**Institution:**
Queen Mary University of London

**Unit of Assessment:**
UoA3

## 1. UNIT CONTEXT AND STRUCTURE, RESEARCH AND IMPACT STRATEGY

The Institute of Dentistry (**IoD**) at Barts and the London School of Medicine and Dentistry (**SMD**), Queen Mary, was the top-rated Dental School for research quality in REF2014, with 87% of outputs and all impact case studies classed as world-leading or internationally excellent. Our research environment was rated 4-star. Post-REF2014 our research has been driven by our social responsibility and strong commitment to improving the lives of our local population, with its high health needs and inequalities, and of wider society nationally and globally. It is this distinctiveness that dictates our priorities towards finding solutions to challenges in oral health and wider impact on health and society. Continued innovation and investment have strengthened our research productivity, critical mass, and impact for this entirely Dentistry-based UoA3 submission.

In 2016, we reorganised the IoD into three inter-disciplinary research-led Centres; Centre for Oral Immunobiology and Regenerative Medicine **(COIRM),** Centre for Oral Bioengineering **(COB)** and Centre for Dental Public Health and Primary Care **(CDPH)**. In 2016, we reorganised the IoD into three inter-disciplinary research-led Centres; Centre for Oral Immunobiology and Regenerative Medicine **(COIRM),** Centre for Oral Bioengineering **(COB)** and Centre for Dental Public Health and Primary Care **(CDPH)**. This re-organisation enabled focus and strengthening of our capabilities, resulting in the ranking of IoD as 1$^{st}$ for research citations and 11$^{th}$ in the world on all metrics (QS2020), and overall top dental school in England (The Complete University Guide 2021). It also ensured alignment of the strategy across SMD and Queen Mary.

A £1.2 billion redevelopment of Barts Health NHS Trust enhanced our infrastructure and cross-organisational research. We have translated our basic science into improved clinical care, for example, our biomaterials work led to the introduction of a new toothpaste (*Biomin*), and platform technology development for the rapid detection of anti-drug antibodies is now used in the diagnosis of antibody drug failure in Behcet's disease (also in development for SAR-CoV-2 antibodies). We have increased our clinical trials to translate our work on wound healing and immunology. These developments are complemented by an expansion of our clinical postgraduate programmes including Level 8 Doctorates. As of 2020, we had 126 postgraduate students. Our research quality is further evidenced by numerous research awards (see below).

Our new £78m shared IoD and Royal Dental Hospital building opened in 2016 and provides state-of-the-art facilities fostering internationally leading research and education. We have invested a further £1.67m in a new **Clinical Research Unit (CRU)**, to enhance research capacity and income through funded clinical trials. The Dental Hospital is adjacent to the Blizard Institute of the SMD, where many of our researchers are located, working alongside researchers in cancer cell biology, genomics and immunology. It is also close to the Institute of Population Health Sciences which facilitates joint work with primary care and population health. This collaborative working environment, allows the IoD to capitalise on exceptional translational medicine expertise, clinical trial design and associated facilities. We recognise that dental clinical care operates at the

interface of many other clinical specialities and disciplines, from public health through to oncology and have cultivated an environment of collaboration.

We have expanded our links with the School of Engineering and Materials Science (SEMS) at Queen Mary, through interdisciplinary research projects and joint PhD supervision. This is reflected in our shared impact case studies. This collaborative way of working, coupled with investment in staff and physical infrastructure, has allowed us to flourish in basic science, clinical biometric and patient- and population-based research. The focus on our three key themes means that we now return 41.53 FTE (headcount 46) academic research staff from **COIRM** (24) including 5 in the Clinical Research Unit; **COR** (16); and **CDPH** (6).

**1A. Achievement of strategic aims for research and impact**

Following REF2014, we further enhanced our research quality by delivering in the following ways:

1. Reorganisation of the IoD into the three research centres (above). We recruited staff (including early career researchers) and developed and promoted existing staff. We ensured **sustained funding** with numerous grants involving collaboration across SMD. An example is the link between periodontal disease and malnutrition to outcomes for mothers and newborns in Zimbabwe (Donos/Allaker with Prendergast [UoA2], £1.2m MRC).
2. Increased the **numbers of postgraduate research students,** we established Clinical Doctorate (DClinDent) programmes producing Level 8 research as part of their postgraduate specialist training. This has produced excellent outputs leading to national and international prizes (Table 1, Section 2B). We have 64 DClinDent students and have introduced new Doctorates in Oral Medicine (2019), Endodontics (2020) and Oral Surgery (2020). Applications have risen from 215 in 2017 to 380 in 2020. Completed PhDs have increased by 37% over the last five years.
3. Developed a bespoke **Clinical Research Unit** to expand patient-oriented and translational research (see 1C).
4. Enhanced **inter-disciplinary links and external collaborations**. We have invested in annual research away days (>70 participants), fostering collaborations across the whole faculty.
5. Expanded **research links with industry** by building on established links with commercial companies in the Oral Healthcare sector, including GSK, with whom we have a Master Services Agreement for Contract Research. Between 2014-2018, GSK have funded over £550K in external contracts, 6 CASE Awards and a COVID clinical trial (£256K). The IoD has developed and tested bioactive glass-based toothpastes and varnishes, worked with industry on dental implants (Straumann), soft tissue grafts (Geistlich) and antibacterial devices (Dexcell). Much of this work capitalises on our basic science expertise leading to clinical studies within IoD.
6. To expand our national and international **collaborative research activities in oral cancer**. We have appointed key staff: Professor Irene Leigh was appointed in 2018 as a research leader in cancer with Dr Sequeira joining in 2019 (Section 2A). Leigh was awarded a grant from Sanofi (2019; £640K). We established numerous international collaborations including the funding of two PhDs per annum with academic institutions in India.
7. Embedded **research impact into all of our research activities.** We have continued to engage extensively with end-users of our research including industry, policymakers and the public.

To develop and deliver the IoD research impact action plan, we have implemented three main approaches:

1. ***Improving the infrastructure for staff.***
   - We have provided dedicated support for dental researchers from the Queen Mary Impact Office and appointed a full-time Research Manager (2018) with responsibility for research impact administration.
   - A senior academic (Allaker) was appointed as Research Impact Lead.
   - Formed an Impact Advisory Board (2019) with representatives from the Queen Mary Impact Office, Business & Innovations and Public Engagement teams. The Advisory Board meets quarterly with the IoD Research Strategy Committee.
   - We showcased our impact case studies at IoD events inviting external researchers and stakeholders (2019).

2. ***Providing staff opportunities, incentives, and increasing collaboration.***
   - Strengthening partnerships with industry by increasing CASE PhD studentships and industry-funded trials.
   - Increasing opportunities for staff exchange visits, e.g. Hill spent time with Abbott Laboratories Oral Health, India. Exchange visits have increased with Dental Schools in Bauru and Sao Paulo, Brazil. Joint Research and Impact Meetings have been established with GSK.
   - Enhancing translational aspects of our activities. We have strengthened links with GSK Oral Health in dentine hypersensitivity, caries, acid erosion and oral malodour. We have strong links with smaller Oral Health companies and have developed international research collaborations with academic Institutions (see Section 4B).
   - Increasing the development and support for female staff through research activities. Calciolari (CRU) received 2 international awards for translational/clinical research in bone regeneration (2017, L'Oreal UNESCO for Women in Science and the 2018-International Association of Dental Research Women in Science Distinguished Research Award).
   - Research impact is factored into the criteria for staff promotion. For example, Cattell, developed novel glass-ceramics for dental restorations such as veneers (Lumineers), reducing the need for tooth tissue removal. This was taken into account in the promotion round when he was promoted to Reader (2018).

