIONS: The combination of high internal porosity and sufficient mechanical stability highlights the suitability of the produced PLGA microspheres for controlled and prolonged drug release applications. The interconnected pore architecture facilitates diffusive transport of BSA, while the measured micro- and nanomechanical properties confirm robustness during handling and potential downstream processing. Overall, the results demonstrate that large-scale production of mechanically and structurally well-defined PLGA drug delivery systems is feasible.

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Laser-Induced Oxide Heterogeneity on Titanium: Implications for Implant Surface Function

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INTRODUCTION: The successful use of titanium-based implant materials in harsh physiological environments relies on the properties of a nm-thick, passivating oxide layer (TiO_x) at the implant surface. The oxide protects the underlying metal from corrosion and guides biological reactions at the interface between body and implant. MedTech commonly employs laser-based surface treatments that can locally modify oxide properties such as crystallinity (Fig 1A). Although the amorphous and crystalline oxide have comparable stoichiometry, they differ in chemical stability and electronic structure, thereby influencing surface potential and their susceptibility to transform or dissolve in aqueous environments ⁽¹⁾. It remains insufficiently understood how oxide phases and their heterogeneity, arising from adjacent amorphous and crystalline domains, affects the functional behavior of implant surfaces.

METHODS: In this study, model heterogeneous TiO₂ surfaces containing spatially separated dissimilar oxide-phase pairs (amorphous/crystalline) were fabricated by means of deep UV-laser irradiation of an amorphous atomic layer deposited (ALD) thin film. Parameter tuning enabled the production of customizable phase-transformation patterns with μm resolution (Fig 1B). Detailed oxide characterization was performed - combining micro-Raman spectroscopy, SEM, AFM and Kelvin Probe Force Microscopy (KPFM) to establish a link between oxide structure and resulting surface properties underlying oxide reactivity.

RESULTS & DISCUSSION: We show that amorphous and crystalline domains on the same TiO₂ surface exhibit a phase-dependent surface potential variation of 50 - 60 mV, as revealed by KPFM (Fig 1C). This potential contrast is in the range of cell membrane potentials of living cells, suggesting that local oxide modifications might translate into distinct reactive surface domains

and phase-selective biological interactions. Preliminary experiments with fibrinogen, a common blood plasma protein, showed preferential adsorption to crystalline domains of laser-treated surfaces.

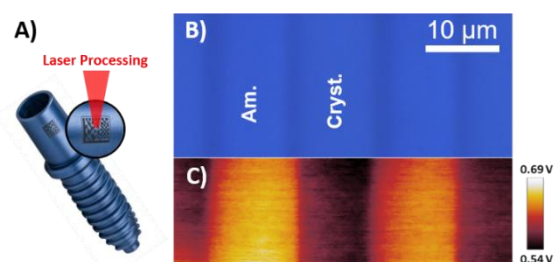


Fig. 1: A) Laser-based surface processing is used to functionalize implants, which can impact local oxide properties and generate heterogeneous oxide landscapes. B) Light Microscopy image of oxide phase patterns, consisting of adjacent amorphous (Am.) and locally crystallized domains (Cryst.), highlighting the high lateral resolution of localized phase transformation. C) KPFM map showing surface potential variations of up to 60 mV between the two domains.

CONCLUSIONS: These findings show that local oxide crystallinity can shape functional heterogeneity on implant surfaces, highlighting oxide structure as an important yet often overlooked parameter for functional implant surface design.

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REFERENCES:

(1) Eddy, Diana Rakhmawaty, et al. "Heterophase polymorph of TiO₂ (Anatase, Rutile, Brookite, TiO₂ (B)) for efficient photocatalyst: fabrication and activity." *Nanomaterials* 13.4 (2023): 704.

A Computational Framework for Parameter-Specific Design Evaluation of Ultrasonically Assisted Subcortical Fixation Implants

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INTRODUCTION: Ultrasonic suture anchors combined with a fenestrated titanium implant provide a bone-preserving alternative to conventional interference-fit anchors and may help overcome fixation challenges in low-density bone. In this concept, the implant guides liquefied polymer through predefined outlet windows to establish subcortical anchoring with reduced dependence on local bone quality. Although extensive design iterations have been performed, the individual influence of implant features on polymer flow and mechanical fixation remains insufficiently understood. As a result, optimisation has largely relied on engineering intuition rather than quantitative, feature-specific evidence. To address this gap, thermofluid and structural finite element models were developed to characterise implant performance and establish a grading metric for systematically ranking prototype designs prior to fabrication.

