NEWSLETTER – SEPTEMBER 2005

Content:

1. NEWS FROM MASSEY UNIVERSITY

Kylie, Sebastian, Jonathan and John all attended the symposium Jules organised at the IADR Conference in Queenstown and thoroughly enjoyed it. We would like to thank Jules very much for arranging the meeting and opportunities to meet and talk with other jaw mechanics research groups. We were impressed especially with the warmth and helpfulness of people in general to what we are all trying to achieve. Also the opportunity to talk with other members of this group was a valuable experience and highlighted the need for us all to meet as a group more frequently and present progress on our respective activities.

Peter and John have been successful in receiving a Postdoctoral research fellowship from Massey University. The postdoc will be appointed for 2 years and will be involved in implementing real time decision making for the robot while chewing. This involves a mix of artificial intelligence, mechatronics and data mining. We are currently advertising for suitably qualified candidates (http://jobs.massey.ac.nz/positiondetail.asp?p=3568). Please advise anyone you know of who might be interested.

Jonathan Torrance has now resumed his PhD after some months away with illness. He is making excellent progress towards developing a full set of kinematic equations for the latest evolution of the robotic jaw model. Sebastian is working towards a final mechanical design for the robotic jaw which will be under construction in our workshop in the next week or two. We are on track to have a working jaw by December this year. We have had two French internship students from INSA, Toulouse working with us for the last three months investigating position tracking of the jaw actuators and force sensors to evaluate loads on the teeth during chewing. Charles at Albany campus is also making progress towards his masters on control of the linear actuators used in the robot.

Christine's PhD experimental trials are now underway thanks to assistance from Jules in carrying out dental examinations on her subjects. We have also extended the group of academics involved in her project and in general to include Dr Jim Jones and Dr Roger Lentle, from Massey Palmerston North. Jim is a chemical engineering with a major interest in powder technology and granulation. Roger is a medical doctor who has been researching in the phenomena occurring during digestion of the stomach bolus. This has meant he has a strong interest in the particle size distribution of the food bolus and has been contributing greatly to our project recently.

Finally Kylie and John have been trying to finalise a lease deal with Carstens in Germany to bring a 3D articulograph to Albany for 3 years. This looks promising and we might have access to a machine by mid 2006.

Kylie has been awarded a Massey University Research Fellowship for 2006. This funding will be used to develop further model foods presenting other textural characteristics (e.g. brittleness). It will also be used to set up a surface electromyography system for measuring muscular activity. It is intended to record muscle activity and 3D jaw movement (using the Carstens articulograph) during the chewing of these model foods to allow further understanding of mastication modulation in response to changes in food texture.

3. THE BIOENGINEERING INSTITUTE (BI), UNIVERSITY OF AUCKLAND

Thanks to Iain Anderson's successful grant application, the Bioengineering Institute was able to buy a Micro-CT. The system finally got delivered and installed in early August. It is a SKYSCAN 1172, with 10 Megapixel cameras, a 68mm scanning area and has a nominal resolution of less than 1 μm. We have already successfully scanned several teeth and a TMJ. The results are very nice and will hopefully open up some new research directions. If someone is interested in using it, it is best to contact Iain directly via email (i.anderson@auckland.ac.nz).

Jules Kieser, Ionut Ichim, and Sebastian Pap visited the Bioengineering Institute within the last three months. Interesting developments and research directions have developed from these meetings.

Sebastian's visited the Institute for a half day to get an update on the current research conducted at the BI and at the University of Otago (Ionut visited the BI for several days the same week as Sebastian did). Based on discussions with Ionut, we started to work on the idea to obtain anatomically accurate material properties from CT data. To do this, we first needed to transform our generic model of the mandible to the patient specific model stemming from CT scans. We were successful in creating the patient specific model and obtaining the grey values at specific locations of the CT scan. With appropriate algorithms, we can now estimate/determine the material properties at each of these points separately and, hence, obtain an anatomically accurate patient specific model of the mandible. Currently, the first tests are underway. These tests simply group the points into two averaged materials, cortical and cancellous bone. Further test are necessary to validate this approach.

