# NEWSLETTER – AUGUST 2009

**Content:**



## 1. NEWS FROM THE VAN DER VEER INSTITUTE (BY MAGGIE-LEE HUCKABEE)

New students coming into my group in July:
Aamir Al-Toubi comes to us from Oman. He completed his BSLT with honours at Canterbury and will now initiate his PhD studies after a short return home. He will likely be studying neural contribution of the primary motor cortex in swallowing motor control.

Steffi Bauer is a student at University of Hildesheim and will be completing her thesis research in our laboratory. Steffi will be studying the influence of resistance exercise on floor of mouth muscle dimension and hyoid elevation using ultrasound.

Two conferences of note:
Mark your calendars for the 18th Annual Meeting of the Dysphagia Research Society on March 4th – 6th in San Diego California. Great interdisciplinary meeting focusing on both impaired and normal swallowing processes. And in San Diego…great Mexican food with the Mexican border and tequila in abundance just around the corner.

For anyone that might be interested, Maggie-Lee offers a two week intensive course in dysphagia diagnosis and management to primarily practicing speech language therapists within NZ, but occasionally others attend as well. This year the course will be offered Nov 16-21 for the first week and Jan 18-23 for the second week….both weeks, Monday through Saturday from 9-4:30 or so. Cost for both weeks $650. Please contact Maggie-Lee if you are interested.

## 2. SOFTWARE AND GRAPHIC USER INTERFACE FOR ANALYSIS OF HUMAN CHEWING MOTION (BY PETER XU)

An intern, Mr Vincent Parinet, from Ecole Nationale Superieure D'Ingeniurs De Lomges, France is now at Massey University Albany, working on the software and graphic user interface (GUI) for analysis of human chewing motion. The input is the data of the magnetic sensors placed on the teeth and head, in terms of 3D coordinates, which are given in the coordinate system defined in the Articulograph AG500. A number of channels of data can be fed into the software, where the data noises are also filtered out. The output, which can be chosen in GUI by user, will include 3D trajectories of incisor, molar or any tooth you choose, frequency/magnitude/cycle in the beginning or end of the chewing process, velocity/acceleration at any time instant. The output will be defined in a reference coordinate system rigidly fixed on the mandible. With this reference system in hand, many mastication measurements can be compared, with a consistent base, within subjects and between subjects.

Vincent is a second year engineering student back in France. He started the project on 22 June and will leave New Zealand in the middle of September. Peter Xu, Kylie Foster and John Bronlund are his supervisors.

## 3. 3RD ANNUAL BIOMOUTH SYMPOSIUM (BY KYLIE FOSTER)

A great time was had by all at our Biomouth Symposium held in the very crisp Dunedin on the 10th and 11th June 2009. A big thank you to Peter Lucas for being our keynote speaker, not only for the interesting talk you gave on the mechanical interaction between food and teeth but also for the stimulating conversations had over coffee over the two days. It was great to have the Canterbury group join us this year and Maggie-Lee has kindly agreed to host the symposium next year. The abstracts are attached at the end of this newsletter. And now for some photos…

Figure 1: Maggie-Lee Huckabee and students along with Otmar Nitsche and Peter Lucas.

Figure 2: Peter Lucas.

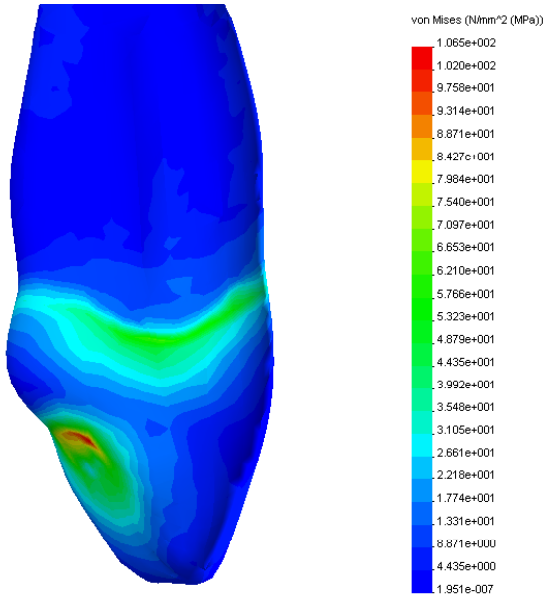
# 3Rd ANNUAL BIOMOUTH SYMPOSIUM

## 10-11 June 2009
## Sir John Walsh Research Institute
## Faculty of Dentistry, University of Otago

VENUE
Room 123 HUNER CENTRE

PROGRAMME
*Wednesday*
2-4 Registration and collaboration planning
4.00 Cocktails
7.00 Symposium Dinner

*Thursday*
9-10.30 Opening & keynote
10.30-11 Coffee
11-1.00 Presentations
1- 2.00 Lunch
2- 4.00 Presentations