METHODS: A thermofluid finite element model was developed by coupling heat transfer, laminar flow, and phase-field physics to simulate the insertion-induced flow of a temperature- and shear-rate-dependent polymer. A complementary structural model represented the post-extrusion state, in which the solidified polymer mechanically engages with the cortical bone under tensile loading. Penalty-based contact formulations were applied across the polymer, titanium, and bone domains to investigate the effects of extrusion length, window aspect ratio, and cortical thickness on fixation performance.

RESULTS: Thermofluid simulations identified a critical window area of approximately 0.6 mm² for achieving effective polymer extrusion, corresponding to the middle geometry in Fig. 1. Structural simulations showed that increasing extrusion length improves fixation only up to an optimal range of 0.8–1.1 mm, beyond which additional extrusion provides limited benefit. Higher window aspect ratios reduced mechanical performance due to increased stress

concentrations. Cortical thickness affected fixation through a coupled interaction between polymer–bone contact area and contact width. To capture this relationship, a Window Grading Index (WGI) was defined as

$$Grade = \frac{w(t)}{w_{max}} \left(\frac{A(t)}{A_{max}} \right)^2 \quad (1)$$

where $w(t)$ and $A(t)$ denote the contact width and contact area as functions of cortical thickness, respectively. When combined with the critical window-area criterion, the WGI successfully reproduced pull-out trends observed across both simulations and experiments, as shown in Fig. 2.

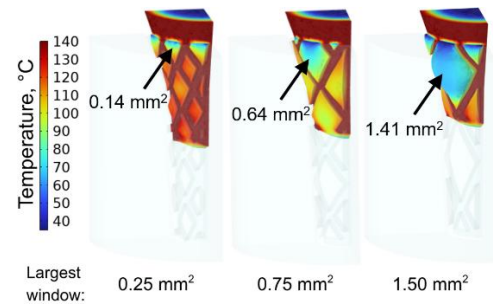


Fig. 1: Simulated polymer extrusions at varying window sizes

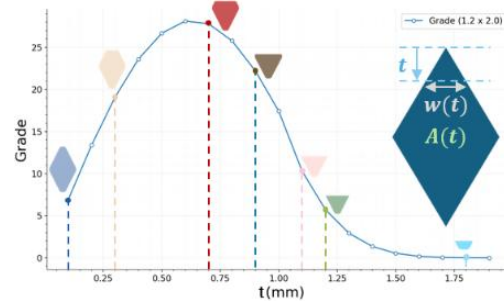


Fig. 2: Relative window size rankings using WGI

CONCLUSION: The proposed computational framework enables quantitative, parameter-specific assessment of ultrasonically assisted subcortical fixation implants. By linking polymer flow behaviour with structural fixation performance, the framework provides a rational basis for screening and ranking implant designs before fabrication and experimental testing.

Medical Device Integrated Hybrid Manufacturing

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INTRODUCTION: Orthopedic, dental, and custom-made medical devices require complex geometries, functional integration, and strict regulatory compliance. Laser Powder Bed Fusion (LPBF) enables unparalleled design freedom for patient-specific implants, yet standalone additive manufacturing (AM) has limitations in dimensional accuracy, necessitating precision post-processing.

Hybrid Manufacturing, the direct integration of AM and CNC machining in a single, interconnected workflow, overcomes these limitations.

METHODS: Hybrid workflows are built on four interdependent process domains:

- Deformation-free printing: optimized LPBF parameters to minimize residual stress and preserve dimensional references.
- Optimal part positioning: build plate orientation to maximize accuracy at functional surfaces.
- Tailored heat treatment: stress relief, HIP, or solution annealing protocols adapted per alloy and device class.
- Precise coordinate transfer: CNC machining performed directly on the build plate or via advanced fixturing, eliminating re-clamping tolerance loss.

