

Pangong-Tso) require specific focus to help maintain the sensitive ecological balance. Mountain communities are dependent on natural resources for their sustenance and livelihood and hence positive support is required for entrepreneurs (entrepreneurs focusing on niche sector natural resource-based livelihood). Traditional knowledge and cultural beliefs have long been protecting the mountain biodiversity. The speakers urged the National Mission for Sustaining the Himalayan Ecosystem task force on the cross-cutting theme of traditional knowledge to help capture and integrate

the local knowledge and practices for sustainable eco-development. Population expansion and increasing inflow of tourists are threatening the sensitive mountain ecosystems, and suitable measures are required to help stay within the carrying capacity. Development projects in the sensitive eco-zones call for approval processes to be linked with comprehensive research for long-term and downstream impacts with stringent monitoring for compliance of norms. It is critical to create common responsibility of all stakeholders (local communities as protectors of these resources, downstream

beneficiaries, high per capita resource users in urban centres) for safeguarding mountain biodiversity. Rigid and non-inclusive regulations often curb the rights of indigenous communities. Hence the legal framework must be more conducive to address the primary needs of communities while protecting the sensitive ecozones.

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MEETING REPORT

Design and manufacturing technologies for orthopaedic biomaterials*

Among the human health problems, cases of patients suffering from musculoskeletal disorders are rapidly increasing, even in the middle-aged populations. Under such diseased conditions, an appropriately designed and fabricated biomaterial with bone-mimicking properties and architecture is necessary for the restoration of hard tissue structure and function. Rapid prototyping (RP) techniques like stereolithography, selective laser sintering, 3D plotting and 3D printing of metal, ceramic and polymer powders or biopolymer-based pastes are being applied extensively for the fabrication of porous, three-dimensional scaffolds. These techniques are based on layer-by-layer construction of 3D structures with pre-defined geometry and porosity as determined from the CAD/CAM datasets of the defect region generated from computed tomography (CT) or magnetic resonance tomography (MRT) of the patient. Such a scaffold-based tissue engineering strategy for healing large bone defects has been necessitated by the inherent clinical limitations of autografts and allografts in orthopaedic surgery. The combination of geometrically fabricated synthetic scaffolds representing the

supporting extracellular matrix and cells (autologous stem cells isolated from the patient) guided by growth factors and signalling molecules in a 3D-bioreactor system forms the crux of tissue engineering-based approach for treating osteochondral defects, for cartilage repair and other diseased conditions of the bone.

The Indo-German symposium held in Dresden, Germany recently provided a unique platform for the exchange of scientific ideas among a select group of active researchers from the biomaterials, tissue engineering and medical field. The objective of the symposium was to bring to light, some on the state-of-the-art manufacturing technologies based on rapid prototyping for the design and fabrication of advanced biomaterials and implants. The symposium also provided an impetus for Indo-German joint research venture and collaboration, aimed at scaling up the production and commercialization of such healthcare products in the future. In line with the objective of the symposium, the proceedings were distributed over two days and categorized under eight technical sessions, each of which consisted of 4–6 speakers. Among the 33 presentations, 15 were made by participants from the Indian delegation while the rest were from the German contingent apart from a couple of representatives from Latvia and Lithuania. The Indian delegation had representatives majorly from IISc (Bangalore), NIT Rourkela, Jadavpur

University (Kolkata), SCTIMST (Thiruvananthapuram), DST Laboratory, two orthopaedic surgeons from Bangalore and Kolkata and a dyad of private enterprises – Excel Matrix Pvt Ltd, Hyderabad and Data Metallurgical Company, Kolkata. The German contingent consisted of speakers from universities spread across the country – Würzburg, Erlangen, Bremen, Rostock, TU Dresden and Fraunhofer-IWU (Dresden and Chemnitz).