## GUEST LECTURER: PETER LUCAS
## GEORGE WASHINGTON UNIVERSITY
## Organiser : Jules Kieser

# Mechanical interactions between food and teeth

Peter Lucas[1], Paul Constantino[1], James Lee[2], Herzl Chai[3], Brian Lawn[2]
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An understanding of the structure and function of the human dentition has suffered because the teeth are now divorced from their environmental context. Ever since cooking and other processing techniques became established (practices with probable considerable antiquity), eating became easy on the mouth. Feeding for other animals is very different: it is a long drawn-out fight. Foods resist fracture because the plant and animal tissues that happen to end up inside mouths are, with the exception of fruit flesh, not intended to be eaten. They are thus defended. The teeth of mammals contact food particles aiming to fracture them, but in so doing they must try themselves not to be damaged. Mechanical tooth-food interactions are repeated thousands of times daily, so dental injuries are inevitable. My question here is: does thinking this way lead to the discovery of any interesting structural mechanisms in human teeth? The research reported here concerns the problems of feeding on hard seeds or nuts (such as hardly exist in the modern human diet, but could plausibly have been a major part of the diet of our ancestors) and compares the outer layers of such foods and the outer layer of teeth: the enamel. Enamel is intricate. Its basic structural unit, the rod (or prism), is an elongate multi-crystalline structure partially bound by an organic sheath. Rods begin close to the dentinal junction, traversing almost to the outer surface of the teeth. Sometimes rods are straight, but often they display a 'planar crimp', a wave restricted to one plane. Adjacent bundles of rods wave slightly out of phase, with progressive change across a region referred to as 'decussation' (crossing). Decussation is a marked feature of the enamel of many mammals, with a wide variety of patterns documented: (i) radial enamel in which rods pass in parallel towards the surface without deviating, (ii) enamel with decussation restricted to the region close to the dentine (as in modern humans), and (iii) enamel where decussation is all-pervasive. Seed/nut shells composed of (sclerenchyma) fibres broadly mimic enamel rods showing all these structural variants. One thick shell discussed here (that of *Mezzettia parviflora*, Annonaceae), has the same fibre arrangement as the rods of human enamel, with 'decussation' only in its deep aspect. Why? A potential answer is when such a seed is eaten by a mammal, fractures are most likely to initiate on the deep surface. 'Decussation' does not stop the cracks initiating (the best prevention is probably shell thickness), but it does help to arrest them. Such 'radial' cracks are well-known in bilayered structures. Mammals that feed on hard objects may need to resist radial cracks in their enamel. Thick enamel with deep-seated decussation is human: so could such a diet have typified our ancestors? Several lines of other evidence for fossil diets will be outlined in the talk, but a key difference between nutshells and enamel needs stressing. Shells quickly fragment when fractures reach the surface. However, enamel does not, even though nutshells are only broken once by a predator, while the predator's tool kit (i.e. its teeth) is used repetitively. It appears that enamel possesses an intricate arrangement of flaws that, paradoxically, frustrate catastrophic failure of the tooth crown. These flaws (actually, tufts) run through deep enamel resembling pre-critical radial cracks. Recent work suggests that when stresses becomes high enough, protein-filled tufts may crack in 'droves', the strategy apparently being that parallel enlargement of many flaws frustrates the critical growth of any single one of them. On relief from stress, tufts gradually close up again. Such a mechanism seems novel.

# Assessment and Prediction of Bone's Responses to Dental Restorations

Qing Li[1], Daniel Lin[1], Clarice Field[1], Chaiy Rungsiyakull[1] and Michael Swain[2]
[1]School of Aerospace, Mechanical and Mechatronic Engineering,
The University of Sydney, Sydney, NSW 2006, Australia
[2]Faculty of Dentistry, The University of Otago, Dunedin, New Zealand

The ability to assess the effects of dental implants and fixed partial denture (FPD) on bone's responses is of particular importance for prosthesis placement planning and associated treatment assurance. Prediction of on-going osseointegration and/or bone remodelling will enable us to improve the performance of a restoration for maximising longevity. Although the bone remodeling laws for long bones had been extensively studied, there have been relatively few studies for dental bone remodelling. Recently, we developed a systematic protocol to simulate mandibular bone remodeling induced by two most typical dental restorations of implantation and fixed partial denture, which extends the remodeling algorithms well-established for the long bones into the dental scenarios.

The remodelling studies showed that the difference of biomechanical signal determines the bone's engagement of turn-over. In this study, the finite element analysis technique is used to quantify the level of biomechanical responses that drive bone remodelling. Strain energy density (SED) or equivalent strain is used as mechanical stimulus in our study. An iterative algorithm is developed to simulate the change in bone density, in which the current bone density distribution is updated to a new level by using the difference of SED or equivalent strain in terms of using the Euler forward approach. The remodelling parameters were determined by progressively relating the remodelling results (density contour) against the clinical X-ray or in-vivo resonance frequency test results.

The simulated bone remodelling result induced by the dental implant is compared with the clinical follow up. The similarity of bone density contours between the prediction and the X-ray follow-ups is clearly observed. The FPD remodelling results are compared against computerised tomograph (CT) data and also a clear correlation is obtained.

The computational framework of dental bone remodelling established provides a new means to the assessment and prediction of bone's response to dental restorations, which could form a tool of design of prosthetic devices in the future.