All processes operate under an ISO 13485:2016 and FDA-compliant quality management system.

RESULTS: Integrated hybrid manufacturing delivered improvements across three dimensions:

- Reduced lead time: eliminating intermediate handling and re-inspection between AM and CNC operations shortened production cycles compared to decoupled workflows.
- Lower cost of quality: direct coordinate transfer reduced dimensional non-conformances, scrap, and rework.

- Expanded design space: the process enables specific designs, and precision-threaded interfaces unachievable by AM or CNC alone.

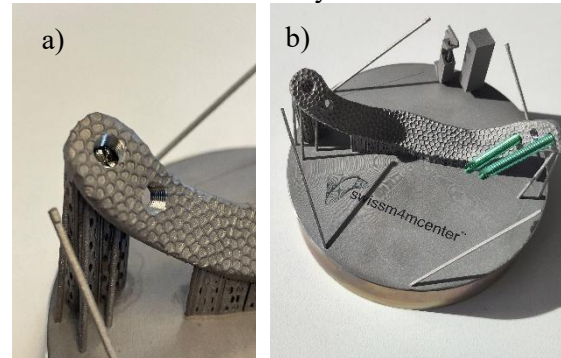


Fig. 1a): CNC machined locking screws in 3D printed plates 1b): On-plate integrated hybrid manufacturing combining AM and CNC for locking mechanism manufacturing.

DISCUSSION & CONCLUSIONS: The findings mentioned in the section results confirm that tight AM-CNC coupling with shared coordinate systems and unified quality control represents a substantive advance over sequential, disconnected operations. For regulated medical devices, where dimensional accuracy, repeatability, and traceability are mandatory, this integrated approach directly reduces technical and compliance risk. This hybrid manufacturing technique delivers accuracy equivalent to conventional CNC-machined parts. Locking holes are finished to a tolerance of 0.05 mm. This enables final 3D printed implant delivery time within 7 days compared to 3 weeks for conventional CNC machined implants.

REFERENCES:

- [1] ISO 13485:2016. Medical devices, Quality management systems. ISO, Geneva.
- [2] Monfared, et al. (2023). Science and Technology of Additive Manufacturing Progress: Processes, Materials, and Applications. Metals and Materials International, 29, 3442–3470.
- [3] Future trends of additive manufacturing in medical applications: An overview. (2024). Heliyon, 10(5), e26641.

Interesting applications of pin-on-disc in biotribology

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INTRODUCTION: Many biomedical applications require careful characterization of frictional properties. While the importance of low friction in natural and artificial joints is well recognized, tribological performance is equally critical in less obvious applications such as catheters, where low friction facilitates insertion into the vascular system, or orthopaedic implants, where controlled friction at the bone–implant interface contributes to initial stability and successful osseointegration. Many of these conditions can be reasonably reproduced using ball-on-disk or pin-on-disk tribometers, provided that the relevant loading and environmental conditions are known or can be estimated with sufficient accuracy.

METHODS: The pin-on-disc method was used in all cases, with adapted load, sliding speed and counter-body and environmental conditions. For the hip implant study, different counter-body materials were used, and the moving specimen was bovine cortical bone in PBS solution which moved at different linear speed to simulate post-operation movements. For the coated knee implants, linear movement was applied between a 1x1 cm² section of coated (and uncoated) implant static counter-body and UHMWPE moving part. The sliding speed and the mean contact pressure were similar to that in the knee during gait. Finally, three types of catheters were mounted on a steel pin and were tested at 1 cm/s sliding speed against a steel pin with 1 N load. During all the experiments the coefficient of friction (CoF) was measured.

