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Education

PhD in Physics — **University of Aberdeen**
(funded by Scottish Universities Physics Alliance-Inspire) — **Aberdeen, UK**
September 2010 – July 2014

Brief Synopsis of Research:

Bone is primarily made up of a mineral part (hydroxyapatite) and an organic part (collagen). My research was split into understanding these two parts.
Hydroxyapatite and silicon-substituted hydroxyapatite materials were investigated alongside a Scottish medical device company, Sirakoss, where synthetic bone graft substitutes are developed. My work involved understanding the methods of producing a bone graft material and used scientific analysis to expand upon the knowledge of what was happening at the fundamental stages of the product synthesis.
Osteoarthritic and osteoporotic human bone collagen was investigated at the molecular level using neutron diffraction, with a theoretical model developed to explain the behaviour of collagen. Also, material studies were performed to further understand the composition of diseased bone.

BSc Mathematics-Physics — **University of Aberdeen**
First Class Honours — **Aberdeen, UK**
September 2006 – June 2010

- Honours options included Group Theory, Further Real Analysis, Complex Analysis, Rings and Fields, Electricity and Magnetism, Research Skills in Physics, Energy and Matter, Quantum Atomic and Molecular Physics, Optimisation and Numerical Analysis, Ordinary Differential Equations, Special Relativity, Knot Theory, Solid State Physics, Modelling Theory.
- Honours Project Thesis titled "The Foundations of Special Relativity and Electromagnetism"
- Demonstrated excellent organisational and research skills during the 4th year Honours Project.

Secondary Education — **Mackie Academy**
Stonehaven, UK
August 2001 – August 2006

- NQ Highers – Mathematics (A), English (A), Modern Studies (A), Physics (B), Crash Higher Italian (C).
- NQ Standard Grades all at Credit Level 1 – Mathematics, English, Physics, Chemistry, French, Modern Studies, Geography, Administration.

Employment

Physics Lab Demonstrator/Tutor — **University of Aberdeen**
Aberdeen, UK
November 2010 – June 2014

- Demonstrated physics undergraduate labs for first and second year students.
- Demonstrated physics labs for secondary school visitors.
- Tutor for first year physics course.

Easter/Summer School — **University of Aberdeen**
Mathematics Tutor/Marker — **Aberdeen, UK**
2008 – 2009

- Tutored school pupils studying for Standard Grade examinations.
- Tutorial assistant for students applying for university.
- Assisted in problem solving exercises and explained mathematical concepts in a clear and understandable manner.
- Member of the marking team which involved marking and grading assessments.

Student Ambassador **University of Aberdeen**
Aberdeen, UK
May 2007 – May 2010

- Provided tours of the university campus to prospective students and visitors.
- Assisted in the university Open Days.
- Airport 'meet and greets', meeting students from abroad and providing information regarding the university, travel and accommodation.

Offshore Europe **Aberdeen, UK**
Events Team **September 2007, 2009**

- Team Leader.
- Duties included visitor information, meet and greet, cloakroom assistant and hospitality.

House of Dun **Montrose, UK**
Guide/Shop Assistant **Summer 2008, 2009**

During summer vacation I worked at the National Trust for Scotland House of Dun, where my duties included providing guided tours to visitors, answering questions on the property, closing of the property at the end of the day, selling items in the gift shop and cashing up at the end of the day.

Skills

Teaching Skills

- Demonstrated physics labs for undergraduates and secondary school visitors.
- Marker for undergraduate lab projects.
- Tutor for first year physics undergraduates.
- Mentor to a final year honours student.
- Tutored school pupils studying for Standard Grade examinations.
- Tutorial assistant for students applying for university.
- Member of the marking team of the Summer School which involved marking and grading assessments.

Computing Skills

- Microsoft Office Suite, Matlab, LaTex, Origin, Internet Explorer, Firefox.

Other Skills

- Scientific Techniques – Raman Spectroscopy, Neutron Diffraction, X-Ray Powder Diffraction.
- Trainer/Maintenance of Raman Spectroscopy instrumentation.
- Knowledge and experience of working in a research laboratory, in both academic and industrial environments.

Conferences

- **Bone Research Society/British Orthopaedic Research Society Joint Meeting**: 3rd – 5th September 2013 (**Poster Presentation**).
- **International Conference on Neutron Diffraction:** 8th – 12th July 2013 (**Oral Communication**).
- **Royal Society of Chemistry Solid State Chemistry Group Annual Christmas Meeting:** 18th -19th December 2012 (**Poster Presentation**).
- **Bioceramics-24:** 21st – 24th October 2012 (**Oral Communication**).