3. ***Measurement of impact indicators and new opportunities for impact.***

Impact is monitored in conjunction with the SMD Deputy Dean for Impact and the dedicated officer. We have submitted four studies: i. Interventions to improve the oral health of vulnerable children; ii. Behçet's Centre of Excellence; iii. mandibular advancement devices for sleep apnoea; iv. bioactive glasses to create the world's first 'smart' toothpaste.

In line with our strategic focus, there are numerous other examples of impacts, two are described further below.

*Nitric Oxide Delivery Systems for Wound Dressing.*

Allaker developed a wound dressing for clinical use in partnership with Edixomed (now 30-Technology). The dressing generates Nitric Oxide (NOx), based on the acidification of nitrite (2017). NOx is a two-layer wound dressing system which has anti-microbial, healing and anti-inflammatory action, mimicking natural physiological processes. NO is delivered through a safe, robust and versatile system which has multiple forms of delivery. Its efficacy and safety has been demonstrated in the treatment of diabetic foot ulcers. Other delivery systems for oral ulceration,

respiratory and critical care are under development. We recently (October 2020) commenced a multi-centre Phase 2/3 trial with an antiviral NO-generating product (RESP301) for the treatment of hospitalised Covid-19 patients. This is also an example of our collaborative working across dentistry and medicine.

*Discovery of the FOXM1 oncogene in human cancer.*
We capitalised on the invention of the world's first digital oral cancer (qMIDS) test (2012) to develop an improved version, for which a second patent has been filed (25/07/2019). The test has been validated in over 500 patients from the UK, Norway, India, Pakistan and China. The results demonstrate excellent diagnostic efficiency (>90% sensitivity, specificity and accuracy).

**Research Impact evidenced in Novel Commercial Products and Patents**
We have a track-record for translating research into commercial products, exploiting opportunities and developing partnerships (**Figure 1**).


**Figure 1. Products developed: A: Ceram II LC, B: BioMin Toothpastes C: Ultradex Recalcifying Toothpaste. D: Lumineers, ultra-thin porcelain veneers.**

Our Business Development Office facilitates commercial links for all UoA3 staff. These have been aided by the appointment of Dr Jay Patel (formerly with Phillips Oral Health). Queen Mary Innovation (QMI) supports Translational Research through a variety of Proof of Concept (PoC) and Intellectual Property (IP) initiatives (See REF5a). The Dental School has been particularly successful in obtaining PoC funding and has filed 8 patents since REF2014. QMI also provides opportunities for engagement with Industry, Angel Investors and venture capitalists. In 2018, the QMUL Enterprise Investment Fund was launched by QMI to support start-ups.

**Patents**
Three patents arising from IoD research form the basis of BioMin Technologies, a Queen Mary spin-out set up in 2014 which won the Armourers and Brasiers Venture Prize. BioMin produce a halogen-containing bioactive glass which is included in toothpastes selling a fluoride bioactive additive (BioMinF) such as those produced by Abbott Laboratories and Group Pharma which market Hydent Pro and Elsenz in India. The company also sells BioMinF and BioMinC to Kwang Wang in China and BioMinC (a fluoride-free chloride bioactive glass) to Dr Collins in the USA.

A further patent provides the basis of 'Ultradex Recalcifying and Whitening' a nanohydroxyapatite toothpaste and oral rinse marketed by Periproducts (now Venture Life) sold in Boots and Lloyds Pharmacies. This is based on our Impact Case from REF2014. The oral rinse is now available and patents have now been granted in Europe and the USA (2018-19).

We have developed Ceram II VLC, a new resin modified Glass Ionomer Cement. This arose from a Knowledge Transfer Partnership involving the IoD and PSP Dental, a UK based manufacturer of Restorative Dental Materials. The product contains a new adhesive monomer and offers improved bonding to tooth tissue. Ceram II VLC is now PSPs best-selling product. We have adapted a Nanohydroxyapatite toothpaste to develop a mouth-rinse and a CAD-CAM version of Lumineers (REF2014 Case Study) is now in worldwide use.

**Knowledge transfer across commercial areas**

- A patent was filed by Hilti, a German-based company, to use our Glass Ionomer Cement in the Building Industry.
- A Flake Glass patent was filed for dental coatings based on a modification of wear-resistant coatings used in oil pipelines.
- A Fluoride Ion battery patent was based on an undergraduate BDS project led by Patel. The two first inventors (Franks and Hines) were undergraduate dental students and received a prize for their work (£10K 1st prize in BDA/Dentsply competition).

**1B. Unit context and structure**

Our research and culture have been enhanced by integrating SMD and Queen Mary. The reorganisation in 2016 was designed to focus our work in **research-led Centres**, bringing together clinical disciplines with basic science (**Figure 2**). The laboratory-based activities of the Centre for Oral Immunology and Regenerative Medicine (COIRM) are housed in the Blizard Institute. Translational research activity is located in the IoD and Royal Dental Hospital. The Centre for Oral Bioengineering (COB) is co-located at the Mile End campus, allowing interaction with the School of Electronic and Material Sciences, thereby facilitating access to their facilities including Nanovision Microscopy and solid-state magnetic resonance spectroscopy. To amplify the reach and impact of our work in public health, we established the Centre for Dental Public Health and Primary Care (CDPH) located within the IoD and working closely with the Institute of Population of Health Sciences.

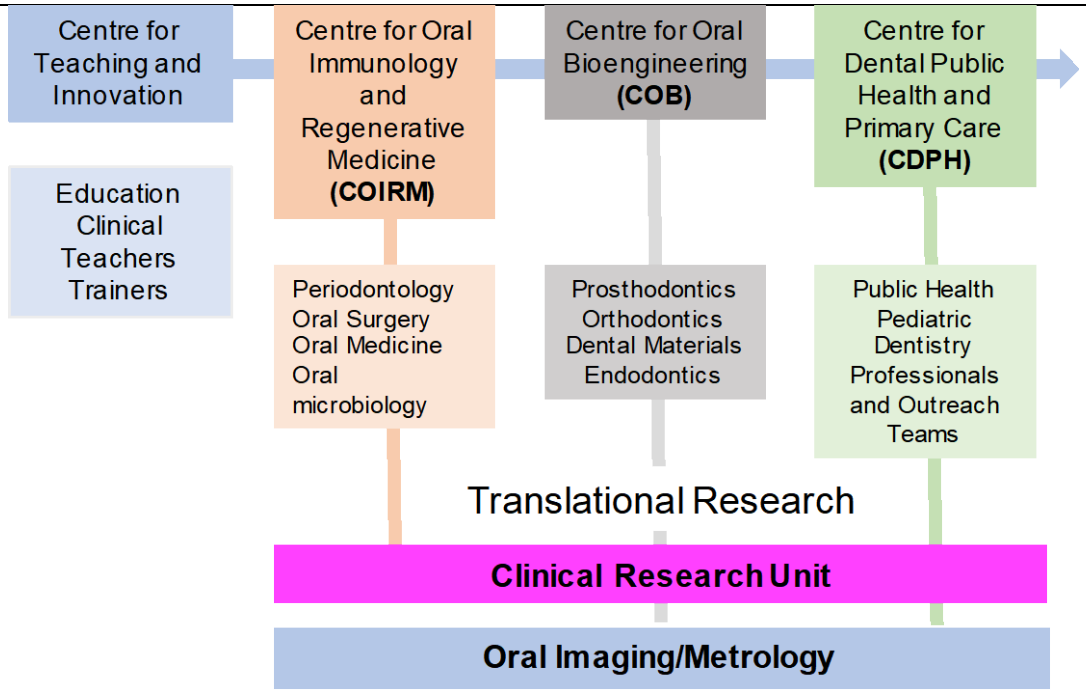


**Figure 2. Structure of the Institute of Dentistry.**

**Centre for Oral Immunobiology and Regenerative Medicine (COIRM- including the Clinical Research Unit [CRU]); Centre Lead: Professor Nikos Donos**

COIRM builds upon established inter-institute collaborations, particularly with the Immunobiology Group of the Blizard Institute and the cross-Institute Centre for Inflammation and Therapeutic Innovation (CiTI). COIRM has built a cohesive, inter-disciplinary research strategy around the **three overarching themes** of wound healing, inflammation and cancer.