RESULTS & DISCUSSION: In the first case study, friction measurements of hip implant stems against bone were performed under clinically relevant conditions. For sliding speeds between 0.1 mm/s (walking) and 100 mm/s (jumping) and loads between 1 N and 50 N we measured CoF of polished and sand-blasted commercially pure Ti, Ti-6Al-7Nb alloy, and 316L stainless steel. The CoF decreased with increasing sliding speed from ~0.6 to ~0.3 but it was relatively constant for various loads and across different materials and surface finishes. Only 316L stainless steel exhibited a lower CoF of approximately 0.5. Under the most relevant

physiological conditions (8 N load and 0.1 mm/s sliding speed), all Ti alloys exhibited a CoF of approximately 0.6, which was subsequently used for modelling the movement of the hip implant stem relative to bone. The second case study aimed to compare CoF of coated (TiN, TiNbN, and ZrN) knee implants with their uncoated counterparts (Ti6Al4V, CoCrMo). At a mean contact pressure of 30 MPa (5 N load) the measured CoF of all coated implants was in the range of 0.08 to 0.1 which were very similar or even lower than that of the uncoated CoCrMo and Ti6Al4V. It confirms that the protective coatings maintain or even improve the frictional performance of knee implants. The third case study allowed to compare the friction of three types of catheters and measure their CoF. Although the tests did not closely simulate physiological conditions, the pin-on-disc tests found significant differences in the CoF: Gentlecath Glide had the highest CoF of ~1, followed by Self Cath with CoF of 0.5. The lowest CoF was measured on the Speedicat Flex (0.2). Further experiments under physiological conditions (lubrication and tissue-like counter-bodies) are currently underway.

CONCLUSIONS: These three case studies demonstrate that a well-designed tribological testing provides important information about the frictional and mechanical performance of implants and biomedical devices, even when the experimental conditions only approximate the real application. The results show that laboratory tribological methods can support better material selection, coating development, and numerical modelling, thus contributing to the design and optimization of biomedical implants and devices.

REFERENCES:

- [1] C. Voutat, J. Nohava, J. Wandel, P. Zysset, *Biotribology* 17 (2019).
- [2] M. Ovesy, M. Aeschlimann, P.K. Zysset, J. Biomech. 107 (2020)
- [3] M. Herbster, J. Döring, J. Nohava, C.H. Lohmann, T. Halle, J. Bertrand, *J. Mech. Behav. Biomed. Mater.* 112 (2020).

Antimicrobial Cationic Surfaces for 3D-Printed Immediate Denture Base Resins

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INTRODUCTION: Immediate complete dentures are inserted directly over freshly extracted tissues and are particularly susceptible to early microbial colonization during the healing period. With the increasing use of digital workflows, 3D-printed denture base resins enable rapid and reproducible fabrication; however, their surface properties may contribute to biofilm development. This study aimed to develop and characterize a drug-free cationic surface treatment for a 3D-printed immediate denture base resin through 2-hydroxyethyl methacrylate (HEMA) functionalization followed by 3-aminopropyltriethoxysilane (APTES) silanization, with the goal of reducing early microbial adhesion while preserving material's performance [1,2,3].

MATERIALS AND METHOD: Discs of 3D-printed denture base resin (Prisma) were used as the control group (CG). Surface functionalization with HEMA was performed to increase hydroxyl group availability, generating the GH group. Subsequently, specimens were treated with APTES (83.8 mM), forming the GA group. Surface morphology and topography, elemental composition, chemical bonding, wettability over 7 days, zeta potential at different pH values, color stability, hardness, and flexural behavior were evaluated. Antimicrobial performance was assessed using initial adhesion and biofilm models with *Streptococcus mitis* and a polymicrobial biofilm containing *Candida albicans*. Outcomes included colony-forming unit (CFU) counts, XTT metabolic activity assay, scanning electron microscopy, and confocal laser scanning microscopy.

RESULTS: The surface treatment preserved the morphology of the printed resin and produced a more homogeneous surface with a glaze-like appearance. Chemical characterization confirmed the incorporation of silicon in GA specimens, while FTIR analysis identified C–O–

Si bonds, indicating stable silane attachment to the resin surface. Wettability analyses demonstrated time-dependent changes in surface polarity, and zeta potential measurements confirmed the establishment of a positively charged surface over a broad pH range. Color stability was maintained after treatment. Mechanically, GA specimens exhibited high stiffness and did not fracture during testing, supporting the structural reliability of the modified material. In the monospecies model, GA reduced *S. mitis* biofilm formation by more than 50%. In the polymicrobial model, GA also reduced microbial activity and biofilm development accumulation.