Publications/Conference Papers

- **Harden, F.J**, Gibson, I.R, Skakle, J.M.S; *Simplification of the synthesis method for Silicon-substituted Hydroxyapatite: A Raman Spectroscopy Study*, Key Engineering Materials; 2012; 529-530, 94-99.
- **F Harden**, R Aspden and J Skakle; *Neutron diffraction studies of collagen behaviour in human bone for patients suffering from osteoporosis and osteoarthritis* [abstract]. In: Abstract Book of the International Conference on Neutron Scattering; 8-12 July 2013; Edinburgh, UK: ICNS; 2013. P79.

Awards

- Inspire Video Pitch Competition Winner 2013.
- Inspire Commercial Presentations 2013.

Synopsis of PhD Research

In modern society people are living longer and expecting a consistently high standard of living. But as the body ages bone failure becomes more probable due to lifestyle, accident, age or bone disorders. Understanding the mechanical and material properties of bone and developing synthetic bone replacement materials has therefore become an increased need in society in order to maintain the standard of living that is desired.

Investigations into silicate-substituted hydroxyapatite (Si-HA) were performed where it was found that the aqueous precipitation method produced phase pure Si-HA consistently with modifications to the method causing a greater likelihood of impurities being incorporated into the material. Also, Raman spectroscopy was used to investigate the ionic species of Si-HA, specifically the silicate ions in the material. Having the capabilities to follow the ionic behaviour of the silicate ions provided a deeper understanding regarding the molecular interactions of the material. This novel study, which followed the behaviour of the silicate ions at different calcining/sintering temperatures, provided a new interpretation regarding how silicate is substituted into HA. It appeared that the silicate ions created interactions with the hydroxyl ions initially, with increased silicate substitution creating a higher number of these interactions, which then reduced upon sintering of the material due to dehydroxylation. However, the fact that the silicate ions do not behave independently in the HA structure initially, which has been a general belief to those studying Si-HA, has led to the suggestion that these interactions may be a contribution to the improved bioactivity of Si-HA. Industrial aspects of Si-HA were also investigated due to biomaterials, such as Si-HA, being used worldwide in the bone graft industry. When producing a commercial product it is important to test the reagents used. Therefore a study was performed to investigate the silicate reagent (i.e. TEOS) of Si-HA and to test whether different brands of TEOS, different grades of TEOS and different percentage concentrations of TEOS altered the material. It was found that a small difference of 1% in the percentage concentration caused a decrease in the amount of silicate substituted into HA. However, different brands and grades of TEOS did produce Si-HA with similar structural properties. Therefore, from an industrial point of view, a variety of brands and grades of TEOS can be used to produce Si-HA and therefore when purchasing the reagent the most cost effective choice can be made. However, the important point from this study was that the amount of TEOS used needed to be corrected with regards to the percentage concentrations as a 1% difference in the percentage concentration of the reagent was not negligible.

The first analytical investigations into the molecular arrangement of fully mineralised osteoarthritic (OA) and osteoporotic (OP) bone were also performed through small angle neutron scattering (SANS) studies. This innovative study provided an accurate description of the molecular arrangement of collagen molecules, along the lateral plane, with respect to the collagen molecular diameter and the packing of these molecules into the fibril by the successful development of a theoretical model based on SANS theory. Along the lateral plane, collagen molecules behave like a 2-dimensional liquid-like system. Through the development of the theoretical model describing the lateral arrangement of collagen molecules, the first written numerical solution for the structure factor for a system of hard-disks was stated. This study provided the backbone for the understanding into how the collagen molecules of OA and OP bone are arranged. Also, compositional studies on OA and OP bone were performed and iterated that there may be differences between the organic content of OA and OP bone. This suggested that the organic content of bone may play a role in the OA or OP bone disorder.

By digging into bone two areas of research were investigated, the bone substitute material of Si-HA and two bone disorders, i.e. OA and OP. The Si-HA studies have further enhanced the knowledge as to how substituting silicate into HA affects the behaviour of the material providing more information on the material as a whole. The studies into OA and OP bone have provided a fundamental model that can be used by future investigators to study the molecular arrangement of collagen molecules in fully mineralised bone and have emphasised some new lines of enquiry as to the primary cause of the bone disorders. Therefore, significant contributions to the knowledge of Si-HA and bone disorders have been achieved.