The integral CRU is equipped with state-of-the-art clinical research facilities and incorporates a laboratory for patient investigation and biomarker discovery. It promotes thematically-driven, funded trials (including commercial) whilst providing postgraduate research training in clinical research methodology and innovative treatments. A Senior Lecturer in Periodontology & Translational Dental Medicine (Caciolari; *Clin Oral Implants Res 2018*) was appointed to further develop collaboration between COIRM, Oral Cancer, Immunology and Inflammation.

**(i) Wound healing, tissue repair and regeneration**

We have undertaken commissioned systematic reviews in Periodontology and Implantology on hard tissue regeneration, wound healing and host modulators. These contribute to European treatment guidelines. Our guideline work flags areas which require further investigation leading to pre-clinical studies and clinical trials (Donos, Calciolari, Mardas). In the area of tissue regeneration and implant dentistry, we have charity (Osteology Foundation: £305K) and industry (Geistlich £182K; Straumann £60K) grants. These have led to publications in healthy and systemically compromised patients. An example is the genetic and proteomic profiling of bone regeneration in osteoporotic and diabetic patients. This work is important for titanium implant surfaces and has resulted in a series of highly-downloaded publications (2018-2020; e.g. *Clin Oral Implant Research 2016,2018*). It was recognised by the International Association of Dental Research Award for Women in Science.

In regenerative medicine, focussed on scar healing, we recruited Sequeira to investigate the molecular and cellular mechanisms of oral cancer, and understand the regenerative potential of the oral mucosa. This tissue has rapid and scarless healing properties compared to skin (*Cell*

*Stem Cell 2019, 2020*). The group combines imaging and computational modelling to map cellular interactions. These techniques, combined with transcriptomics are used to understand the intrinsic and extrinsic signals required for oral wound healing and tumour formation (PhD fellowship: €121K). The research has broad translational application including the identification of micro-environmental signatures in scarless tissues. It offers the potential to accelerate wound healing after oral cancer resection whilst improving the quality of life amongst cancer patients (*Nature Comm 2018*)

Our work on wound healing (Barts Charity, £830K) uses non-invasive, three-dimensional imaging to investigate the treatment of periodontitis. Collaborative publications linking oral and systemic health have been produced. A paper on metabolic control and oxidative stress on the treatment of periodontal disease was awarded the American Academy of Periodontology Clinical Research Award (2020; *J Clin Periodontol 2020*) for an outstanding scientific publication (Donos/Gkranias).

**ii) Inflammation, immunology and infection**

In conjunction with the Institute of Metal Research in China, Johnson Matthey and Promethean Particles, Allaker is preventing implant infection with nanoparticle-based coatings and Copper-bearing alloys (Innovate UK: £734K; HEC Pakistan: £60K; *J Biomed Mater Res A 2014*). We are also analysing microbial samples from a large cohort of patients with peri-implantitis (with Brazil: ITI Foundation: $120K, Donos/Calciolari), neutrophil defects (Barts Charity: £464K Donos/Gkranias), metabolic syndrome and periodontal bony lesions (Allaker, Stephen)

Our oral microbiome studies investigate the role of volatile compounds in oral malodour and periodontitis (GlaxoSmithKline £206K; Allaker). We are also looking at the microbiome in disrupted peri-implantitis biofilms (Osteology £30K, Soussa/Donos/Allaker). Other studies include antimicrobial oral and skin product testing (Virbac™: £30K: Allaker) and the impact of oral microbiome on birth outcomes in rural Zimbabwe (see above, MRC: £1.2M; Donos/Allaker).

The translational nature of our immunology research is reflected in projects on senescent cells (Parkinson; *J Proteom Res 2015*), pivotal to many age-related diseases. We identified metabolites that accumulate outside senescent cells with the potential to be non-invasive biomarkers. One of these, citrate, has been shown to be related to Type 2 diabetes and cancer. We are investigating the mechanism of extracellular accumulation of citrate to identify novel therapeutic targets for age-related diseases and cancer as these are applicable to oral diseases.

Kang developed a platform technology for the rapid detection of anti-drug antibodies in multiple sclerosis, haemophilia, Behcet's and irritable bowel disease using GloBody™ reagents (e.g. *Scientific Reports 2020*). This led to a patent (2019) and a spin-out company (ASK Bioinnovations 2019). The technology is transferable to all therapeutic monoclonal antibodies and CAR-T cell therapies. We are now developing it for the detection of SAR-CoV-2 antibodies. In collaboration with Camstech, we were awarded an NIHR grant (2020, £1.2m: Kang). In allied work, we won £100k from NIHR for the rapid, sensitive detection of resistance to therapeutic antibodies (Kang). This complements our work in multiple sclerosis (Giovannoni, UoA1). At present, Kang is setting up national testing for anti-drug antibodies among haemophilia patients treated with the antibody Emicizumab (FVIII-mimetic).

Translational work in mucosal inflammation has utilised *in vitro* oral mucosal model techniques to understand the mechanism of oral inflammation and how ulceration develops in Behcet's disease (Hagi-Pavli/Fortune; *J Oral Microbiol 2015*). The inter-relationship between the host immune response (a functional defect in Toll-Like Receptors -2 and -4) and oral microbiome dysbiosis in Behcet's has been comprehensively studied leading to potential therapeutic drug applications (Seoudi/Fortune; *Innate Immun 2014*). In response to the Covid-19 pandemic, Seoudi has investigated, with Science & Engineering, the characteristics of aerosols generated by dental

procedures. This work has implications for risk reduction strategies. Furthermore, GSK has funded a study on the reduction of virulence of bacteria following the use of antibacterial mouth-rinses (£252K, Donos).

**iii) Oral Cancer**

Research on the cellular and molecular mechanisms of oral cancer range from basic keratinocyte biology and the tumour microenvironment (fibroblast senescence; Parkinson) to the development of diagnostic platforms (The; *BMC Cancer 2015*). Recent studies on desmosomal cadherins (Dsg3- pemphigus vulgaris antigen) have increased our understanding of the role of Dsg3 (Wan) signalling pathways which suppress p53, critical in cellular stress and carcinogenesis (Barts Charity: £50K).

Our genomic and transcriptomic work in cutaneous squamous cell carcinoma (cSCC) has identified the stem cell signature in high-risk lesions, metastatic spread and disease progression (Leigh *Nature Commx2*; £681K Sanofi). The investigation of screening biomarkers (Defensins 2 and 3) for oral cancer in the high-risk population of East London (Tappuni/Flores-Borja) has recently been funded by Barts Charity (£50K).

Hutchinson led the first CRUK-funded study related to oral cancer (£1m). This multi-centre randomised study involved >700 patients with early mouth cancer and compared primary tumour resection alone with primary tumour resection and simultaneous selective elective neck dissection (*Br J Cancer 2019*). The results demonstrated an improved cure rate of 31% (5-year disease free survival) with elective neck dissection. There were no adverse effects on quality of life and no significant resource implications. Hutchinson received £950K from the Health Quality Improvement Partnership to develop a database related to the clinical management of oral cancer.

