Innovative biomaterials research…

…under the Northern Lights…

In most developed countries today dentists aren't focusing as much on restoring individual teeth following tooth decay, but rather on attempting to improve patients' dentition and smile esthetics. The impact on dental health services of a generation of elders who today are dentate instead of wearing dentures is formidable. Many elders nowadays choose to re-establish a youthful state of dentition, which is repeatedly restored after being worn down over their lifetime. This group is joined by the increasing number of adults who, for a variety of reasons, have a total or local makeover of body parts, including their teeth.

To meet the needs and demands of these emerging patients, dentists require innovative and novel dental biomaterials to replace oral hard and soft tissues. Moreover, such materials need, in many cases, to be combined, for example, in multiple layers, and this intermixing of materials with different physical and mechanical properties poses challenges. The current novel materials used in dentistry fall within the categories of composite resins, glasses and ceramics, which are placed in or on teeth or on tooth analogues and are termed dental implants. Dental implants are made from metal, metal alloys or are ceramic, with combinations existing as well as multiple ingenious surface treatments. Dental implants are surgically placed into the jaw bone, with the intra-oral restoration accomplished by using a transmucosal element termed an 'implant abutment'. While in the past abutments were mostly prefabricated, today's trend is to use customised implant abutments that are manufactured by dental laboratory technicians.

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Within each of the biomaterials groups described, there is an abundance of commercial products, which indicates that none has so far been identified as superior. Over the last decade there has been a sudden increase in new products, for example, the number of implant manufacturers has grown from approximately 90 to close to 300 today, manufacturing some 2,000 different implant brands. Likewise, within ceramics, dentists can now choose from a wide range of traditional feldspathic ceramics with or without aluminium oxide crystals, feldspathic glasses, ceramics containing leucite crystals, tetra silicon mica glasses, lithium-disilicate glasses, pre-sintered aluminium oxide glass infiltrate, high pressure sintered aluminium oxide and zirconium oxide (alternatively called zirconia) combinations. Within the zirconium oxide group alone, which is used widely in dentistry and orthopaedic medicine, minor chemical differences between products are reflected in great variations with regard to hardness, fracture resistance, grain size, tension strength, elasticity module, opacity and sintering (powder fusion) time. The net effects on long-term clinical performance are hitherto largely unknown. Examples of current combinations of zirconium oxides are (TZP tetragonal zirconia polycrystals) consisting of ZrO_2/Y_2O_3 (95/5%), TZP-A ($ZrO_2/Y_2O_3/Al_2O_3$, ~95/~5/0.25%), FSZ (ZrO_2/Y_2O_3, 90/10%), PSZ (ZrO_2/MgO, 96.5/3.5%) and ATZ ($ZrO_2/Al_2O_3/Y_2O_3$, 76/20/4%). Even the temperatures used for sintering different types of zirconium oxides used in dentistry and orthopaedic medicine vary between ~1350°C to -1530°C. Finally, some of the ceramics mentioned here have inferior optical properties, which mean that they need to be veneered with a layer of a second type of ceramic; this introduces challenges manufacturing wise, and also uncertainty with regard to unknown potential future thermal or chemical incompatibility problems. The overall message being that there are exciting avenues for the developing and testing of innovative biomaterials to meet the clinical performance requirements of an emerging, large group of patients. The biomaterials research environment at the Department of Clinical Dentistry in Tromsø is capable and eager to contribute in such endeavours. We anticipate that the biomaterials research of our faculty colleagues within the Department of Clinical Medicine will also focus on orthopaedic medicine investigations.

Moreover, new additive and subtractive fabrication processes are being implemented to produce 3D customised objects, i.e. implants, abutments or restorations. One example is the machining of zirconium oxides to fabricate customised abutments or restorations, which can

be done in multitude of ways: one method is machining of the porous or green state prefabricated blanks, a second involves the pre-sintered state blanks, while a third uses sintered or sintered and HIP-ed blanks. In some environments, machining is done in the dental office using a milling unit running at 8K rpm, while across Europe high output, high volume 5-axis milling machines operating at 45K rpm with excessive cooling churn out restorations at very high rates. Little is known how the actual ceramic surface or immediate subsurface is altered within these manufacturing processing parameters. Confounding the complexity is the need to veneer the ceramic with more translucent ceramics, introducing compatibility issues between different types of ceramics. All the developments described here occur in spite of lack of persuasive published medium or long-term clinical data. No regulatory bodies check, for example, ceramic veneering compatibility, optimal veneer layering thicknesses, or the properties of the ceramic blanks versus intended usage in dentistry or orthopaedic surgery.

The unwanted clinical performance of materials and restorations in dentistry include bulk or margin discoloration, surface wear, margin leakage or structural degradation. The problem is to identify the optimal combination of a material's physical and mechanical properties, as well as how the handling, casting or machining processes influence properties.

Consequently, a critical activity in the development of novel materials and fabrication procedures is to design *in vitro* tests that predict clinical performance, thus avoiding expensive and time consuming clinical testing. The development of such tests is undertaken by experts working within the framework of TC106 of the International Organization for Standardization (ISO). The Department of Clinical Dentistry in Tromsø, Norway, can boast a faculty that represents and has represented for many years the ISOTC106 delegations from Norway, Sweden and Canada (Professors Arne Hensten, Ulf Örtengren and Asbjørn Jokstad). Hence, the accumulated experience that is available here is quite unique.

With our recently purchased mechanical testing equipment for biomaterials research (UTM DO 711903, Zwick GmbH & co., Germany), we will be able to conduct measurements of materials or products subjected to static stresses (compressive (crushing) strength, tensile strength, transverse strength, flexure/bending/modulus of rupture, modulus of elasticity (Young's Modulus), shear modulus). Alternative tests are dynamic (compressive modulus, tensile modulus, bending modulus, resilience, fatigue, fracture toughness). Of relevance are also tests for flow (creep) tests, dimensional change upon polymerization (setting contraction/expansion), Vickers hardness tests, thermal expansion coefficient, water solubility or water sorption, abrasion resistance (wear), adhesion, colour stability or surface roughness tests.

We have recently negotiated with the Department of Physics and Technology, Faculty of Science and Technology an agreement whereby they host a new industrial 5-axis milling machine that is maintained by their engineers but owned by the Department of Clinical Dentistry. Our ultimate objective is to study how the processing of prefabricated blanks made from various new biomaterials can be influenced by the rotating tools and other machining parameters. The milling machine will be able to machine base, gold, non-precious and titanium alloys, commercially pure titanium, composite resins, cast resins, wax, polymethylmethacrylate (PMMA), porous or sintered aluminium oxides, feldspathic ceramics, lithium disilicate ceramics and zirconium oxides in the porous or green state, pre-sintered state, and sintered as well as sintered and HIP-ed state.

Ceramics cannot be placed directly on to teeth; they need to be 'glued' onto tooth structures using quite advanced organic chemistry products. Tooth substance is first etched to create microretention before being primed with a low viscous water-soluble resin. The surface of the ceramic can be sandblasted, etched using hydrofluoric acid and silanized to create an active surface. Finally, an intermediate adhesive, which is most commonly some form of polymer resin-based material, bonds the ceramic to the tooth's surface. As for the other dental biomaterial groups, there is a wide range of commercial products available, which highlights a lack of any superior product.

For partnering enterprises looking to venture into the advancement of new dental biomaterials applicable to current trends in dentistry and orthopaedic medicine, research conditions at the Department of Clinical Dentistry, Faculty of Health Sciences at the University of Tromsø are very favourable. The biomaterials research environment here is capable and eager of contributing to such endeavours.

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