Similar to the mandible, we would like to develop an anatomically accurate model of the TMJ. For this purpose, on Jules's trip to Auckland he brought us a TMJ, which we Micro-CT'd immediately. The Micro-CT scans of the TMJ depict very well the trabecular structures of the TMJ. Oliver wants to create a Finite Element model of this trabecular structure and use these scans to determine the material properties at given locations. Since we typically use large high-order finite elements to represent the geometry it is necessary to be able to define different material properties within one element (bony structures and bone marrow next to each other). The mathematical behaviour of such a computational framework is not yet well exploited and needs some further validation before we can apply this methodology to the TMJ. Experiments for validation are already in preparation. Neil from the University of Otago prepared for us a bi-material sample. This sample should serve us as an excellent test to validate the proposed process of generating anatomically accurate models from (Micro-) CT scans. The idea here is to use the Micro-CT to scan the sample, to generate different meshes (comparing one coarser element to several smaller elements) in order to assess and better understand the computational differences and properties of defining different material properties within one (finite) element. If we are capable of computationally validating some of the experimental results, we can then proceed and apply this framework to the TMJ or other specimens. In the case of the TMJ, we could use these anatomically accurate computer simulations to test several hypotheses involving the TMJ.

Further, Oliver will present some of his work at the ICBME, the 12th International Conference on Biomedical Engineering from 7-10 December in Singapore. His abstract got accepted and he submitted a 4 page conference paper *"From Jaw Tracking Towards Dynamic Computer Models of Human Mastication"*. After Singapore, he will travel on to Germany to explore and set-up some future research collaborations.

In the time between now and the conference, Oliver is trying to create an anatomically accurate model of the TMJ, and plans to put together drafts of papers for publications. One paper will be a joint work with Kylie describing our method of collecting three dimensional chewing data with six degrees of freedom. Another paper attempts to describe the current work on applying the dynamic chewing data to our computer model of the human mastication system.

Oliver is going to set-up a webpage for our "Biomouth" project in the near future. The webpage can be hosted by the BI. In our opinion, it should include all the previously published newsletters, the talks from the IADR symposium (suggestion to keep the file sizes down, we should all post the talks as a pdf-file without the movies), the publications relevant to this project and maybe a small tracker of ones planed visits to better coordinate our joint research efforts. As usual, all kinds of suggestions are welcome!!!

3. The "Cranofacial Biomechanics Symposium" at 45th Annual Meeting of the Australian/New Zealand Division of the International Association for Dental Research, Millennium Hotel, Queenstown, New Zealand, 25-28th September 2005 (from Jules Kieser, University of Otago)

Tuesday, 27 September 2005

2:30 – 5:00	***Craniofacial Biomechanics*** (Meeting room V) Chairperson: Jules Kieser; Co-chair: Mike Swain
0086 2:30	Modeling Human Mastication and its Applications. O. RÖHRLE*, I.A. ANDERSON, and A.J. PULLAN *(The University of Auckland, New Zealand)*
0087 3:15	Characteristics of dentine wear: an in vitro study. S. RANJITKAR*, G.C. TOWNSEND, J.A. KAIDONIS, A.M. VU, and L.C. RICHARDS *(University of Adelaide, Australia)*
3:30 – 4:00	***Afternoon tea*** (Galaxy III)
0093 4:00	Making a Mechanical Jaw Chew Food – An Engineering Approach. J.-S. PAP*, W.L. XU, K.D. FOSTER, and J.E. BRONLUND *(Massey University, Palmerston North, New Zealand)*
0094 4:15	Model foods: a controlled stimuli for mastication. K.D. FOSTER*, A. WODA, and M.-A. PEYRON *(Massey University, Auckland, New Zealand)*
0095 4:30	Mandibular Biomechanics and Development of the Human Chin. P.I. ICHIM*, M. SWAIN, and J. KIESER *(Otago University, Dunedin, New Zealand)*
0096 4:45	Biomechanical Analysis of the Canine Tuberculum Dentale. J. KIESER*, I. ICHIM, and M. SWAIN *(Otago University, Dunedin, New Zealand)*

Abstracts

0086 (71957)

Modeling Human Mastication and its Applications. O. RÖHRLE*, I.A. ANDERSON, and A.J. PULLAN, The University of Auckland, New Zealand

Objectives: As part of the Physiome Project, which aims to provide a framework for modeling the human body using computational methods, we present an anatomically-based computer model of the human masticatory system that provides an initial framework for simulating the chewing process. Further, we introduce an anatomically accurate model of the mandible based on a given patient's CT scan.