Biddle (MRC NIRG; *EBiomedicine 2016*) explored the concept that in cancer, heterogeneous stem cell phenotypes exist within individual tumours. He is investigating the underlying cellular plasticity that drives this heterogeneity. He studied the behaviour of a distinctive sub-population of amoeboid tumour keratinocytes which appear to play an important role in metastasis. The regulation of immune mechanisms and epithelial differentiation in squamous cell carcinoma is synergistic with our work on tumour-associated keratins (Waseem, Sequeira). Our local South Asian population has a high rate of oral cancer associated with Betel nut chewing, as well as exposure to tobacco, alcohol and Human Papilloma virus. A dedicated tissue bank has been developed to support epidemiological and basic science research by collecting samples from the more that 1000 patients a year that attend Barts Health with squamous cancer (Biddle, Leigh).

**Centre for Oral Bioengineering (COB); Centre Lead: Professor Mangala Patel**

The COB supports clinical academics from a variety of areas in translational and interdisciplinary research using IP-protected materials. COB has strong research links with the Institute of Bioengineering and Materials Research Institute (both Faculty of Science & Engineering). There are **three main research areas**:

**i) Dental Physical Sciences**

We have developed fluoride-containing bioactive glasses (Hill, Davis and Karpukhina) used in remineralising toothpastes and our patents have been licenced by BioMin Technologies (see Impact Case Study and above).

Novel leucite glass-ceramics have been produced (Karpukhina, Hill, Cattell) which have high flexural and bond strengths (*Materials Letter 2015,2016*; *Scientific Report 2018*). These can be accurately machined in thin sections which are ideally suited to minimally invasive, adhesive applications. We have obtained industry funding (£73K) and glass production costs (£15K) leading

to collaboration with a UK glass manufacturer. A US patent has been granted and there is significant commercial interest.

A cross-disciplinary team of COB researchers with SEMS, SMD and Barts Health (Cattell), developed a sustained and controlled release chlorhexidine. This attracted QMI Innovation funding (£75K), a patent was filed and a license signed with a commercial partner. The work was shortlisted for the Royal Society of Chemistry prize (2018) and the 2019 QMI Innovation Award. The group, in collaboration with the William Harvey Research Institute (UoA1), recently obtained funding for the development of 'smart' antimicrobial mouth-rinses for orthodontics (Cattell, Johal; £139K, 2019-2022).

Anderson established collaboration between COB and SEMS to establish new approaches to material design to improve hard tissue repair. This resulted in high quality papers (*Nature Comm 2018, Front Physiol 2017x2*) and a patent.

**(ii) Clinical, mixed-methods and translational research**

We have integrated clinical and non-clinical academics in Orthodontics (Fleming, Johal), Paediatric Dentistry (Wong), and Dental Materials (Hill, Patel, Karpukhina and Shahid) (*Acta Biomaterialia x2; RSCAdv2016*). In addition to the examples outlined above, the clinical effects of fluoride-containing bioactive glasses have been investigated in Composite Varnishes, Orthodontic Adhesives (for prevention of secondary caries), Dentine Bonding Agents, Cements and Air Abrasives. These resulted in over 100 publications in the current REF period, 7 PhDs and 8 DClinDent/MSc students having completed and additional projects are underway. An industry-sponsored trial (£70K; Johal) investigated the effect of bioactive fluoride-containing toothpaste on white spot lesions following orthodontic treatment.

A further example of translational research has been the development of dental compositions such as double layered hydroxide. These rechargeable materials act as slow fluoride/cariostatic ion-releasing systems (Patel; *DentalMaterialsx2*). Since 2014, we attracted funding (>£60k) in addition to an EPSRC PhD studentship, leading to the development of a toothpaste with controlled delivery of fluoride. This has been shown to adhere to tooth surfaces, is rechargeable and water-insoluble, improving its efficacy. A European patent has been granted (EP3060192 B1) and a US patent pending. Related prizes include: Colgate (2014), Barts Healthcare Innovation Prize (2016) and the VOCO British Society for Oral and Dental Research Materials Award (2018).

A novel electronic orthodontic application was developed (Fleming) with funding from the European Orthodontic Society (£15K). It was demonstrated to improve compliance and alleviate pain and anxiety associated with orthodontic appointments in two randomised trials (*Cochrane Database System Rev 2016*). It was subsequently shortlisted for the Houston Prize at the European Orthodontic Society (2020). COB encourages clinical academics to work with NHS colleagues leading to numerous successful grant awards and publications, such as an £600K MRC Biocatalyst grant, a joint commercial pre-trial (£38K) and a clinical trial (£150K).

There are numerous examples of national and international collaboration. We have attracted funding for mixed-methods research (British Orthodontic Society/Royal College of Surgeons: £157K) leading to the development of a Core Outcome Set for Orthodontics (Fleming). Multi-centre international trials in Paediatric Dentistry (Wong; *Dent Materials 2017*) have been done on preformed Stainless-Steel Crowns to treat decay and molars with poor prognosis. These demonstrated benefits in caries prevention, financial savings and the effect of early extraction in children.

**(iii) Digital dentistry**

Our Life-Surface-Imaging facility uses non-invasive, dual-modality imaging producing simultaneous 5-dimensional information (3D, space, time and thermal). This technology underpinned collaborative clinical trials (£1.3m; PI: Donos), with over 40 peer-reviewed publications in this REF period. Facial scanning has been used for phenotyping of sickle cell anaemia, other haemoglobinopathies and obstructive sleep apnoea.

Liversidge used imaging and digital archives to develop an age estimation atlas of tooth formation which attracted over 800 citations since REF2014. Recent developments include the use of wisdom teeth as legal evidence for age determination, the estimation of age in early fossils of modern humans and the growth pattern of Neanderthals (*Science 2017*).

COB houses the internationally-recognised X-ray microtomography facility (Davis) with in-house designed scanners and bespoke software used to study the dynamics of tooth mineralisation. Collaborations include researchers from the IoD, SEMS and external organisations. There have been widely publicised (and televised) studies on the recovery of text from historical scrolls, visualisation of images from damaged black-and-white film, and investigation of bone density in osteoporosis.

Our range of expertise is typified by the design and build of a new Polarising Light Microscope at a cost of circa £100K, which combines six or more separate images to create a three-dimensional image (Boyde). This has been used to examine birefringent orientated structures and is invaluable for the study of mineralised tissues.

**Centre for Dental Public Health & Primary Care (CDPH; Interim Centre Lead: Professor David Williams)**

Research in population and public health is a strategic priority for the SMD and

Dental Public Health is an important component. Our research is focused on reducing oral health inequalities and in developing theory-based interventions to promote oral and general health. This reduces the burden of chronic disease and integrates oral health into wider general health promotion. Methodologies include qualitative and quantitative research, epidemiology, health behaviours, behaviour change, healthcare research and systematic reviews. We are a recognised Centre for specialty training in Dental Public Health and have trained 2 NIHR Clinical Lecturers and an Academic Clinical Fellow since 2014.

**i) Public health policy impact**

The Centre has **extensive partnerships with local and national NHS and Public Health organisations** providing the environment to undertake research and translate into societal benefit. Pine and Muirhead are Honorary Academic Consultants in Public Health England (PHE); Yusuf has a substantive Consultant appointment at PHE's London Centre and is the Clinical Lead for Childhood Obesity. She is a member of London's Child Obesity Taskforce and the Clinical Public Health Lead for Homeless Health. Muirhead's research on the unmet oral health needs of vulnerable children was jointly funded by the Healthy London Partnership and NHS England's London Region (*BMJ Open 2018*). We have submitted joint applications with PHE to NIHR HS&DR and HTA for primary care feasibility studies and clinical trials.