# Surface Acoustic Wave Evaluation of Human Dental Enamel

Hsiao-Chuan Wang[1*], Simon Fleming[1], Yung-Chun Lee[2], Sue Law[1], Michael Swain[3]
[1]Insititue of Photonics and Optical Science, School of Physics, University of Sydney, NSW 2006, Australia
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[3]Faculty of Dentistry, University of Sydney, NSW 2006, Australia

Application of a laser ultrasonic non-destructive evaluation (NDE) method for clinical dental diagnosis is an attractive possibility for replacing current examination techniques that are either destructive or impractical for *in-vivo* inspection. In this presentation an optical NDE system that can perform remote elastic modulus evaluation of small sample dimensions is presented. A low energy focussed laser pulse is used to generate broadband surface acoustic wave impulses of surfaces of materials. A focused laser line-source is used to generate acoustic surface or Rayleigh waves which are detected with a simplified non contacting optical fibre interferometer. The measured surface wave velocity dispersion spectrum is in turn utilised to characterise the elastic response of the specimen. Different metal and coated structures were measured to verify the system performance. The results agree well with theoretical values and confirm the reliability and accuracy of the laser NDE system. This technique was then applied to evaluate the surface of sound natural human dental enamel. The measured dispersion spectra match theoretical expectations and the influences of both the enamel and the underlying dentine on the surface wave propagation were observed. This is the first time, to the best of our knowledge, that a laser based surface wave velocity dispersion technique has been successfully applied on human dental enamel. The possible extension of this device for in

# Monitoring tongue movement during feeding using an articulograph (AG-500)

Hongyan Yao[1], Kylie Foster[1], John Bronlund[2]
[1]Institute of Food, Nutrition & Human Health, Massey University, Auckland, New Zealand, [2]School of Engineering and Advanced Technology, Massey University, Palmerston North, New Zealand

A Carstens articulograph (AG-500) was used to monitor the tongue movement during the consumption of liquid and semisolid food. One subject consumed constant volumes of water, full fat milk and yoghurt. 5 sensors were fixed on the front of tongue surface, 3 reference sensors were fixed to the upper incisor and behind both ears. The AG-500 recorded the positions of sensors during food consumption. The signals were converted to positions and head movements removed using associated software. Similar movements were obtained for the 5 replicates of each food. In contrast, some differences were seen between the different foods tested, e.g., displacement of the tongue in the anteroposterior direction was greatest during the consumption of yoghurt. Preliminary work also showed that the viscosity of liquid and semisolid foods effect the volume that the subject is comfortable to ingest. It was also observed that sensors and wires may restrict tongue movement during consumption of semisolid food.

# Strain distribution in the human mandible as a result of misfit of fixed partial Implant-supported prosthesis. A preliminary study.

Jaafar Abduo[1] Vincent Bennani[1]/ Neil Waddell[1]/ Karl Lyons[1]/ Michael Swain[1]
[1]Department of Oral Rehabilitation, School of Dentistry, University of Otago, 310 Great King Street, Dunedin 9016, New Zealand.

**Objectives**: The purpose of this study was to quantify the pre-load stress developed on the peri-implant bone and the prosthetic framework as a result of misfit using a recently developed mandible replica.

**Materials and Methods**: A master model was fabricated by placing two implants in a CT derived resin mandible with properties closely matched to those of natural bone. The implants were inserted in the position of the 35 and 37. The mandible with the implants was scanned by CAD system for resin framework fabrication. Vita CAD-Wax was milled by CAM system with the design of long beam and for screw retention. 4 linear strain gauges were bonded around each implant on the peri-implant structures as close to the implant neck as possible. 2 linear strain gauges were bonded on the middle of the framework. The misfit-induced microstrains were recorded as the framework was fixed by screwing the retaining screws to the required torque (10 Ncm). The results were simultaneously monitored from a computer connected to data acquisition system (PowerLab). The microstrain measurements were converted to stress values.

**Results**: Stress values increased gradually as the screws were tightened to the required torque till it reaches the plateau as the tightening is accomplished. On the mandible some sites were in compression and others were under tension. Stress values ranged from 6.4 MPa for compression to -6.9 MPa for tension. On the framework, the 2 strain gauges recorded tensile stresses of up to -6.8 MPa.

**Conclusion**: From these results, this method is a valid and reliable means for quantifying the stresses that resulted from screwing a framework without passive fit. This in vitro method will provide more clinically relevant results regarding the distortion of the framework and the peri-implant structure by using a model of similar anatomy and physical properties of real mandible.

# A food classification approach based on the principal mechanisms occurring during oral processing.

Eli M. Gray-Stuart[1,2], John E. Bronlund[1,2], Jim R. Jones[2], Robert I. McLachlan[1,3], Jason P. Hindmarsh[1,4]
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[2]School of Engineering and Advanced Technology, Massey University, Private Bag 11222, Palmerston North, New Zealand
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[4] Institute of Food Nutrition and Human Health, Massey University, Private Bag 11222, Palmerston North, New Zealand.

The mastication process is complex, involving many processes to transform food in its initial state to a safe to swallow bolus. Particle size reduction, moisture addition, particle dissolution, moisture absorption, loss of particles and oral fluid can all occur concurrently. The relative rates of these processes vary significantly with the structure and physical properties of the food. These processes when broken down and looked at individually are analogous to well understood and researched process engineering applications.

It is desired to develop and adapt well established models from chemical and process engineering literature that will enable the changes undergone by food during mastication and bolus formation to be predicted.

To develop a single ‘one size fits all’ model to predict and model food oral processing for a range of foods is an improbable task. A sensible approach is to assess foods and categorise them into groups according to the most relevant processes occurring during mastication. This approach will greatly simplify the modelling process, making sound engineering assumptions and disregarding effects that are of little consequence to the final ready to swallow bolus.

This paper presents a classification system for foods based on the relevant mechanisms occurring during mastication that cause alterations to food structure. The proposed classification system will form the basis of mathematical model development for food chewing.

