Biomaterials, biomechanics and oral implantology

Programme leaders: Dr Carolina Loch (Biomaterials and Biomechanics) and Professor Warwick Duncan (Oral Implantology).

In biomechanics and biomaterials, we conduct experimental and observational research in themes such as:

- Dental materials - development of new dental restorative materials for dental CAD/CAM systems.
- The use of 3D printing in the fabrication of dental appliances and prostheses.
- Craniofacial biomechanics - prosthodontic failure mechanisms, adhesion of dental restorative materials, bite forces and stress on teeth and dental restorations, failure prediction in synthetic and biological materials.
- Structure of dental hard tissues and evolutionary oral biology research – characterisation of animal teeth and other biological materials to elucidate the biology, evolution and interactions with the environment of fossil and recent species.
- Remineralisation of early caries lesions and development of bioactive materials for caries management.
- Forensic biology - forensic odontology, in vitro modelling of blunt force trauma, wounding and ballistic blood splatter analysis, development of simulant materials for forensic modelling.

In oral implantology, our research focuses on:

- Grafting and regenerative therapies.
- Surface treatments of implants for enhanced osseointegration.
- The effects of implant fixtures corrosion products on periodontal structures.
- Developing ultrasonic diagnostic devices for dentistry.
- Silver and gold nanomaterial technology: developing nanoparticles for use in therapeutic technologies.
- *In vitro* modelling of masticatory forces on implant overdentures, their supporting sub-structures and surrounding bone.

Key personnel

Staff

Dr Carolina Loch
Prof Warwick Duncan
Prof Paul Brunton
Prof Mauro Farella
Prof Karl Lyons
Prof Darryl Tong
Prof Neil Waddell
A/Prof Vincent Bennani
A/Prof Jonathan Broadbent
A/Prof Dawn Coates
A/Prof Mani Ekambaram
A/Prof Sunyoung Ma
A/Prof Andrew Tawse-Smith
Dr Tanmoy Bhattacharjee
Dr Peter Cathro
Dr Joanne Choi
Dr Angela Clark
Dr Gemma Cotton
Dr Kai Chun Li
Dr May Lei Mei
Dr Jithendra Ratnayake
Dr Ian Towle
John Aarts
Ludwig Jansen van Vuuren
Wendy Jansen van Vuuren

Postgraduate Students

PhD
Dina Abdelmoneim
Deanna Beckett
Ambre Coste (Geology)
Asrar Elahi
Christina Gee
Ludwig Jansen van Vuuren

DClinDent
Shafiq Abdul Aziz
Abdelrahman Badarneh
Huda Mohammed
Yu-Lynn Lee
Suneil Nath
Raj Singh
Sunethra Tennekoon

MDentTech
Vidya Mudliar

How hard can you bite? Bite force analysis (L Jansen van Vuuren)

Current research projects

Development of novel white shell crowns for dental caries treatment in deciduous teeth

Dental caries is the most common chronic childhood disease in New Zealand. Traditional treatment involves surgical removal of the infected dental tissues and restoration using a filling material. The Hall Technique (HT) is known as a 'no-drill, no pain' restorative procedure using metal preformed crowns (PFCs). Although effective clinically, this technique has an aesthetic limitation—the crown is silver rather than tooth-coloured. The metal PFCs also have other disadvantages: cost to healthcare providers is high and placement can be difficult. Our research team has successfully developed a novel white shell crown system for the Hall Technique, improving both aesthetics and crown placement, while reducing treatment costs.

Aim: To develop novel white shell crowns for dental caries treatment in children using the Hall Technique.

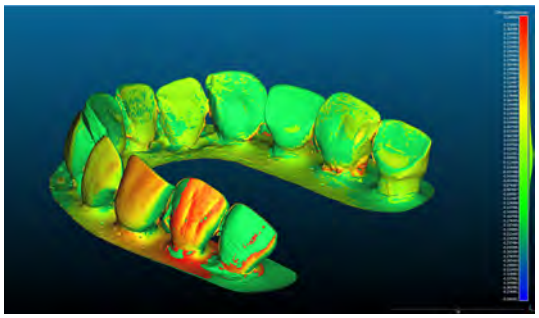
Source(s) of funding: Cure Kids Innovation Seed Funding, University of Otago Research Grant.

Mucosa sensor development for edentulous patients

Complete tooth loss (edentulism) results in difficulty in eating, speaking and socialising. Removable complete dentures, however, are associated with a high failure rate and appreciable pain, leading to tissue damage (denture stomatitis and traumatic ulcers) and bone resorption. Thus, patients often need to have their dentures relined or remade, which could be time-consuming and expensive. The real-time measurement of pressure distribution underneath dentures has always been a challenge within both clinical and lab set-ups. An accurate measurement of the contact pressure induced by the denture insertion could significantly influence optimization of prosthetic design. This could also lead to development of patient-specific solutions targeted at minimizing the occurrence of residual ridge resorption and traumatic oral lesions. The impact of different denture designs on the load distribution across oral soft tissues has been studied in a few cases. However, when it comes to researching the human stomatognathic system, simulation models need to be constructed in order to improve our understanding of the biomechanics.