**ii) Promoting children's oral and general health**

Pine leads a programme on the role of sugar and fluoride delivery on the **prevention of dental caries** in children and families. This focusses on theory-driven behavioural interventions in individuals, communities and the population (*Int J Environ Res Public Health 2014*). National multi-centre clinical trials funded by NIHR (£350K Dental RECUR) and industry (GSK; £550K) evaluated

parental efficacy in controlling dietary sugar intake and the use of fluoride toothpastes. Nurse-parent therapeutic conversations reduced childhood dental caries through behaviour change. The results have implications for changing paediatric dental practice globally. Muirhead also led pivotal research involving **Looked after Children,** a vulnerable group often excluded from research because of complicated parental responsibility and consent issues.

In recognition of the impact of tooth decay and childhood obesity, Yusuf forged collaborations with the Public Health Department in Tower Hamlets and the Global Health Unit in SMD to develop a health promotion intervention for primary schools. This involved 3,700 children in 2019-20. We were the first dental school in the UK where Dental and Dental Care Professional (Dental Hygiene and Therapy) students led on a sugar reduction intervention, consistent with England's Sugar Reduction Strategy. We received funding from Harrow Council and Health Education England (£30K) to develop a training intervention resulting in improved in health promotion in families. The work was promoted by the Chief Dental Officer as an example of the benefits of academic and public health collaboration. Yusuf (in collaboration with Eldridge, Director of the Pragmatic Clinical Trials Unit) submitted a grant application to develop and evaluate obesity interventions in adolescents.

**iii) Improving oral and dental services**

Coulthard initiated an Online Referral Management and Triage System with Dental Public Health colleagues for specialist referrals. He was co-investigator on a large mixed-methods study to evaluate the effects (£670K: NIHR SDO) and he chaired three NHS England committees. Guidance was published on improved access, the reduction of inefficiencies & inequalities, better quality care and enhanced patient outcomes. Coulthard leads the strategy and a UK dental team to identify domestic violence and abuse at the time of referral (£250K: NIHR HS&DR). He has produced several high-quality systematic reviews providing the evidence for improving postoperative pain in patients after surgical and non-surgical dental treatment (*Cochrane Database System Rev 2014; J Head Pain 2015*).

Fleming developed a *Core Outcome Set* for Orthodontics and evaluated *orthodontic and dental treatments*. These studies (British Orthodontic Society/Royal Collee of Surgeons: £158K) involved international collaboration with academics in Orthodontics, Dental Public Health, Paediatric Dentistry and Health Economics. Meta-epidemiological research (Fleming) involving Stanford, New York, Bern and Athens has evaluated methodological, reporting and statistical aspects of dental research. Williams led the International Consortium for Health Outcomes Measurement. In conjunction with the FDI-World Dental Federation, he developed a minimum adult oral health standard set of outcome measures used in clinical practice, research, advocacy, and population health. This collaboration involved researchers, service users and clinicians from fifteen universities and health authorities across the world.

**1C. Future strategic aims and goals**

The IoD is proud of its heritage and location in East London and is driven by social responsibility. In the next period, we will focus our research on solutions to important oral health questions relevant for the local, national and global population. Our strategy is aligned with the research strategy of SMD, Queen Mary and Barts NHS Trust. Our focus will be on cancer, immunology global and public health, and materials. We will continue to develop current staff and invest in new posts in these areas, particularly cancer and global and public health.

**Focus and Investment in key research themes**

We will invest in the following key research themes in the next REF cycle:

*Caries and Oral Health*

We will build on our research activity in **Caries and Oral Health**, linking with Oral Healthcare Companies and materials science. We will enhance our translational research, clinical trial design and execution. We will increase our work on oral cancer diagnostics, the systemic effects of oral health and the impact of oral conditions on patients and populations.

*Oral Cancer*

We will bring together researchers across the SMD who work on squamous cancers of oral mucosa, skin and oesophagus. With £2.6m funding (2021-2026; Barts Charity) we will create the cross-Institute '**Barts Centre for Squamous Cancer'** based within the IoD. We will recruit 3 new senior investigators in the fields of molecular carcinogenesis, translational cancer research and oral cancer epidemiology. We will enhance core facilities for tissue banking, *in vitro* models and bioinformatics. An exemplar project will determine the transcriptomic signature in oral cancer and perform single cell RNA sequencing to identify the immune response. Mutational signatures for exogenous triggers such as tobacco will be elucidated. The strategy builds on our interdisciplinary expertise in stem cell biology, tumour heterogeneity, genomics and transcriptomics as well as initiatives in database development and analyses.

*Dental Public Heath*

Two recent appointments, Wanyonyi (Senior Lecturer; 2020; *PLoSOne 2017*) and d'Antoni (ECR in Behavioural Science; 2018; *Journal Health Communication 2017*) have brought together molecular science, population health and health services research. Wanyonyi has expertise in developing efficient, prevention-focused, integrated dental services and has established collaborations in sub-Saharan Africa. Her focus is the integration of oral and general health services as well as workforce modelling in health systems. She also works on interventions to improve dental services in older people (funded by NHSE; £24K). We will make further appointments and establish a research network in primary care. The recent strategic Barts Charity grant (£2.6m) will further develop Dental Public Health research and support new appointments including an oral cancer epidemiologist. Coulthard will develop trials in dental injury, facial injury, domestic violence and domestic abuse in conjunction with public health, policy, law and social sciences.

**Develop and attract talented researchers**

We will continue to recruit new and develop existing staff, adhering to the Concordat to Support the Career Development of Researchers (See REF5a**)**. This return includes three new Professorial appointments and seven new early career researchers (ECRs). We will continue to invest in ECRs allowing them to make the transition to independent researchers, providing support *via* grant-writing clinics, fellowship application mentoring and mock-interviews from experienced staff. The Barts Academy acts a forum for mentorship, away-days, training events and favours peer-to-peer interactions. We have recently appointed Sirovica (*Nature Comm 2020*), who will augment our research on resin-based restorative materials, collaborating with Hill and Patel in Dental Physical Sciences. This is part of our bigger succession plan to enhance our world-leading status in Dental Biomaterials.

**Further embed inter-disciplinary and cross-faculty collaboration**

We will reinforce our links with medicine during the next REF cycle, including those with the Diabetes Research Group (Finer [UoA2]; NovoNordisk funding), CiTI (see above) and rheumatology (Pitzalis, UoA1) to study the links between periodontitis and rheumatoid arthritis.

We will further our interdisciplinary links with SEMS and use genetic, molecular and cellular investigations to address oral health challenges. These will inform our social and public health studies improving oral health in individuals and the population.

Our multi-disciplinary work fits with the Barts Life Sciences (BLS) initiative, a joint enterprise between Queen Mary and Barts Health NHS Trust to develop a precision medicine and dentistry programme adjacent to the dental hospital. This is likely to be a £600mill initiative to improve patient care through precision screening, prevention and treatment. BLS is a cross University development which brings together engineering, materials, mathematicians and information technologists with researchers in medicine and dentistry. The BLS dovetails perfectly with the post-REF2021 research plans of the IoD.

## 2. PEOPLE

### 2A. Staffing strategy and staff development

**Our staffing strategy** has three main aims: 1) to invest in existing staff by supporting, recognising and promoting excellence; 2) to recruit the next generation of researchers to develop existing and new areas; and 3) to continue to build interdisciplinary research between our scientists and clinicians.