Methods: To track the motion of the mandible during chewing, we used the motion capturing system VICON MX located in the Department of Sport and Exercise Science at the University of Auckland. For our computational models, we use the Finite Element method with cubic Hermite basis functions. To obtain an accurate representation of the mandible, the material properties of the bone are determined at a large set of locations from CT scans.

Results: A kinematic model of one chewing cycle is simulated by solving for deformations of the muscles given the location of the mandible at a sequence of time steps. A realistic description of a chewing process is achieved via our ability to record the location of the mandible in intervals of 0.01 seconds using the motion tracking system mentioned above. Stress and strain calculations are presented for different loading conditions of the mandible.

Conclusions: The use of cubic Hermite basis functions provides an efficient representation of anatomical structures in the jaw. With the use of the motion tracking system and by solving the equations of finite elasticity, we can realistically simulate a normal chewing cycle. We have demonstrated how this model can be customized to a given person. Most important, we have an extensible framework to which we can add more detail to further improve our representation of the mastication process.

Acknowledgments: This work is funded by the Foundation for Research in Science and Technology (FRST) under contract UOAX0406.

0087 (71686)

Characteristics of dentine wear: an in vitro study. S. RANJITKAR*, G.C. TOWNSEND, J.A. KAIDONIS, A.M. VU, and L.C. RICHARDS, University of Adelaide, Australia

Previous studies have described the nature of wear in enamel and various restorative materials under conditions simulating attrition and erosion. Objective: The aim of this study was to investigate the pattern of dentine wear under various loads and with different lubricants. Methods: 53 human third molar teeth were sectioned longitudinally in a mesio-distal direction. After removing enamel from one half of the teeth, dentine surfaces were worn against enamel in a purpose-built electromechanical tooth wear machine at different loads (3.2, 6.2 and 9.95 kg), and with different lubricants (water at pH 7.0 and hydrochloric acid solutions at pH 1.2 and 3.0). Tooth wear was quantified by measuring reduction in dentine volume over time using Dr PICZA 3D Scanner (PIX-4) and MATLAB software package (version 6, The Mathwork Inc, Natick MA, USA). Qualitative assessment was also carried out using Scanning Electron Microscopy (SEM). Results: Dentine wear increased with increasing loads at each pH level ($p<0.05$). Dentine wear rate was greatest at pH 1.2 ($p<0.05$) and there was a trend for the wear rate at pH 3.0 to be less than that at pH 7.0 under all loads. Dentine was noted to wear more slowly than enamel at loads of 3.2 kg and 9.95 kg at pH 1.2 ($p<0.05$). SEM analyses showed extensive surface destruction of dentine wear facets due to erosion at pH 1.2, whereas dentine wear facets were smoother at pH 3.0 compared with pH 7.0. Conclusions: This study provides evidence of different wear mechanisms in dentine under different experimental conditions. Dentine wear rate is linear with load but its relationship with pH is more complicated. This project was supported by the National Health and Medical Research Council of Australia (Grant no: 207803).

0093 (71708)

Making a Mechanical Jaw Chew Food – An Engineering Approach. J.-S. PAP*, W.L. XU, K.D. FOSTER, and J.E. BRONLUND, Massey University, Palmerston North, New Zealand

Background: The architecture of the human mastication apparatus and its control are very sophisticated. From a mechanical engineering perspective it is possible to build a robot that achieves the same masticatory function in a simpler way. Objectives: This paper outlines the design of a robot to reproduce human masticatory function in such a way that direct comparison of actuator work and control with the human mastication apparatus was possible. Methods: Degree of freedom analysis showed that the full range of movement of the jaw requires six linear actuators attached with spherical joints. These actuators were used to replace the temporalis, masseter and pterygoid muscle groups based on published biomechanical findings on how human muscles work while chewing food. Each muscle group was evaluated to derive the optimal length and placement of the actuators to best reproduce the direction and magnitude of force applied to the jaw. The resulting platform robot was simulated using SolidWorks and COSMOS/Motion. The mandible representation was scanned from a human jaw using computer tomography. The three dimensional coordinates of the muscle attachment points were assessed from eight cadavers. Results: The simulation results showed that the platform robot design could follow human mandible movement trajectories. By implementing recorded incisor trajectories in the software simulations, real human chewing patterns have been reproduced. It is very difficult however, to select appropriate real actuators for the mandible movement trajectories and still meet the space, displacement, velocity, acceleration, and force specifications required by the human chewing apparatus. Conclusions: The complexity of the human system may be a necessity for masticatory function given the constraints it must work within. The solutions that nature has developed to meet these requirements may provide useful approaches for future robotic design. Acknowledgements: This project was funded by the FRST, New Zealand UOAX0406