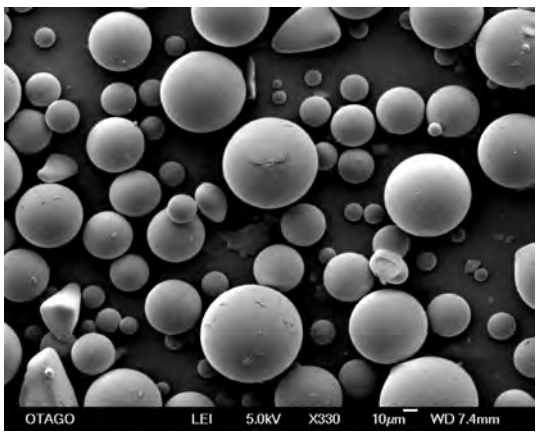
Aims: To measure real-time pressure distribution on the oral mucosa, induced by complete dentures using a novel wireless pressure sensor, an anatomically accurate chewing robot and a jaw simulation model, which will be validated against clinical data, also obtained from this project.

Source(s) of funding: Maurice and Phyllis Paykel Trust, University of Otago Research Grant.



Above: Comparison of mesh distance between different intra-oral scanning conditions (KC Li).

Below: SEM image showing the size range and spherical morphology of glass beads used to polish material in a sand-blasting process (JN Waddell)



Collaborations

Within the University of Otago

Department of Geology, Department of Chemistry, Department of Anatomy, Department of Zoology, Department of Marine Sciences

National

Department of Mechanical Engineering, University of Canterbury; Van Der Veer Institute, University of Canterbury; Department of Engineering Sciences and Department of Mechanical Engineering, Auckland University; Forensic Science Department of Environmental Science and Research; South Island Brain Injury Research Group

International

University of Hong Kong; The University of Western Australia; University of Adelaide School of Dentistry; Impact and Armour Group, Cranfield University /Defence Academy of the United Kingdom; University of the Witwatersrand, South Africa; South African Nuclear Energy Corporation in Palindaba; Tokyo University of Agriculture and Technology; Facharzt für Rechtsmedizin, Institut für Rechtsmedizin, Germany; University of Kent Canterbury, UK; Université Bordeaux, France; Hampden-Sydney College, USA; South Australian Museum Adelaide; Centro Nacional Patagonico, Argentina; Universidade Federal de Santa Catarina, Brazil

We also have **commercial research relationships** with HiTem Korea Ltd, EPD Korea, PackIt Ltd (Dunedin), Kamahi Electronics (Dunedin).

Dental materials

This activity aims to evaluate specific issues associated with a range of dental materials, from composite resin systems to advanced ceramics. Focus on mechanical properties of dental ceramics and their reasons for failure, with an interest in fractography and analysis of failure in brittle materials. A more recent novel area is the silver and gold nanomaterial technology group, which is developing nanoparticles for use in a range of therapeutic technologies.

Aim: Provide basic information about these materials that enables their usage in clinical settings and the development of new treatment technologies and materials.

Source(s) of funding: Neurological Foundation Research Grant, Maurice and Phyllis Paykel Trust, ANZAOMS Research and Education Trust, New Zealand Dental Research Foundation, Otago Innovation, University of Otago Research Grant, SJWRI and proprietary funding.

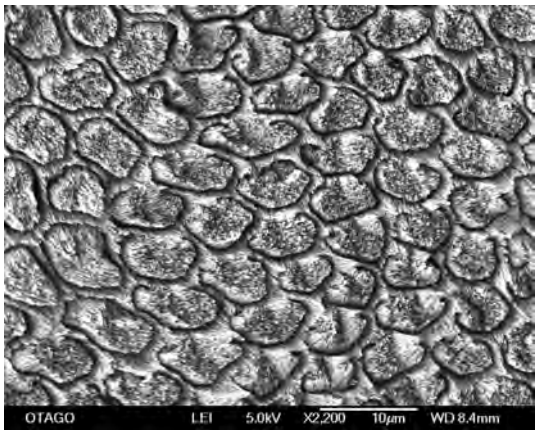
Soft and hard tissue biology, biomechanics and forensic biology

Teeth and bone are special tissues as they preserve a record of their formation in the adult structures. The examination of adult morphology can be used to reveal some of the developmental processes involved, and perturbations of such processes. By studying teeth and other biological materials, we aim to understand the biology, life history, evolution and interactions with the environment of fossil and recent species. Comparative dental morphology and ultrastructure are key elements of this activity. This knowledge can then be linked to clinical findings that can result in better therapeutic outcomes.

Our research has mainly been focused on the structure and function of enamel and dentine in different species, the forces generated during swallowing, and the behaviour of skin and bones during events such as ballistic and blunt force trauma.

Aims: To investigate the basic properties of skin, bones and teeth, to elucidate broad aspects of evolutionary oral biology, comparative dental morphology related to the craniofacial region and forensic issues.

Sources of funding: New Zealand Dental Research Foundation, Leverhulme Fund (UK), Lottery Health Research, University of Otago Research Grant, Otago Medical Foundation Laurenson Award.