This strategy is underpinned by a commitment to ***equality and diversity***. The IoD was awarded an Athena SWAN Silver Award in 2018. All staff undertake both equality and diversity training and unconscious bias training. Regulations and handbooks are regularly updated to address the needs of staff with protected characteristics. All key meetings are held within core office hours and we offer flexible working. In order to ensure Equality, Diversity and inclusion (EDI) in our staffing strategy, we have included Athena SWAN Self-Assessment Team (SAT) representation on all main committees including the promotions committee (4F, 3M). The change in the requirement for Athena Swan Silver to access NIHR funding has not influenced our drive and ambition for equality. We aim to further improve our Athena Swan standing in our next application. Our priority is to ensure a culture of equality for all.

Our commitment to ***recognise the excellence of our existing*** **staff** is evidenced by the promotion in the REF2021 period of all our non-clinical lecturer staff to Senior Lecturer (3F, 3M); promotion of four clinical staff to Professor (2F, 2M); and appointment of a non-clinical female Professor (Patel, 2018). We have transferred excellent research staff from short-term external funding to permanent posts. In 2019, we appointed Stephen (*PLoS One 2016*) as Lecturer in Oral Microbiology, after 8 years of funding from GSK from PhD CASE to an Industrial PDRA fellowship. We will continue to support investigator-led research and the freedom and creativity needed to achieve excellence and impact.

Our profile indicated a preponderance of academics close to retirement so we made an active decision to *recruit the next generation of researchers.* Appointments were based on academic potential, alignment with our strategy and a commitment to interdisciplinary research. The success of this strategy is evidenced by the inclusion of several ECRs in this submission and our shortlisting for a Times Higher Education Award for 'outstanding support to early career researchers'. In order to allow our ECR's to fulfil their potential we invested heavily in support packages. For example, one ECR was provided with salary, a Research Assistant and consumables (at a total cost >£500k. A PhD student was the recipient of a RCS/British Orthodontic Society Fellowship (£157k) to develop a Core Outcome Set for Orthodontics maintaining our focus on holistic, patient-centred research.

***Recruitment of new senior staff*** has been possible due to investment of core funding. In 2015, Donos was recruited to develop patient-centred research, establish the CRU and lead periodontal research. We recruited a total of 11 additional staff and 2 PhD students by winning £670K including >£400K from the Barts Medical College Trustees. Donos now heads the Centre for Oral Immunobiology and Regenerative Medicine as well as the CRU.

A new Dean & Institute Director (Coulthard) was appointed in 2019. He brings extensive experience of leading research-intensive organizations with multi-professional collaborations. He is Professor of Oral and Maxillofacial Surgery and leads research on the identification and referral of patients presenting with physical injury (see above). He has extensive research experience in post-operative pain management.

A high-profile squamous cell cancer researcher, Leigh, was appointed in 2018. She leads dermatological research for which she was awarded the international medal from the US Society of Immunological Dermatology (2016) and has honorary membership of the European Society of Dermatological Research (2016). She is a member of the Academy of Medical Sciences and Fellow of the Royal Society Edinburgh (FRSE).

**Our dental staff development** strategy reflects the overall Queen Mary research plan to invest in excellence and support career development. We won the 'HR Excellence in Research' award from the European Commission. We enhance career development in the following ways:

Personal guidance for ECRs: from a named mentor to help develop independent research.
Clear performance targets: At the annual appraisal, achievements are reviewed using a structured 'researcher score-card' which outlines progress and identifies unmet training and support requirements.
Targeted support for postdoctoral staff: We established Postdoctoral Networks in conjunction with the University Centre for Academic and Professional Development and the Careers Department. In 2018, the IoD established an Academic Training Oversight Panel led by Muirhead for NIHR Academic Clinical Lecturers and Fellows. This supports academic and research leadership and enhances promotion to Senior Lecturer. The panel also provides a high-level review of research progress. We run a biannual Research Day where Clinical Lecturers and Fellows present their work and prizes are awarded.

**2B. Research students**

Regular Post-Graduate Research (PGRs) students' focus groups have been established. We acted on feedback from the annual postgraduate research review to improve the research environment, particularly in the areas of support, training and supervision.

**Support mechanisms for PGRs**

***Dedicated PGR administrator:*** IoD funded the appointment of a dedicated 0.6FTE PhD Programme Administrator. The appointment was commended in the 2018 review of education as having had a significant impact on student experience.
***Enhanced learning spaces:*** Co-locating research students has increased collegiality and peer support. Each full-time research student has a dedicated desk and there are shared spaces for part-time students.
***Support for academic writing***: In addition to University-level support, in 2019, we began annual IoD PGR writing retreats. In the current submission >50% of returned outputs include at least one PhD or DClinDent student as named authors.

The ***Employability*** of PhD students is enhanced by the opportunity to teach undergraduate students, supervise student projects and mentor. In an internal survey (2018), 93% of PGRs said 'male and female students have equal opportunities to contribute to teaching'. We conduct an annual Careers Day for post-graduate students with contributions from former students and industry. We periodically survey our post-graduate students after graduation and more than half stay in academia based on the most recent data (2018).

**Training and Supervision of PGRs**

***Quality of supervision***: All supervisors have mandatory initial and refresher supervisor training. There are transparent progression criteria for students who are assessed at 9, 18 and 30 months. The review is done by an external panel. Dedicated student support is available (http://www.arcs.qmul.ac.uk/media/arcs/policyzone/Research_Degrees_Code_of_Practice_2019-20.pdf). The IoD is an integral part of the Queen Mary Doctoral College which also provides support for doctoral students, supervisors and postdocs. It includes the Centre for Academic and Professional Development, which offers an extensive range of workshops and training courses under four themes: intellectual attributes; core skills; research governance/organisation; and engagement and impact.

***Clarity of PGR learning needs and programme requirements*:** Annual induction was introduced in 2016. Each PGR has a Training Needs Analysis and individual Training Plan based on the Vitae Researcher Development Framework.

***Regular supervisory meetings and wider learning opportunities***: There are electronic records of supervisory meetings which incorporate student feedback. A quarterly newsletter advertises training and seminars, as well as showcasing opportunities and successes.

***Developing presentation skills***: There is an annual PhD and DClinDent Day to showcase student research projects. Each PhD student is expected to present orally at least once at a major international Conference and we offer up to £1,600 for travel bursaries.

***PGR progress and completion***: The IoD Graduate Studies Committee ensures that student progress is regularly reviewed. Additional support for any student can be put in place quickly if needed. We have increased our PhD student numbers, 69 completed a PhD between 2014 and 2020 compared to 41 between 2008 and 2013. There was an increase in publications from student projects, from 218 in the 2008-2013 period to 451 in this. We currently have 68 PGR and 64 DClinDent students enrolled (Jan 2021).

***Enhancing research culture***: In 2015, the Level 8 research component of the Clinical Doctorates (DClinDent) was enhanced. Supervisors must now hold a PhD (or equivalent). There is close alignment between DClinDent research and our research strategy. Research quality is evidenced by national and international prizes (Table 1). Undergraduate dental students are encouraged to undertake research projects on a part-time basis with two of our undergraduates having won a major Colgate-sponsored Prize (£15,000) and filed a patent.