0094 (71982)

Model foods: a controlled stimuli for mastication. K.D. FOSTER*, Massey University, Auckland, New Zealand, A. WODA, UFR Odontologie, Clermont Ferrand, France, and M.-A. PEYRON, Institut National de la Recherche Agronomique, Saint-Genes Champanelle, France

Mastication, a complex process modulated by oral-sensory feedback, is often studied by recording muscle activity and, less frequently, jaw movements. Numerous studies, mainly using natural foods, have attempted to relate this modulation to food texture, in particular hardness, with contradictory results being reported. Objectives: The aims of this work were to: 1) develop edible model foods of defined and controlled rheological behaviours; 2) simultaneously record muscle activity and jaw movement during chewing of two model foods, to determine the effect of differences in food texture on mastication. Methods: Model foods presenting with predominantly either plastic or elastic rheological behaviour were developed. Each model food type consisted of 4 products of different hardness. Fifteen male participants, with normal dentition aged 24.1 ± 1.9 years, were selected. Activities of the masseter and temporal muscles were recorded by surface electromyography. Jaw movements were recorded simultaneously by electromagnetic induction. Participants were instructed to masticate 3 replicates of each plastic and elastic product during two sessions ($3 \times 4 = 12$ samples per session). Results: Food hardness is well described by muscle activity. Jaw movement measurements are required to describe the modulation based on other textural characteristics; vertical and lateral jaw movements are strongly affected by food type. Masticatory frequency is initially dependent on food hardness but overall is more strongly dependent on food type. Conclusions: Model foods are valuable materials to use for studying mastication as they provide controlled and reproducible stimuli to monitor modulation of mastication. This allows the relative effects of different food textures to be quantified. Simultaneous measurement of muscle activities and jaw movements allows greater understanding of masticatory function, illustrating the high level of modulation achieved by the central nervous system. Acknowledgements: This work was supported by French government funding.

0095 (70148)

Mandibular Biomechanics and Development of the Human Chin. P.I. ICHIM*, M. SWAIN, and J. KIESER, Otago University, Dunedin, New Zealand

OBJECTIVES: The development of the chin, a feature unique to humans, suggests a close functional linkage between jaw biomechanics and symphyseal architecture. The present study tests the hypothesis that the presence of a chin changes strain patterns in the loaded mandible. METHODS: Using an anatomically correct 3-D model of a dentate mandible derived from a CT scan image, we analyse strain patterns during incisal and molar biting. We then construct a second mandible, without a chin, by defeaturing the first model. Strain patterns of the second model are then contrasted to the first. RESULTS: Our main finding is that chinned and non-chinned mandibles follow closely concordant patterns of strain distribution. We also show that there is a buccal-lingual crossover of strain distribution in the molar region during function. CONCLUSION: The results suggest that the development of the human chin is unrelated to the functional demands placed on the mandible during function.

0096 (70074)

Biomechanical Analysis of the Canine Tuberculum Dentale. J. KIESER*, I. ICHIM, and M. SWAIN, Otago University, Dunedin, New Zealand

Objectives: We evaluate the structural significance of the development of a canine tuberculum dentale by means of three-dimensional finite element analysis. Methods: Using a scanned human permanent molar, we construct a computer generated canine, together with alveolar bone and periodontal ligament onto which we morph two cingulum shapes - a flat palatal surface and a stylised tuberculum dentale. We then subject the three shapes (flat, normal cingulum and pronounced tuberculum dentale) to a normal occlusal force and we record principal and von Mises stresses in the crowns. Results: Our results show that stresses are concentrated at the cingulum and in the approximal areas, and that these do not differ between the three forms.Conclusions: We conclude that the development of a tuberculum dentale does not confer biomechanical advantage to the human canine.