The symposium began with the welcome address by A. Chakraborty (Indo-German Science and Technology Centre (IGSTC), Gurgaon) which funded the workshop. This was followed by brief welcome notes by Stefan R. Bornstein (Medical Faculty of TU Dresden); K. Venkatarama Sharma (Indian Embassy, Berlin); Christian Hannemann (Fraunhofer Institute for Machine Tools and Forming Technology, Chemnitz) and Martin Goller (International Bureau of the German Federal Ministry of Education and Research (BMBF), Bonn, Germany). The technical sessions were categorized based on the different related areas of orthopaedic research such as the design of biomaterials with bone-mimicking properties, rapid prototyping technologies, drug delivery, commercialization, metallic implants, ceramics and external field application for achieving the desired biological response. The inaugural technical session began with a talk by B. Basu (IISc, Bangalore),

*A report on the Indo-German workshop, 'Strategies for improved bone replacement materials and orthopaedic implants: design – manufacturing – technologies' held during 19–21 February 2014 at the Medical Theoretical Centre of TU Dresden, Dresden, Germany.

followed by M. Gelinsky (TU Dresden), A. Deb (IISc, Bangalore) and C. Hanne-mann (Fraunhofer IWU, Chemnitz), with emphasis on the design of multifunctional composites with bone-like architecture by computer-aided engineering and additive manufacturing techniques. In order to mimic the microenvironment in the native human tissue, it is necessary to have 3D constructs which function as the supporting extracellular matrix for cell growth. In this regard, the design of biomaterial scaffolds with controlled geometry and porosity by rapid prototyping techniques is of relevance. In particular, the fabrication of complex 3D scaffold geometries as tissue engineering constructs by 3D plotting and 3D printing techniques, porous metallic foams as implants with multifunctional properties, alginate-based matrices for the vascularization of bone tissue and additive manufacturing methods for bio-inspired blood vessels were exemplified as illustrative examples of a 3D scaffold-based tissue engineering approach in the second session. Among other instances of the application of rapid prototyping technologies, the design of drug-loaded implants in the form of calcium phosphate-coated alginate for multistage drug release, magnetic field-assisted drug release and tetragonal zirconia polycrystals (TZP)-coated hydroxyapatite for dental

implants, low temperature 3D printing of calcium and magnesium phosphate powders loaded with vancomycin, tetracycline implants and the design of core/shell 3D plotted tissue-engineering constructs were some of the key aspects of the lectures in the third session. The fourth session on day-one included two lectures delivered by a couple of well-known orthopaedic surgeons on the advancements in surgical techniques with special emphasis on metal-on-metal hip prostheses replacement and other orthopaedic biomaterials as suitable bone substitutes. Both, the small investment companies like Excel Matrix Pvt Ltd, Hyderabad and well-established medical care companies like Baltic Orthoservice proposed business models for mass customization of implants with patient-specific needs as an assembly line for tissue manufacturing.

The sessions on day-two of the symposium were dedicated largely to metallic and ceramic implants and the application of external fields for achieving desired cell proliferation and bacterial growth inhibition. Among the orthopaedic implant materials for bone tissue regeneration, both the metallic and ceramic-based biomaterials have their pros and cons, with regard to their performance in terms of strength and load-bearing capability. In the fifth session, additive manufactur-

ing-based open porous titanium scaffolds were evaluated for bone in-growth and finite element modelling as applied to the chosen bone implant materials was dealt with. In the category of metallic bone replacements, titanium in the form of novel β -type Ti-Nb-based alloys with reduced stiffness for long-term application and the functional modification of titanium by individual surface contours for theoretical prediction and practical utility were deliberated. In the sixth session, dynamic microstructural changes occurring during tribological contact that influence the wear behaviour of metals and ceramics in hip prostheses, the possibilities and limitations of the diagnosis of endo-prostheses loosening, an engineering and clinical estimate of the surgical procedures during spine fixations, an experimental numerical insight into the effect of static and dynamic compressive loads on truncated vertebral unit and the application of shape memory alloys for protection against active loosening of implant structures, were a series of lectures that assessed the parameters which determine the mechanical failure of hard tissue implants. In the category of ceramic-based biomaterials covered in the seventh session, calcium phosphates – processing, characterization and application as bone cements in a modified form for the local delivery of therapeutic ions