**Table 1. National/international prizes from Clinical Doctorates since qualification of the 2018 cohort.**

| Programme | Award | Awarding Body | Year |
|---|---|---|---|
| **Orthodontics** | Chapman Prize | British Orthodontic Society | 2020 |
| | BF and Helen E Dewel Award | American Academy of Orthodontists | 2020 |
| **Paediatric Dentistry** | Paediatric Oral Health Group Research Prize | International Association of Dental Research | 2018 |
| **Periodontology** | Research Poster Prize | British Society of Periodontology | 2018 |
| **Prosthodontics** | Schottlander Research Prize | British Society of Prosthodontics | 2019 |
| | Schottlander Oral Prize | British Society of Prosthodontics | 2019 |
| | Schottlander Oral Prize | British Society of Prosthodontics | 2018 |

## 3. INCOME, INFRASTRUCTURE AND FACILITIES

### 3A. Income

The IoD has been awarded circa £9.5m in research awards in the 2013/14 to 2019/20 period. ***Major Research Council Awards*** include research on Dental Implant Coatings with support from the Johnson Matthey company (Innovate UK; £734K; Allaker). We won an MRC Biomedical Catalyst Award for a New Bioactive Glass Cement. Pine was the Principal Investigator of the NIHR-funded Dental RECUR clinical trial (£344K). Kang's research uses novel antibodies for SAR-CoV-2 detection which attracted an NIHR grant (£1.2m) with colleagues in Neurology (UoA1) and Health Economics (UoA2). The HESA research income for this period was £17.5m (REF4b) plus £680k of income-in-kind (REF4c).

***Industrial funding***. We have strengthened our relationship with GSK Oral Healthcare resulting in ≥5 MRC/EPSRC/BBSRC CASE Awards annually, the largest of any Dental School in the UK. In addition, GSK funded £550K in contract research, which reflects the high level of expertise and dedicated facilities such as the $^{19}$F MAS-NMR. Six papers were produced in this REF period that include an author from GSK. We have a GSK employee registered for a PhD. International industrial research funding has been secured from Perioproducts, PSP Dental, Align Technology (USA), Pierre Fabre (France), Curodont (Switzerland) and SDI (Australia).

The ***spin-out company***, BioMin Technologies Ltd. was founded in 2014 to exploit fluoride-containing bioactive glasses for toothpastes and for professional dental products (composites, varnishes and adhesives). The key patents have been licensed to three Dental Materials companies. The company is independently valued at £10-100 million with Queen Mary owning almost 40%.

***Clinical trial*** funding has been provided by a range of companies. In 2016, the CRU was the UK lead for a multi-centre peri-implantitis trial funded by Dexell. Colgate funded a clinical trial in 2016 (£130K; Johal) comparing the short- and long-term effectiveness of powered and manual toothbrushes in orthodontic patients. A GSK award (Pine) supported the development of children's storybooks with embedded behaviour change techniques (£110K) and further funding (Pine; £440K) enabled subsequent evaluation in the BaRTS trial involving over 2,000 families (2019). Straumann funded a clinical trial on implants in osteoporotic patients (Donos; £60K). Geistlich

(Donos; £182K) funded a trial on soft tissue regeneration with xenografts (2019) and the Osteology Foundation supported a trial of plasma rich growth factors for periodontal regeneration (£280K). Funding has been provided by Insmed for a multicentre study to assess the efficacy, safety, tolerability and pharmacokinetics of INS1007 administered to subjects with non-cystic fibrosis related bronchiectasis. Align Technology funded the assessment of Invisalign™ aligners (Fleming; £15K). Recently, we obtained funding (Donos; $181K) with a Brazilian partner from the International Team on Implantology (ITI) for a study on peri-implantitis. In 2020, we undertook a trial with GSK to reduce bacterial virulence using antibacterial mouthwash (Donos; £256K). We obtained support from Barts Charity for two large clinical trial grants on the non-surgical (£439K) and surgical (£319K) treatment of periodontitis. The Medical College of Saint Bartholomew's Trust awarded a PhD studentship (£244K) to investigate autologous platelet concentrates in periodontal regeneration.

**3B. Infrastructure and facilities**

The IoD represents the first new Dental School in the UK for over 40 years. It cost £78m and was commissioned by HRH The Princess Royal in 2015. It has state-of-the-art infrastructure and is supported by strategic cross-cutting core facilities. The University has invested in additional specific dental research facilities.

The ***Clinical Research Unit*** within COIRM, developed with £1.67m investment, has enabled growth in patient-orientated clinical research. There is dedicated space with experienced staff including a manager, clinical researchers, research nurses, trial coordinators and therapists. A co-located sample laboratory permits rapid quantitative analysis of biomarkers facilitating prognostic and diagnostic analysis. The Institute has a number of supporting ***imaging technologies*** including X-ray microtomography, non-invasive 3-D facial and whole-body imaging and optical coherence tomography. These are crucial for our clinical academics. UKRI funding (£400K) has been secured for X-ray beam time. There is substantial external demand for the use of our facilities.

***Infrastructure developments across SMD and Queen Mary (REF5a):*** The Blizard Institute provides high quality facilities for *laboratory science* (UoA1) and hosts the Barts and The London *Genome Centre*. There is an NHS-funded (£12m) Clinical Centre of Excellence for *Behçet's* Disease. Equipment includes a new solid-state *NMR Console* for spectroscopy of dental hard tissues which can detect the formation of minute quantities of fluorapatite (£600K), a high throughput *diffractometer* (£130K), *Scanning Disc Confocal Microscope* (£800K) and X-ray microtomography facilities. We work closely with Barts Health NHS Trust who provide healthcare data for population analytics. We are part of the *UCL Partners* healthcare consortium with 23 NHS Trusts and 8 university partners. This provides the basis for collaboration and oversight of the Academic Health Sciences Centre (SMD Dean, Prof Steve Thornton is Deputy Director), Academic Health Science Network, NIHR ARC North Thames, Comprehensive Research Network, NHS Genomic Laboratory and Data-Can.

The ***Joint Research Management Office*** provides support for pre-award research ethics, grant applications (public sector, charities and industry), governance, finance, statistical support and data management. The office also provides post-award administration (See REF5a). The SMD Research Deanery coordinates and oversees grant applications for IoD staff. The ***Centre for Academic and Professional Development*** runs research funding workshops with specific modules targeted towards writing of applications, development of leadership and improving impact. In 2017, CAPD developed a month-long series of workshops to support researchers applying for fellowships. The ***Research Design Service*** (NIHR £6.5m, Hooper/Taylor, UoA2)

offers support for new grant applications and reviews unsuccessful applications, providing feedback and suggesting alternative funding streams.

***Research Integrity*.** To support the highest standards of research integrity, the SMD appointed Professor Grigg as Deputy Dean for Research Integrity (2019). Grigg provides face-to-face mentorship for senior researchers and advice on research integrity. We developed the infrastructure to allow researchers to upload data to our publicly available system (Elements/QM-Publists). We are committed to developing a culture of reproducibility for clinical and non-clinical research.

***Dissemination and Communications*.** Press Release and Media activity for IoD is managed by the SMD Media Officer who provides regular media training and information at Staff Development days. Media exposure is monitored and celebrated on the college website. It is an integral part of appraisal and professorial reviews and is considered by the promotion panels. There have been >200 media articles concerning fluoride-containing bioactive glasses for toothpastes and other products (including composite-based orthodontic adhesives). In 2016, following the launch of the BioMinF toothpaste, there was extensive media coverage including an article on the front page of the Daily Mail that resulted in 4,500 tweets and 3,500 emails to the company. In 2020, publication of the results of the NIHR-funded Dental RECUR trial resulted in over 8,000 tweet impressions and an interview on the BBC. Fleming is co-editor of a popular orthodontic research blog attracting up to 500,000 unique visits annually. As part of continuous staff development and training in media engagement, Public Engagement and Innovation is celebrated annually with prizes for staff and students to recognise and reward media innovation and enterprising activity. IoD academics with joint University/NHS contracts participated in the Barts Health Innovations in Healthcare Awards. Financial support is available for patient and public involvement in research. We have extensively engaged with our local population and have a dedicated ***Centre for Public Engagement*** which is described in REF5a. This Centre provides financial support, training and advice across the University. The research-informed public engagement has been recognised within the sector by the first award of a gold Engage Watermark.

