19 January 2006

NEWSLETTER – DECEMBER 2005

Content:

1. SCHOOL OF DENTISTRY, UNIVERSITY OF OTAGO (BY IONUT ICHIM)

Happy New Year to all!!

Clinical linkage remains a constant focus of our biomechanical research at Otago. In December, we decided to pursue the study of the biomechanical events which underpin the formation and evolution of the non-carious cervical lesions (NCCL). This came as a continuation of a previous collaboration, we established with the Department of Mechanical Engineering, James Cook University, Townsville, Australia. For this project, Ionut was invited as Visiting Scholar at JCU for December 2005 – February 2006 where he collaborates with Qing Li to the application of discrete FE method on the study of NCCL (a brief technical explanation of the method is given below).

The aetiology and mechanism underlying formation of such lesions remains still obscure although it was the subject of extensive research in the past two decades. Initially, their onset and development was attributed solely to toothbrush abrasion. Later, an increasing body of work linked the aetiology of NCCL to occlusal loading. As such, it is hypothesised that the primary etiologic factor are excessive tensile stresses in the cervical area which arise from mastication and malocclusion, while other local factors may play a secondary role in the dissolution of tooth structure. As a consequence and to distinguish between lesions that occur due to excessive occlusal load and other non-carious cervical lesion (i.e. erosion and abrasion) the clinical term “abfraction” was employed.

At present, it is accepted that non-carious cervical lesions recognize a multi-factorial aetiology which combine elements of occlusal loading, abrasion and erosion and that further studies are needed to determine the sequence and synergy among those factors.

The aim of our project is to determine more precisely the role of the eccentric occlusal loading in the aetiology and progression of abfractive lesions. It involves numerical analysis using discrete finite element method, nano-indentation for mechanical testing of the dentine properties in the cervical area, scanning electron microscopy and confocal microscopy to analyse surface quality of the dentino-enamel junction.

The numerical analysis is completed at this stage and was carried out during Ionut’s visit at JCU in December. As a novel approach, for this analysis we employed different FE software which uses Rankine rotating crack model, designed for computing the tensile failure in brittle materials. This crack model relies on the anisotropic phenomenon which is generally related to the fracture in brittle materials such as enamel or dentine. The micro-cracks within a brittle solid occur in directions that attempt to maximize the subsequent energy release rate and also minimize the strain energy density. In practice, damage accumulates in brittle materials through the growth of voids and micro-cracks, which over time may lead to fracture. A single scalar damage variable ω is assumed to control strain softening due to micro cracks. The elastic scalar damage for monotonic loading at a non-local level is then given by:

$$\sigma = (1-\varpi)E\varepsilon \tag{1}$$

where ϖ is the non-local scalar damage, σ, ε is the local stress, strain and E is the Young's modulus. Generally, all finite elements in the non-local region are not simultaneously damaged and hence it is not possible to achieve total damage equivalent to $\omega = 1$. The problem is overcome by writing the non-local scalar damage variable as a simple function of the non-local strain, i.e.

$$\varpi = \frac{\varphi(\bar{\varepsilon}) - 1}{\varphi(\bar{\varepsilon})} \quad 0 \le \varpi \le 1 \tag{2}$$

The function φ is chosen to ensure complete damage (i.e., $\varpi = 1$) if

$$\bar{\varepsilon} \ge \frac{f_t}{E} + \frac{f_t}{E_t} \tag{3}$$

where f_t is the tensile strength and E_t is the slope of the softening curve. The damage variable, in effect, reduces the apparent stiffness to zero when $\omega = 1$. Using this procedure a continuum with micro-cracks can be treated as an equivalent anisotropic material with degraded properties orthogonal to the crack surface. A rotating crack model is then used to ensure alignment of cracks with the principal axes.

Upon achievement of complete softening, discrete cracks are inserted into the continuum solids in line with an average failure indicator evaluated at each nodal point. The evolution of cracks in a continuum dictates that topology update procedures be available to ensure an adequate mesh representation at each stage.

Applying such method to the study of NCCL yielded very interesting results and now we are in process of writing a paper which we intend to submit for publication in early February.