Prismatic enamel in the polar bear (C Loch)

Oral implantology and associated superstructures

Our research teams have conducted clinical (human) and preclinical (animal) trials and laboratory-based research related to oral implants. Currently, funded research is being conducted into different oral implant systems, materials, surfaces, superstructures, and surgical and restorative protocols, as well as supporting biological and regenerative products.

Our research encompasses immediate placement and/or loading of single implants and implant-supported over-dentures, fit of zirconia prostheses, implant analysis using Micro-CT, and analysis of different implant systems and bone placement grafts in sheep jaw, femur and maxillary sinus models, in vitro modelling of strain distribution within implant overdentures and their supporting sub-structures and bone, in vivo analysis of implant fixture corrosion.

Aims: Evidence-based treatment that reduces the interval between implant placement and loading, by optimising the implant design and the surgical and prosthodontic protocols and materials.

Source(s) of funding: New Zealand Dental Research Foundation; JF Fuller Foundation; International Team for Oral Implantology ITI Switzerland; Straumann AG, Switzerland; NobelBiocare Australia; Southern Implants, South Africa; Korea Science and Engineering Foundation (KOSEF), Megagen Co Ltd., South Korea; Osstem Co. Ltd, South Korea; Neoss Australia Ltd; Keratec Ltd NZ.

Key funding successes

2019

$97,858. Biorhythm of Childhood Growth. Leverhulme Fund (UK). (PI: C Loch)

$57,000. University of Otago Research Grant. Development of 3D-printed crowns to enable non-invasive treatment of dental caries in primary teeth. (PI: KC Li, G Cotton)

$52,500. Lottery Health Research Equipment Grant. A 3D Bioprinter for Tissue Engineering Research in Dentistry. (PI – Coates D, CI – Li KC, Duncan W, Waddell JN, Cannon R, Lyons K, Rich A, Early W, Farella M).

$44,900. University of Otago Research Grant. Investigation of pressure distribution in edentulous patients: Development and validation of simulation systems. (PI: J Choi, CI: S Ma, N Waddell, P Xu)

$25,931. University of Otago Research Grant. Dolphin teeth as a biomonitoring tool of heavy metal exposure. (PI: C Loch, CI: C Kemper (South Australian Museum), J Palin (Geology), K Stockin (Massey University), M Taylor (Macquarie University)

$15,000. New Zealand Dental Research Foundation. A 3D bioprinter for tissue engineering research in dentistry. (PI – Coates D, CI – Li KC, Duncan W, Waddell JN, Cannon R, Lyons K, Rich A, Early W and Farella M)

$15,000. Colgate Palmolive Limited (NZ). Changes in mineral density and nanomechanical properties of enamel white spot lesions. (PI: M Ekambaram, C Loch, A Meldrum).

$15,000. New Zealand Dental Research Foundation. Biomimetic Remineralization: A comparative evaluation of novel peptide-based agents for enamel regeneration. (PI: M Ekambaram, CI: KC Li).

$14,455. New Zealand Dental Research Foundation. The effect of mechanical decontamination procedures on moderately roughened titanium surfaces: quantity and size of the titanium particulate released by mechanical instrumentation. (PI: A Tawse-Smith, CI: W Duncan, A Yu-Chieh Kao, S Ma).

$12,335. New Zealand Dental Research Foundation. Development and characterization of a novel Hydroxyapatite-Silicate cement for use in dental pulp capping. (PI: P Cathro, CI: J Ratnayake, D Yong)

2020

$100,000. MedTech Core. Overcoming dental anxiety with needle-free tooth anaesthesia. (PI: A Taberner (UoA), CI: B Ruddy (UoA), J McKeage (UoA), P Brunton, C Loch, D White (AUT)

$29,488. University of Otago Research Grant (Early Career). Aerosol generation level by different dental high-speed handpieces (PI - Choi J, CI: Waddell JN, Choi J Moffat S)

$15,000. New Zealand Dental Research Foundation. Development and optimisation using supercritical fluid CO2 extraction of bovine bone for oral block grafting. (PI – Duncan W, CI – Waddell JN, Elahi E, Li KC, Coates D).

$14,900. New Zealand Dental Research Foundation. An in vitro study of accuracy of partial denture frameworks fabricated using traditional and digital workflows (PI – S Ma, CI: J Choi, S Salis)

$14,215. Cure Kids Discretionary Project Grant. Development of white crowns to treat dental caries in children, Phase 2. (PI – Choi J, CI – Waddell JN, Foster-Page L, Duncan WJ).

$10,860. New Zealand Dental Research Foundation. Evaluation of mechanical properties, wear behaviour and polishability for occlusal splints fabricated using various manufacturing methods. (PI – Choi J, CI – Waddell JN, Ma S, Grymak A).

Awards

International Association of Dental Research, Joan Chong Award in Dental Materials (ANZ Division) 2019 – Dr J Choi

University of Otago Early Career Award for Distinction in Research 2019 – Dr C Loch

International Association of Dental Research, Oral Biology Award (ANZ Division) 2020 - Dr M Mei

International Association for Dental Research, Centennial Emerging Research Leaders Award 2020 – Dr C Loch and Dr M Mei