# Jaw Exoskeleton for Jaw Motion Disorders Rehabilitation, a Review of the Devices

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[1] School of Engineering and Advanced Technology, Massey University, Auckland, New Zealand
[2] Creative Industries Research Institute, Auckland University of Technology, Auckland, New Zealand

Jaw motion disorder refers to the state in which patients are not able to open their mouths to the extent that gives them full function. In medicine, it is also termed mandibular hypomobility. Causes of mandibular hypomobility are various, but include musculoskeletal dysfunction due to stroke, trauma, head and neck cancers, irradiation by radiotherapy, surgery around the temporomandibular joint, TMD (temporomandibular disorder), and neurologic factors. Patients with myasthenia gravis (severe muscle weakness) in the area of the mastication system may also have difficulty in chewing and they need support of the jaw during daily practice. The causes of the mandibular hypomobility are briefly reviewed in this paper.

Exercise is regarded as the most effective means to recover the range of motion and function of the mandible. The mechanism of such exercise is briefly introduced in this article. CI (constraint-induced) therapy movement and CPM (continuous passive movement) are used in the rehabilitation of the neuro-functions and physical-structures, respectively.

With continuous exercise being pursued and objective of rehabilitation, some kind of portable jaw exercising therapeutic device based on CPM have been developed as a solution to increase the range of motion, reduce the stiffness and alleviate the pain caused by repetitive work that can easily be done by devices. A critical and comprehensive review of such devices developed so far is conducted for improving the limitation of the jaw-opening. Jaw exercisers and dental robots for rehabilitation of jaw disorders are discussed with respect to their physical model, function, structure, together with their accomplishment and what improvements could be made.

Although most devices on the CI movement therapy basis aimed at patients with disabled limbs have been developed to accomplish intensive therapy that lasts for a long time, which are imperative in regenerating the CNS cells; no devices aimed at recovering the functions of the jaw have been invented.

Also reviewed in this paper is the mastication system including its kinematics and dynamics. Several kinematic models have been used to describe the movement of the mandible both in 2D and 3D, and a dynamic model of the masticatory system is presented as well. As mandibular movement is a complex motion consisting of both rotation and translation randomly with 6 DOF in 3 dimensions, the mastication system can be regarded as kinematically and mechanically redundant.

Passive motions and active support are expected to be realized in one device that generates continuous movement to function in the area of masticatory system. The jaw exoskeleton, a new concept for a device aiming at rehabilitating jaw disorders and assisting jaw-movement in cases of patients unable to drive their jaw, is designed to be worn by human to meet all of their needs.

Through the characteristic of the mastication system and the existing devices for jaw rehabilitation, requirements to design the jaw exoskeleton are elicited. And finally, a new prototype of jaw exoskeleton is described with its structure and is compared with the previous devices.

# Effect of pre-processing of rice on chewing aspects and in vitro starch digestibility

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[2]School of Engineering and Advanced Technology, Massey University, Private Bag 11222, Palmerston North, New Zealand

Rice is one of the staple energy-based foods consumed worldwide and is most commonly consumed as a whole kernel. The common pre-processes used in rice production are de-hulling (brown rice), milling (white rice) and parboiling (parboiled rice), each of which have varying texture, hardness, and chemical composition. Food digestion begins with chewing and can be highly variable depending on a number of factors such as individual preference/habits and the properties of the food itself (texture, hardness, and size) which are in tern affected by the processing methods used in production. Several studies have been documented on the effect of the pre-processing of rice on eating quality, chemical compositions and nutritional values, but no investigation has been done on the influence of these pre-processing methods on the chewing behaviour, bolus properties, and thus on starch digestibility. Understanding these linkages will be the focus of a new study currently about to commence.

The study will investigate long grain (Jasmine) rice samples obtained from three different processes (white, brown, and parboiled). Ten subjects will be involved the study, each chewing and expectorating a number of boluses to allow characterisation of masticatory behaviour and bolus properties. The subjects will be selected from people who use rice as a key component in their everyday diet. During each session the chewing time, number of chewing cycles used will be recorded. Food boluses will be collected and used for particle size analysis, moisture content, starch leaching rate, and total starch measurement. The *in-vitro* rate of starch digestibility from different cooked rice samples and boluses will also be compared. Preliminary experiments carried out on one of the authors are presented for particle size distribution, starch leaching rate and bolus moisture content. The results obtained revealed that pre-processing of rice was likely to affect chewing behaviour, particle size distribution, and alters the chemical composition such as moisture content, total starch, and starch leachability which may influence the starch digestibility. The preliminary results suggest useful information will be collected

# Implementation of a humanoid controlling algorithm for a chewing robot

Otmar Nitsche[1], W.L. Xu[1], Kai Müller[2]
[1]School of Engineering and Advanced Technology, Massey University, Auckland, New Zealand
[2]Hochschule Bremerhaven, Bremerhaven, Germany

Within a half year project in 2008, the chewing robot EMMA (Extraordinary Massive Mastication Apparatus) was improved. The final adjustments of the hardware and the controlling algorithms are explained and discussed regarding the data gathered by experiments.

The 1 DOF robot is driven by two artificial pneumatic muscles controlled by two proportional valves. The feedback signal is realized by three thin sensors for measuring the force and an optical encoder for determining the actual position of the jaw. The electric signals are processed by a customized electronic board and fed into a PC.