2. MASSEY UNIVERSITY, PALMERSTON NORTH (BY JONATHAN TORRANCE)

I've recently completed the inverse kinematics for the robotic jaw in Matlab. This means that given a trajectory of the jaw relative to the fixed skull frame the 6 individual trajectories of the 6 actuators can be found. My Matlab results are very close to results obtained from Solidworks.

The inverse kinematics will allow a given trajectory of the jaw to be implimented through the Galil motion control card by commanding 6 trajectory following programs for the 6 actuators.

My next work will be on the forward kinematics, which involves finding jaw trajectory relative to the fixed skull from 6 given actuator trajectories.

3. THE BIOENGINEERING INSTITUTE, UNIVERSITY OF AUCKLAND (BY OLIVER RÖHRLE)

Past experiments trying to track the motion of the mandible while chewing sample foods exhibited some deficiencies. These deficiencies stem in parts from the design of the custom-made brace that was used for the motion tracking. It is believed that the brace was too heavy, too large, and not attached rigidly enough to the mandible. At the IADR meeting in Queenstown last September, Neil Waddell, from the Department of Oral Rehabilitation at the School of Dentistry in Dunedin, offered his help to improve the design of the brace. To follow up on this, Oliver Röhrle visited the School of Dentistry at Otago University in Dunedin in November 2005. During that time, Neill did an exceptional job of designing and constructing such a custom-made brace. The old and new designs are depicted in Figures 1 and 2 below.

Figure 1: Old design

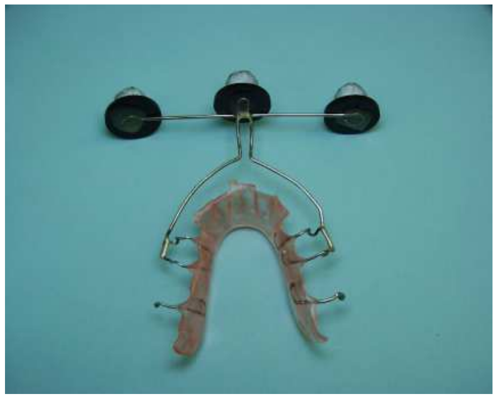

Figure 2: New design

During the same trip, Oliver also met up with Jules Kieser, Mike Swain, and Ionut Ichim to discuss different directions of joint research.

With the new brace in hand, Kylie Foster (Massey University) and Oliver performed some further experiments on tracking the motion of the mandible. The results seem to be much better than from the first set of experiments. Oliver wrote some Matlab code to obtain true motion (to correct the experimental data for head movement). Further, he tried to calculate the angles and translations in such a way that the movements can be transferred to the computer model developed by the Bioengineering group in Auckland. While the trajectory at the incisors can be recovered well, there are still some issues with obtaining the correct movement near the condyle. It is hoped that this is not due to errors introduced by the measurements. Nevertheless, it should be exciting to see if we can transfer this data not only to the computer model but also to the chewing robot currently developed at Massey University.

In December, Oliver attended the International Conference on Biomedical Engineering (ICBME) in Singapore. He presented his current work on the chewing experiments and its applications to computer simulations. From Singapore he continued his trip to Amsterdam to meet up with Jan Koolstra and T. van Eijden[1]. Oliver and Jan met for the whole day. Jan showed him their department and explained his past and current work. Oliver explained the constellation of our Biomouth research group, its current interests and the work. It was a very open meeting and Jan offered his cooperation and collaboration, e.g. access to their data. Oliver also indicated that several people of our research group might want to visit him this summer in Amsterdam. If there is interest, since some of us will be in Europe next summer anyhow (either for the purpose of a sabbatical or for the World Congress on Biomechanics in Munich), Oliver will get in contact with him and organise a one or two day meeting.

[1] A list of their publications is available under http://www.koolstra.net/publ.html

Oliver was also granted an ISAT Linkage Fund grant from the Royal Society of NZ. He will use this money for a research project at the Institute of Orthopaedic Research and Biomechanics in Ulm, Germany (www.biomechanics.de), where he will be located in June and July 2006 (nothing at all to do with the soccer world cup being in Germany though! It is all in the interest of NZ research. For that, he even will skip most of the NZ ski season!).