Institute of Medical & Biological Engineering

Diffusion in a Novel Tooth *In situ* Organ Culture Model for Periodontal Research

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1. Impact

- Severe periodontal disease (gum disease) affects 5-15 % of most adult populations [1].
- A viable tooth *in situ* organ culture model (Fig. 1) with appropriate physiological loading would provide a valuable tool to study **regenerative therapies for periodontal ligament (PDL) regeneration.**

Fig.1. Bioreactor containing porcine tooth *in situ* organ culture model for periodontal research.

2. Objectives

- Investigate whether **diffusion** of medium through the tissues is sufficient in the tooth *in situ* model.
- Maintain **sterility and tissue viability** over 4 days for a porcine tooth in *in situ* within the bioreactor.

3. Modelling Diffusion

- A finite element (FE) diffusion model containing 330,000 elements was built from microCT images of a porcine tooth.
- The FE model predicted **slow diffusion rates** of medium through cortical bone surrounding the PDL (Fig. 2).
- Currently testing experimentally derived properties (see section 4) to validate the model.

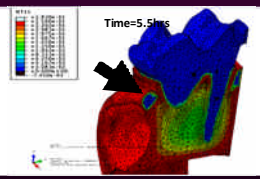

Fig.2: Finite element model (FE). Slow diffusion of medium through cortical bone (arrow). Note: Blue = 0% medium and Red = 100% medium.

4. Diffusion

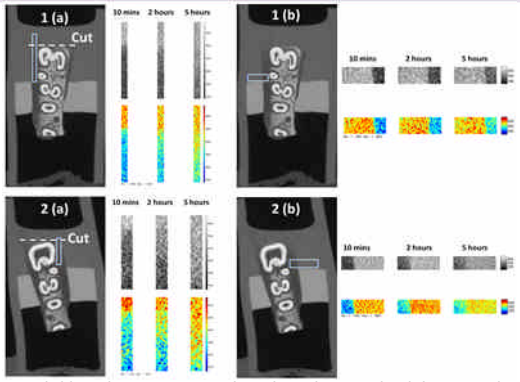

Fig.3: Medial-lateral microCT images through tooth at root level showing Sodium Iodide (NaI) diffusion into gingiva (blue box) for two samples (1 & 2); (a) diffusion through dissection cut (above) and (b) diffusion through the intact gingival epithelium. Note: red = 0.1 M NaI and blue = no NaI.

- **MicroCT Imaging:** Porcine molar teeth (n=2) were soaked in a 0.1 M **sodium iodide solution (contrast agent).**
- Teeth were scanned at 10, 120 and 300 minutes (60KVp, 902 µA, 0.6 mm Al) to monitor diffusion through the gingiva & PDL (Fig. 3).
- **Matlab:** the diffusion coefficient of the gingiva (±SD), derived using **Fick's 2nd law of diffusion** and simplified as a one dimensional problem (Fig.4), was:
  - **6.1×10^{-6} ($\pm 3.5 \times 10^{-6}$) cm^2/s** at the cut and
  - **8.6×10^{-7} ($\pm 5.9 \times 10^{-7}$) cm^2/s** at the gingival epithelium.

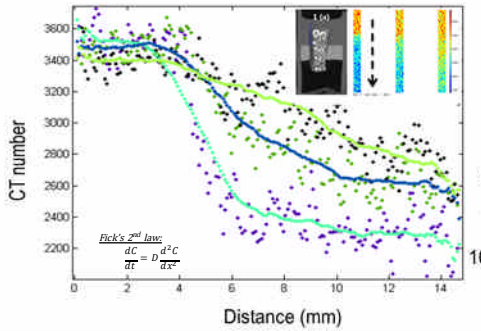

Fig.4. NaI concentration (CT number) against depth of tissue.
Note: Diffusion simplified as a one dimensional non-steady state problem. Currently analysing model as a two dimensional diffusion problem.

5. Biological

- Six porcine first molars were dissected aseptically and cultured over 4 days.
- Microbiological culture for aerobic, anaerobic and fungal infections showed **no evidence of contamination** over the 4 day culture.
- XTT results showed **viability of all tissue components was maintained** between days 1 and 4 (Fig. 5).
- Viability of the gingiva indicated diffusion imaged using microCT in section 4 was sufficient for nutrient and gas exchange.

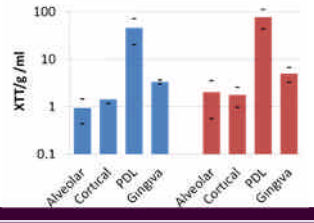

Fig.5. XTT viability assays suggested maintenance of tissue viability from day 1 n=3 (left, blue) and day 4 (right, red) (n=3). Error bars show ± SD. Note: Alveolar & cortical=cancellous & compact bone respectively.

6. Conclusion

- **Viability** was **successfully sustained over 4 days.**
- **Diffusion** through the **gingiva showed higher rates at the surgical cut**. However, diffusion through the PDL was unclear.
- Currently: **testing tooth organ culture model under physiological loading** & further diffusion studies.

References: [1] World Oral Health Report (2003). Access to poster: http://www.imbe.leeds.ac.uk/news/iMBEORS2014.shtml or scan QR code (right).

Conflicts of interest: Professor Eileen Ingham: Tissue Regenix, Stryker, DePuy. The remaining authors have no conflicts of interest to declare.

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