The main focus of the project was the implementation of a Neuronal Network, first developed by Kiyotoshi Matsuoka in 1987. This network is modelled in Mathworks Matlab and evaluates the sensor response and generates the corresponding controlling signals for the proportional valves.

Although the robot still needs some improvement, we showed clearly that the Matsuoka Neuron Network is capable of generating a humanoid controlling signal able to run a physical device and adapt quickly on new circumstances.

The project was awarded with the “study price 2008” by the VDE (German Association for Electrical, Electronic & Information Technologies) in February 2009.

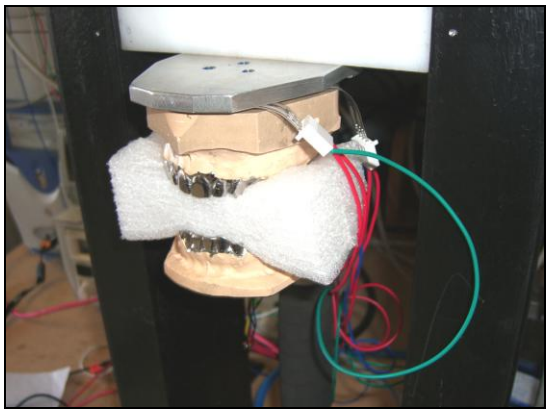

FIG.1: EMMA IS CHEWING A TEST OBJECT.

# Modelling the tongue movement with intrinsic and extrinsic muscles.

Yikun Wang [1], Martyn Nash [1, 2], Oliver Röhrle [3], Andrew Pullan [1, 2], Poul Nielsen [1, 2]
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The tongue is a dextrous organ. Because of its complicated structure and shape, and its limited visibility, its biomechanical function poorly understood. One of the challenges of modelling the biomechanical behaviour of the tongue is its complex material description, in particular the fact that the tongue is made up of several different muscle groups of which three exhibit interlacing muscle fibres in much the same way as woven textiles. The purpose of this work is to develop a 3D finite element model of the tongue, which includes an anatomically realistic description of the muscle fibre distribution, in order to investigate the complex deformation patterns of the tongue during normal mastication, swallowing, and speech production.

In this presentation, an anatomically-based, three-dimensional, computational model of the human tongue is described. The large deformations of the tongue stemming from its complex movements are described using the governing equations of finite elasticity, which are solved using the finite element method with tricubic Hermite interpolation functions. The material properties of the tongue are modelled using a multi-fibre-reinforced hyper-elastic material description superimposed with active contractile properties along the fibre directions. For this purpose, the second Piola-Kirchhoff stress tensor is constructed by augmenting an isotropic component, which represents the ground matrix of the tongue, with additional fibre stresses stemming from the respective passive and active components of each muscle group, respectively. The model is implemented and tested using CMISS, a finite element software package developed at the University of Auckland.

The activation of specific muscle fibre groups qualitatively reproduced simple but realistic deformations of the tongue. The influence and biomechanical behaviour of the interlaced muscle fibres within the tongue are studied. The tongue movement that is driven by specified extrinsic muscle also will be demonstrated. Future extensions to this work are using Articulograph AG500 to estimate the activation level of each family of fibre for reproducing the tongue movement and pressure. Then, the customisation of the presented generic tongue model to subject-specific models can be constructed from MRI data.

# Salivary pellicle

Michelle Dickinson
Department of Chemical and Materials Engineering, University of Auckland, Auckland 1142, New Zealand,

The surface of dental enamel is ever changing due to the varying environmental conditions that it is exposed to throughout the day. Two of the most common oral health concerns with respect to the enamel surface are dental caries and aesthetic appearance. Both of these issues have been studied by many researchers; however there is still no complete treatment for either caries or tooth staining prevention.

Salivary pellicle is an organic biofilm formed by the physisorption of proteins and carbohydrates onto the surface of dental enamel exposed to the oral environment. Extrinsic tooth staining can be caused by the reaction of this pellicle layer to dietary components such as tannins found in tea and red wine. The mechanical properties, growth, structure and morphology of pellicle grown *in vivo* on human enamel surfaces have been analysed prior to and post reaction with dietary polyphenols obtained from black tea. The results show a significant difference in the properties of the pellicles such as surface adhesion, and time dependent effects due to polyphenol interaction when measured using nanoindentation. These results suggest that the stained pellicle is mechanically stiffer, but also less viscous and more fluid like. This could explain why traditional tooth brushing techniques do not efficiently remove this darker stained layer.

White spot lesions are formed by the demineralisation of dental enamel due to dietary and bacterial factors which lower the local pH. If progression of this demineralisation continues the enamel structure eventually fails giving rise to a cavity (carie). The use of artificially produced enamel caries allows the study of lesion formation under conditions of highly controlled demineralisation. This provides a fundamental insight into the process of caries formation in enamel. In this study human premolars have been treated with a lactic acid solution to create artificial "caries-like" lesions in the enamel. In the test samples, the lesions penetrated approximately 100 nm into the enamel structure, accounting for one tenth of the thickness of the enamel. Cross sections through the lesion were characterized with nanoindentation, electron probe micro-analysis and time of flight secondary ion mass spectrometry. From the data obtained maps of both mechanical and chemical properties were plotted across the entire width of the lesions. The results show that the lesions have a significantly reduced hardness and elastic modulus in comparison to sound enamel. These changes in mechanical properties were found to correlate with a loss of calcium and phosphate from the structure. There was also evidence of a stronger, less demineralised layer of enamel close to the lesion's surface.