CONCLUSION: HEMA functionalization followed by APTES silanization produced a stable cationic surface on a 3D-printed denture base resin. The treatment preserved optical and mechanical performance while reducing microbial colonization and biofilm accumulation. This approach may offer a clinically relevant strategy to limit early microbial colonization of immediate dentures during post-extraction healing, potentially reducing inflammation-related complications.

ACKNOWLEDGEMENTS: This work was sponsored by Unicamp University and the French embassy in Brazil.

REFERENCES:

- [1] Shibli, J. A.; Marcantonio, E.; d'Avila, S. . J Periodontol 2005, 76, 1092–1099. <https://doi.org/10.1902/jop.2005.76.7.1092>.
- [2] Iqbal, F.; Shafiq, B.; Noor, S. S. Clinics in Orthopedic Surgery 2020, 12, 470–476. <https://doi.org/10.4055/cios20037>.
- [3] Pirc, M.; Gadzo, N.; Balmer, M. Clin Implant Dent Relat Res 2025, 27, 2–9. <https://doi.org/10.1111/cid.13405>.

Needle-like Hydroxyapatite Particles as Immunological Modulator for Enhanced Osteoinduction

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INTRODUCTION: Interactions between biomaterials and the immune system play an important role in bone healing and regeneration. Early inflammatory events regulate angiogenesis, recruitment of progenitor cells, and subsequent tissue formation. This immune response is also crucial for successful regeneration in the case of bone graft implantation. A balanced response appears to be particularly important, as both prolonged and overly limited inflammation may compromise new tissue formation. These observations suggest that tuning the magnitude and duration of the early inflammatory phase could serve as a design parameter to enhance material-induced bone formation.

This project aims to study whether bone substitute materials inducing a tailored boosted transitory immune response could generate more potent bone formation. This approach is studied in the case of calcium phosphate (CaP)-based materials.

METHODS: Needle-like hydroxyapatite (HA) particles were synthesised via hydrothermal processes, namely α - and β -tricalcium phosphate (α -TCP, β -TCP) hydrolysis and hydrothermal homogeneous precipitation. Physicochemical characterisation was performed using scanning electron microscopy (SEM) and X-ray diffraction (XRD).

To investigate immune responses to these particles, a primary macrophage platform is being developed. Bone marrow cells were isolated from the tibiae and femurs of FVB/NJ mice and cultured in the presence of 0, 3, 10, 30 and 100 ng/mL macrophage colony-stimulating factor (M-CSF) for 7 days to study differentiation into macrophages. Morphology and proliferation were assessed by light microscopy, and cell activity was evaluated using XTT assays. To confirm differentiation, flow cytometry measurements were performed at day 7 using F4/80 as a marker. The particles will also be implanted with CaP bone grafts *in*

vivo in an intramuscular mouse model to study bone formation in relation to the observed inflammatory reactions.

RESULTS: Needle-like HA particles with controlled lengths ranging from 1–100 μ m were produced while maintaining comparable aspect ratios (20–30) and phase composition (Fig. 1). Exposure of bone marrow cells to M-CSF promoted cell attachment and an apparent increase in cell number. XTT assays showed an increase in metabolic activity with increasing M-CSF concentration, although this effect appeared to plateau above 10 ng/mL. Increased F4/80 expression supported differentiation into macrophages, with a similar plateau observed above 10 ng/mL. Surprisingly, a large proportion of the cells were DAPI-positive, indicating low cell viability. This high level of cell death may have resulted from the cell collection method.

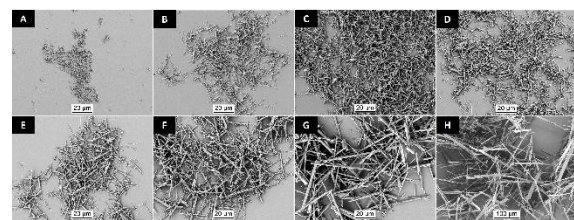


Figure 1: SEM micrographs of needle-like HA particles produced for the *in vitro* experiments. Increasing size from A to H.

DISCUSSION & CONCLUSIONS:

Overall, these results establish a strong basis for investigating how the size of HA particles, independently of chemical composition, influences the inflammatory response. Further optimisation of the macrophage platform will enable a more reliable assessment of particle-cell interactions and help identify particle characteristics associated with specific inflammatory responses. Ultimately, combining these *in vitro* findings with *in vivo* results will provide insight into whether controlled particle-induced inflammation can be used as a strategy to enhance bone formation and improve the performance of CaP-based bone grafts.