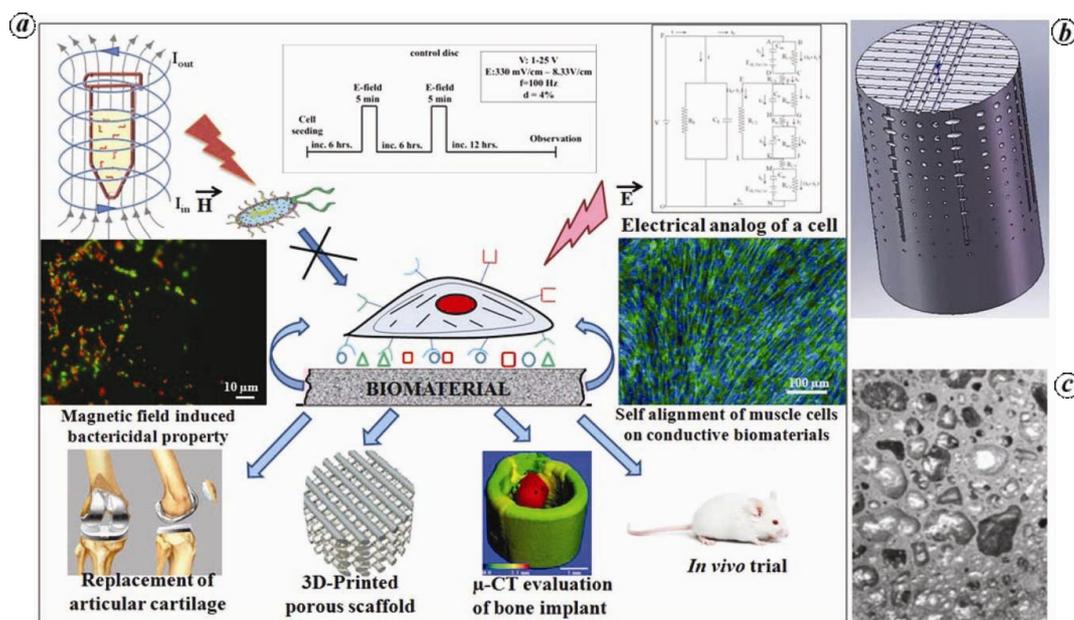


Figure 1. **a**, Thematic scheme of the major scientific deliberations on orthopaedic biomaterials during the Indo-German symposium held at TU Dresden, Germany. **b**, A design concept of a graded porous 3D scaffold. **c**, A closed porous titanium scaffold developed at Fraunhofer IWU, Chemnitz, Germany.

at osteoporotic defect sites and application in maxillo facial and orthopaedic surgery and tailor-made bioactive ceramics for clinical applications were discussed. In the concluding session that largely belonged to young researchers, the application of external electric and magnetic fields for desired cell proliferation and microbial reduction respectively, were illustrated on conducting polymeric and magnetic ceramic substrates. A theoretical model to understand the cellular deformation due to bioelectric stress development in electric field-stimulated culture conditions was proposed. In another talk, the cross-linking of polymer chains as a strategy for the synthesis of tissue engineering matrices with tunable properties was elucidated. In the concluding talk by a representative from DUCOM Instruments Ltd, the advances in the instrumentation for tribological testing of hard tissues by updated design

of machine technology were presented. Some of the scientific concepts discussed during the symposium as well as the design concept of a graded porous 3D scaffold and closed porous titanium scaffold are presented in Figure 1a–c respectively.

In order to encourage young minds to compete at the international level, young researchers in the symposium were evaluated by judges for the quality of research and presentation of the data in a scientific and integrated manner. The two best presentations in the young researchers' category were awarded. The final day of the symposium was utilized for laboratory demonstrations and raising joint collaborative project proposals between Indian and German institutions in the related areas of biomaterial design for orthopaedic applications. Post-lunch, the participants witnessed the facilities of the Centre for Translational Bone, Joint

and Soft Tissue Research at TU Dresden which centred around biomaterial development and 3D plotting of porous scaffolds. This was followed by a visit to Fraunhofer IWU, Dresden and Chemnitz, which gave some insights into the machining of automobile design, manufacture, testing, and the fabrication of open porous metallic implants. Thus, this symposium proved to be another endeavour towards greater collaborative scientific research between Germany and India in the area of human healthcare.

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