The use of nanomechanical testing on the enamel surface allows unique research into two prominent oral health concerns, and a new understanding for potential treatment and prevention.

# Neurorehabilitation of swallowing impairment: What are we doing when we do what we do?

Maggie-Lee Huckabee[1,2], Sebastian Doeltgen, Phoebe Macrae; Norsila Abdul Wahab, Oshrat Sella, Tessa Goldsmith, Aamir Al-Toubi, Margaret Monroe, Frauke Heck, Steffi Wild, Julie Corbett, Rianda Roetts
[1]Department of Communication Disorders, University of Canterbury, Christchurch NZ. [2]Van der Veer Institute, 66 Stewart St, Christchurch NZ

Swallowing impairment (dysphagia) represents a substantial health issue in New Zealand, presenting as a symptom of multiple medical conditions in childhood (prematurity, birth syndromes), adolescence (head injury) and adulthood (stroke, neurodegenerative disease, head and neck cancer). When looking only at stroke, up to 70% of the approximately 3000 new stroke events each year in NZ will present with dysphagia. Up to 44% of those with dysphagia will have persisting swallowing impairment and aspiration in the post-acute phase. Rehabilitation practitioners have devised behavioural strategies to alter swallowing pathophysiology, primarily through a presumed goal of muscle strengthening. However, strength training for swallowing rehabilitation may not be the most appropriate approach. Swallowing depends primarily on precision and speed of muscle movement rather than strength. Additionally, neurological insult may produce a dysphagia that is not based on weakness, but other neuropathologies as well, such as spasticity, myotonia and the like which have been grievously under-explored in dysphagia research.

The University of Canterbury Swallowing Rehabilitation Research Laboratory is housed in the multi-disciplinary and multi-institutional Van der Veer Institute for Parkinson's and Brain Research in Christchurch.
Our primary research aim is to investigate the neuromodulatory & biomechanical effects of intervention for swallowing impairment. Quite simply: when it's broken how do we fix it? We have suggestions from past research that behavioural intervention has the potential to influence swallowing biomechanics. However we don't possess a good understanding of HOW we influence biomechanics. Therefore our secondary aim: When we fix it, what exactly are we doing? Are we changing muscle? Are we changing brain? Or are we only encouraging compensatory behavioural adaptations?

With a well stocked laboratory of state-of-the-art instrumentation and exceptional post graduate students from around the world, our group has made a substantial dent in the Black Box that is neural control and modulation of swallowing physiology. Electromyography, pharyngeal manometry, endoscopy, sensory testing and neuromuscular ultrasound are a few of the tools used to assess peripheral biomechanics. Recent research is incorporating the use of neuromuscular ultrasound and MRI to document rehabilitative changes in cross-sectional peripheral muscle area. Electroencephalography, transcranial magnetic stimulation induced motor evoked potentials and fMRI allow us to evaluate central and peripheral brain function.

This session will provide a sampling of student researchers and research activity undertaken in the laboratory with the hope of facilitating collaborative links with other research groups within NZ.

# The effects of neuromuscular exercises on biomechanical and neural mechanisms of swallowing: investigations by motor evoked potentials, ultrasound, and manometry.

Phoebe Macrae,[1,2], Richard Jones, [1,2,3,4], Maggie-Lee Huckabee,[1,2]
[1]Department of Communication Disorders, The University of Canterbury, [2]Van der Veer Institute, [3]University of Otago, [4]Canterbury District Health Board, Christchurch, New Zealand.

Swallowing impairment (dysphagia) negatively impacts survival and quality of life, therefore development of innovative and effective rehabilitative techniques is crucial. Swallowing rehabilitation techniques are commonly prescribed after neurological insult, but with very little understanding of their effects on certain swallowing parameters. Recent studies have shown that some rehabilitation techniques have an inhibitory effect on swallowing execution. Effortful swallow and head-lift manoeuvre are neuromuscular exercises used frequently in the management of dysphagia. The efficacy of both head-lift manoeuvre and effortful swallow has been demonstrated through investigations of immediate biomechanical changes in swallowing that occur during execution of the techniques. Such measures are indicators of relatively short-term adaptations and do not provide an understanding of how neural and biomechanical mechanisms are influenced by cumulative effects of behavioural techniques. This study represents a first step in documenting the modulation of swallowing parameters as a cumulative function of neuromuscular rehabilitation techniques used in dysphagia management.

40 healthy volunteers aged 50 years and over and 10 patients at least 3 months post-stroke with chronic dysphagia will be included in this study. Participants will be assigned to one of two treatment groups: head-lift manoeuvre or effortful swallow. Initial sessions will be completed to obtain several baseline measures prior to initiation of a 6-week exercise programme. Baseline sessions will involve the following measurements: submental muscle motor evoked potentials (MEPs) triggered by transcranial magnetic stimulation (TMS); pharyngeal and upper esophageal sphincter (UES) pressures measured with pharyngeal manometry; submental muscle area measured by ultrasonography; and submental muscle activation measured using surface electromyography (sEMG). The 6-week exercise programme will consist of 33 repetitions of the given exercise, 3 times daily, 5 days a week. On completion of the exercise programme, participants will return for outcome measures consisting of the same procedures as the baseline session outlined above. Changes in these measures will be described as a function of technique.