Two fix-and-replace techniques for acetabular T-type fractures: primary stability under cyclic loading, measured optically

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INTRODUCTION Acetabular fractures with traumatic pelvic discontinuity (PD) are a biomechanical challenge of growing clinical relevance [1-2]. Fix-and-replace strategies are promising, but comparative biomechanical evidence is limited. This study compared the primary stability of two established constructs: a Ganz reinforcement ring with a posterior-column plate and anterior-column screw (GRP) versus a Burch-Schneider reinforcement ring with additional anterior- and posterior-column screws (BSR).

METHODS Six 4th-generation Sawbones[®] hemipelvis models each received a standardized T-type fracture (PD) created with a water-jet cutter. Three were reconstructed with GRP and three with BSR, using cemented acetabular fixation. Relative 3D micromotion of the fracture gap was measured along the fracture lines in four zones (Zone 1: posterior column) with an optical motion-tracking system (ATOS Core 300 / Aramis, Carl Zeiss GOM Metrology). Cyclic load was applied on an electrodynamic machine (LTM 10, ZwickRoell) at 200, 400, 800 and 1200 N (10 × 100 cycles/level, 1 Hz). A fracture gap ≥ 1 mm was defined as fixation failure.

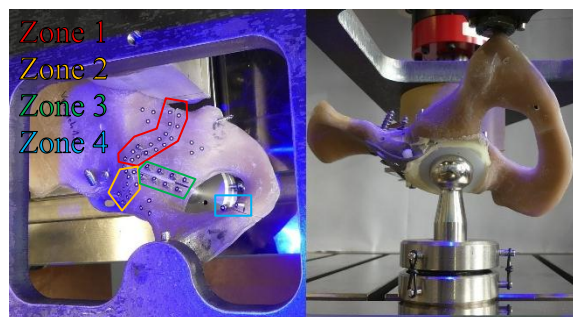


Fig. 1: Optical reference markers along the fracture lines (left) and the replicated prosthetic head resting on a low-friction sliding support for load transfer (right).

RESULTS Fixation failure occurred in none of the six specimens. Up to 400 N, micromotion

was minimal in all zones with no significant differences between techniques. At 800 N, GRP showed a non-significant increase in the fracture gap. At 1200 N, significantly greater displacements were observed with GRP than BSR in Zones 2–4 ($p < 0.005$), whereas Zone 1, the clinically most relevant, load-bearing posterior column, showed no significant difference ($p = 0.424$). All gaps remained below 1 mm.

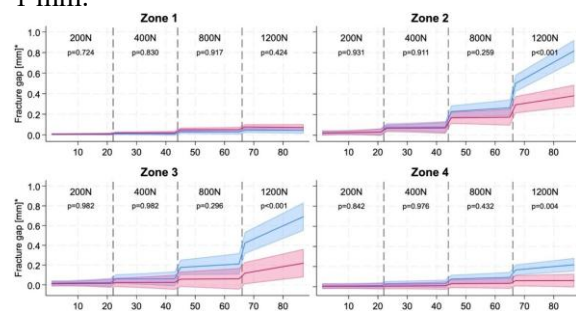


Fig. 2: Modelled fracture gap under increasing cyclic load in the four zones for BSR (red) and GRP (blue).

DISCUSSION & CONCLUSIONS Both constructs provided sufficient primary stability under cyclic, partial-weight-bearing load, with minimal displacement (< 1 mm) and no catastrophic failure. BSR showed significantly smaller fracture-gap motion at high loads, particularly in Zones 2 and 3, while stability at the posterior column (Zone 1) was comparable. Optical 3D tracking under cyclic loading enables quantitative, zone-by-zone assessment of construct stability. Further clinical evaluation is required for patients with acute traumatic PD.

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REFERENCES [1] Ding A, et al. J Orthop Trauma 2018;32:e251–e257. [2] Ebrahimi HDN, et al. Arch Orthop Trauma Surg 2023;143:6665–6673.

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