This study will provide insight into how multiple levels of swallowing behaviours may be influenced by dysphagia rehabilitation techniques. On a morphological level, changes in muscle size will be documented, while adaptations in the movements associated with effective swallowing will provide biomechanical evidence, and neural adaptations elucidated with TMS induced MEPs.

The information gleaned from this research will contribute to the limited knowledge base of the cumulative effects of rehabilitation techniques on various swallowing parameters.

# Effects of olfaction and gustation on motor-evoked potentials of the submental muscle group associated with swallowing behaviour.

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Smell and taste are used in managing patients with dysphagia; however, the mechanisms of how they influence swallowing are not clear. Sour taste has been shown to modify swallowing behaviour, albeit with contrasting effects among studies. This project aimed to evaluate the effects of odour and tastant on amplitude and latency of motor-evoked potentials (MEPs) from the submental muscles, which were evoked by transcranial magnetic stimulation (TMS). This information may provide support for the use of sensory stimulation in dysphagia management.

Sixteen volunteers (8 males; age range 19-43) participated in this study. 25% and 100% concentrations of lemon concentrate were presented separately as olfactory and gustatory stimuli. The olfactory stimulus was nebulized and presented via nasal cannula inserted into both nares. Filter paper strips impregnated with the lemon concentrate and placed on the tongue served as the gustatory stimulus. Tap water was used as placebo. 15 trials of TMS-evoked MEPs triggered by volitional contraction of the submental muscles or volitional swallowing were measured at baseline, with placebo, during stimulus presentation, and immediately, 30-min, 60-min, and 90-min poststimulation. Experiments were repeated using the combination of odour and tastant concentration that most significantly influenced the MEP.

Repeated-measures ANOVA were performed to evaluate the main effect of concentration (low, high, and combined stimulation) and time (computed separately with or without stimulus presentation during MEP recordings) on both odour and tastant during volitional contraction and volitional swallowing. The test on volitional contraction revealed no significant main effect of either concentration or time on MEP amplitudes or latencies. Repeated-measures ANOVA on volitional swallowing also revealed no significant main effect of either concentration or time on MEP amplitudes or latencies. Analyses of individual data, however, suggest that individuals responded quite differently to stimuli thus negating a significant group effect. Additionally, t tests were performed as other research reported MEP changes at 30- and 60-min poststimulation. T tests for MEP amplitude during swallowing showed differences at 30- and 90-min poststimulation when combined stimulation was given [$t(8) = -2.48$, $p = .04$; and $t(8) = -3.37$, $p = .01$; respectively].

This study revealed no significant effect of odour or taste on MEP amplitude and latency across healthy participants. However, combined odour and taste stimulation (flavour) altered motor evoked potential amplitude. A follow up study is now underway to define biomechanical changes produced by altered MEPs and facilitate translation of these data to clinical dysphagia management.

# Skill vs. strength training in swallowing rehabilitation

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Swallowing impairment, or dysphagia, is a common consequence of stroke and other medical conditions. The most common complications of dysphagia are aspiration pneumonia, malnutrition and dehydration (Schindler et al., 2001). Rehabilitation approaches have been developed to reduce these negative consequences and restore function. The prevalent assumption in dysphagia subsequent to stroke is that impairment is a consequence of weakness, thus most rehabilitation approaches focus on strength training. However, accuracy, speed of reaction and timing of motor events, may be equally if not more important.

This research will evaluate the use of a novel treatment approach, skill treatment, for swallowing impairment. Specifically, we will compare biomechanical effects and, in a smaller sample, neural effects of this treatment compared to the more traditional approach of strength training for swallowing management.

40 healthy participants will be randomly assigned into 2 groups: 20 in the skill training (StT) group and 20 in the strength training (SkT) group. Both treatments will be administered using custom designed Surface EMG biofeedback software. The strength training will target increased strength of muscle contraction during swallowing; whereas the skill training will target precision of movement during swallowing; ie…having the participants meet movement targets within a temporal and amplitude plain using submaximal muscle contraction. Treatment for both groups will consist of a single 1 hr session per day, 5 days a week, for 2 weeks. Pre and post treatment measurements include: pharyngeal pressure (amplitude, timing & speed) during saliva swallow and 5ml water swallow using pharyngeal manometry; submental muscle contraction (amplitude and slope) during normal and effortful swallows using sEMG; submental 2 dimensional muscle volume using ultrasound; and hyoid bone displacement (distance and speed) during saliva swallow and 5ml water swallow using ultrasound. Additionally, 20 participants (10 from each group) will be evaluated for changes in cerebral representation using fMRI during saliva & 5ml water swallows.

It is anticipated that both treatment approaches will produce changes in functional swallowing biomechanics (pharyngeal pressure, EMG activity and hyoid displacement), albeit through different mechanisms. StT will produce increased peripheral 2-dimensional muscle area post treatment, suggesting that biomechanical changes are muscularly driven. However, SkT will produce greater changes in cortical representation and pre-motor activation of the supplemental motor area, suggesting that biomechanical changes are due to adaptation of the neural plan underlying swallowing.

# Immediate and longer-term effects of submental *neuromuscular electrical stimulation (NMES)* on pharyngeal pressure generation in healthy individuals.

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Neuromuscular electrical stimulation (NMES) is an emerging treatment for swallowing disorders but its acceptance in clinical practice is perhaps overly enthusiastic. This is especially alarming given conflicting research outcomes and the potential for adverse effects regarding the application of NMES in patients with swallowing problems. There is yet a startling lack of knowledge when it comes to the actual effects that NMES has on biomechanical aspects of pharyngeal swallowing.

The aim of this study is to evaluate biomechanical effects of a previously investigated program for neuromuscular electrical stimulation (Doeltgen, Darlymple-Alford & Huckabee, manuscript in preparation). Since swallowing is considered to be a synergistic motor response, it is hypothesized that the application of the electrical current via surface electrodes beneath the chin may also have an impact on the pharyngeal pressure generation. Specifically this study will to determine 1) If EREstim (event-related stimulation) of the submental muscles influences pressure and/or duration of pharyngeal swallowing; and 2) If there is a gender difference in response to the intervention.

Twenty young healthy subjects (ten females) will be evaluated. Surface electrodes will be placed at midline on the suprahyoid muscles and will serve to deliver a small event-related current while two different electrodes are used to record the activity of the underlying muscles and trigger the stimuli when a pre-determined threshold is breached. A manometer will be inserted into the pharynx and proximal esophagus. The manometry will repeatedly measure the pressure generation for different positions in the throat while the subjects are asked to perform two types of swallows.

It is anticipated that a maximal treatment effect on pharyngeal pressure generation will be seen 60 minutes post intervention. An immediate change in the performance of the upper esophagus sphincter (UES) is thought to be due to increased contraction of floor of mouth muscles during the stimulated swallow. This evaluation of how non-impaired individuals respond to a treatment program with electrical stimulation will add further information to how NMES affects swallow physiology and contribute to lay the foundations for establishing this treatment method for patients with dysphagia.

# Mastication of peanuts embedded in different food matrices: a pilot study

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The purpose of mastication is to transform solid food into a food bolus ready for swallowing. Food is swallowed when a threshold is reached, based on particle size and lubrication. The aim of this study was to identify whether the particle size distribution of peanuts in the food bolus could be manipulated by embedding them into different food matrices. Four matrices (scone, chocolate, brownie, gelatine gel) containing embedded peanut pieces were chewed and expectorated by a single subject after self-estimated complete mastication. Significant differences in peanut particle size in the food bolus, and in moisture content and hardness of the peanuts, were found depending on what matrix the peanuts were inside. Results showed the type of matrix affected the peanut particle size distribution after mastication by inducing differences in the moisture content and hence textural properties of the peanuts. It is unclear whether other physical properties of the matrices altered the particle size of the peanuts in the food bolus. This finding suggests the breakdown of food particles in the mouth can be manipulated. Applications may exist for changing the nutrient and flavour release rates from manufactured foods.

# Enamel --- a functionally graded natural biocomposite coating

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The study of enamel using various approaches has illustrated its graded properties from the outer (near occlusal surface) to the inner region (adjacent the enamel-dentine junction) in a cross sectioned surface and discusses how natural design achieves such graded functions. Nanoindentation, Raman spectroscopes and SEM were employed to compare the inner and outer regions of the cross sectioned enamel from different perspectives, namely mechanical properties such as elastic modulus and hardness, indentation energy absorption ability, indentation creep behaviour, indentation residual stress distribution pattern, compositional differences, and microstructural differences. As a result, it was found that inner enamel has lower elastic modulus and hardness but higher creep and stress redistribution abilities than outer counterpart, which is related to the gradual compositional change through the enamel. It is argued that the role of the minor remnant protein within enamel is responsible for the excellent damage tolerance response of this biocomposite. In conclusion, enamel can be regarded as a functionally graded natural biocomposite, which requires further attention using numerical analysis to fully appreciate the consequences of such a structure for the mechanical behaviour of teeth and restorations placed therein. Moreover, by considering its excellent hierarchical microstructures, the smart design of enamel is an excellent model for use in functional graded materials/coatings design and development.

# Citric-Acid Inhalation Cough Challenge – Establishing Normative Data.

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Silent aspiration is the occurrence of aspiration before, during or after the swallow in the absence of a cough. Following stroke or other neurological illness, the cough can be weakened or not present at all. One of the most elusive challenges in the diagnosis and treatment of dysphagia is the reliable identification of silent aspiration on clinical examination. The citric acid inhalation cough challenge offers potential for aiding in identification of silent aspiration; however clinical application of this technique is currently problematic due to an absence of normative data.

Therefore, this study aims to establish a normative data set for the Citric-Acid Inhalation Cough Challenge, as administered with facemask method.

80 healthy subjects will participate in this study, constituting 2 age groups: above and below 60 years, with equal gender representation. They will be asked to passively inhale, via a facemask, nebulised citric acid of concentrations ranging from 08M to 2.6M. Placebo of saline solution will be interspersed throughout. Three trials of each level will be administered. Intervals of 30 seconds between each trial will ensure tachyphylaxis is minimised. 'Natural cough thresholds' will be reached when subjects cough on at least 2 out of 3 trials. Once this threshold has been reached, subjects will be asked to try to suppress the cough, in order to identify 'suppressed cough thresholds'. The time in seconds after stimulus presentation begins and before onset of cough will be noted.

As well as constituting the first normative data set for this test, the data will also be analysed for differences between age and gender. The normative data will allow application of the Citric Acid Inhalation Cough Challenge to the clinical setting, in order to help identify patients at risk of silent aspiration.