Research produced by the IoD is showcased through the ***Centre of the Cell,*** the first informal science learning centre (ISLC) in the world to be located within working biomedical research laboratories (the adjacent Blizard Institute) and seeks to have a positive impact on the educational, career and health choices of children, young people and families. In 2018/19, the Centre of the Cell delivered 24,957 individual experiences to young people, their families and members of the public. Centre of the Cell represents a major portal for public engagement for the Life Sciences at SMD and Queen Mary, with a programme of activities which includes an immersive digital interactive cell biology experience, live science shows, workshops, debates, science talks, on-line and card games. All activities are developed with researchers across the SMD providing Centre of the Cell with its unique and cutting-edge content. Since 2013, there have been over 155,000 participants in the Centre activities with overall participants since its opening in 2009 of 207,000. The website has had 100 million+ hits from over 160 countries, whilst there are also four free science Apps with 8810 downloads to date and four different Trumps card games (Cell, Virus, Bacteria and Gene Trumps) with thousands of sets sold or distributed free to young people.

***Public presentation of research*:** Davis developed Time Delayed Integration X-ray Microtomography and applied this to Dentistry, leading to presentations on BBC's 'The One Show' and on the Technology program 'Click'. Hill appeared on BBC radio 4 for his work on bioactive glasses. He was also part of a program on the BBC Radio 4 and World Service called 'Elements' which discussed Fluoride and Caries. He also appeared on 'Supa Shoppers' on Channel 4 which

evaluated mouth-rinses. Pine discussed the results of the Dental RECUR trial on BBC radio and advice for parents on the prevention of dental caries

**4. COLLABORATION AND CONTRIBUTION TO THE RESEARCH BASE, ECONOMY AND SOCIETY**

**4A. Contribution to the discipline and research base**

***Major Research Awards*:**

Boyde: Anatomical Society Prize (2019);
Brauer (Former PDRA): Gottardi Award for work on Bioactive Glasses (2015);
Huang, D'Onofrio, Hoxa: PhD students awarded the VOCO™ British Society for Oral and Dental Research Award for Dental Biomaterials Research (over three consecutive years, 2016,2017,2018);
Anderson and Saroash Shahid: International Association of Dental Research Cariology Research Group Prize (2017)
Pine: International Association of Dental Research EW Borrow Memorial Award (2018), European Organisation for Caries Research (ORCA) Prize in recognition of outstanding contributions to the field of dental caries research (2015);
Hill: Varshneya Frontiers of Glass Technology Award from the American Ceramic Society (2019);
Donos: Clinical Research Award, American Academy of Periodontology (2019);
Leigh: International medal from the US Society for Immunological Dermatology (2016), British Society for Investigative Dermatology Medal for Contributions to Dermatological Research (2017);
Fleming: Dewel Award, American Association of Orthodontists (2020), Chapman Prize, British Orthodontic Society (2020);
Al-Moghrabi (PhD Student): Seamus Keating Research Award (2019).

***Major National and International keynote lectures*** by our academics include:

Hill: Dame Julia Higgins Lecture, 2015; International Congress of Glass, 2016; Inaugural Meeting in Europe of the American Ceramic Society (2016); Indian Dental Association, 2016;
Davis: Gordon Conference on Scientific methods in Cultural Heritage (2018);
Pine: European Organisation of Caries Research (2016); Public Health Conference, All India Institute, Delhi, (2016);
Boyde: Bone Research Society (2016);
Allaker: International Conference on Oral Malodour, 2019; European Association for Osseointegration (2020);
Patel: International Association of Dental Research, 2015;
Fleming: Martin R. Kean Memorial Lecture, New Zealand Association of Orthodontists, (2019);
Coulthald: Jordanian Society of Oral and Maxillofacial Surgeons (2017), South Korea Oral and Maxillofacial Surgery Association, (2018); Spanish Oral Surgery Society (2018); Kuwait International Dental Conference (2018); UAE International Dental Conference (AEEDC), (2017, 2019), 8th World Workshop on Oral Health in HIV/AIDS (2019); IRIS (Identification and Referral to Improve Safety) Conference (2020); European Academy of Paediatric Dentistry, (2020); Royal College of Surgeons of Ireland (2020);
Donos: European Association for Osseointegration (2017); 3rd Osteology U.K. Congress (2018); and Europerio 9 (2018).

**Editorial Roles** **Table 2. Journal editorships (Ongoing unless stated).**

| Role | Staff Member | Journal |
|---|---|---|
| **Editor-in-Chief** | Coulthard | Oral Surgery (2013-18) |
| **Associate Editor** | Allaker | International Journal of Antimicrobial Agents, Frontiers in Oral Health: Oral Infections and Microbes. |
| | Anderson | Caries Research |
| | Coulthard | Cochrane Oral Health Group |
| | Donos | BMC Oral Health |
| | Fleming | British Dental Journal, Journal of Dentistry, American Journal of Orthodontics and Dentofacial Orthodopedics, Progress in Orthodontics |
| | Teh | PLoS ONE |
| **Editorial Board Membership** | Boyde | Journal of Microscopy, Microscopy Research & Technique, Calcified Tissue International, Journal of Bone and Mineral Metabolism |
| | Cattell | Journal of Dentistry |
| | Fleming | Angle Orthodontist, Journal of World Federation of Orthodontists, Journal of Irish Dental Association, Korean Journal of Orthodontics |
| | Leigh | British Journal Dermatology, Acta Dermato-Venerologica, Disease Models and Mechanisms |
| | Tappuni | Journal of Dental Research (2015-17) |

***Major National and International Roles*:** President British Association of Oral Surgeons 2019-2021 (Coulthard); President 2020 British Society of Periodontology (Donos); Fellow of the International Society of Antimicrobial Chemotherapy (Allaker); Fellow or the Royal Society Edinburgh (FRSE) and elected to the Academy Medical Sciences (Leigh). Chair of NIHR Research for Patient Benefit Committee North-West (Pine) to 2016.

Bioactive Glass Composites Symposium Dental Materials Group, International Association of Dental Research, 2018 and Organiser European Dental Materials Conference in 2017 (Cattell); Scientific Chair, British Orthodontic Conference (2021-22; Fleming); President of the International Association of Dental Research Oral Medicine and Pathology Group (2018-2019; Tappuni), Scientific Chair Osteology UK 2018 (Donos), Scientific Chairman British Society of Periodontology conference 2021 (Donos); President of the Oral Medicine and Pathology Group, British Society for Oral and Dental Research (Tappuni).

EPSRC funded Working Group on Collaborative Computational Project in Tomographic Imaging (Davis); UK Coordinator on EU Network "NewGen" Coordination of Research on Bone Grafts (Hill); Founder International Association of Dental Research, Global Oral Health Inequalities Research Agenda (Williams); Osteology Foundation Board Member (Donos), Association for Dental Implantology (ADI) Board (Donos).

Numerous academics hold Visiting and Honorary Professorships across the world including Hong Kong, Griffiths and Queensland, Australia (Donos); Adelaide, Australia and Messina, Italy (Fleming); Saveetha, India (Tappuni); Lahore, Pakistan (Anderson).

**4B. Collaborations, networks and partnerships**

At the IoD, we foster a spirit of collaboration within and outside the University. Of the papers published in this return, over 50% include an external author, 28% a co-author from abroad and 12% from another Faculty in Queen Mary. We have a strategic partnership with the Dental School in Sao Paulo State which enabled secondments and joint papers to be published. We formed a partnership with the Harvard School of Dental Medicine to advance dental public health research.

We have links with a number of Chinese Universities and have established a scheme with the Chinese Government to fund 4 Dental PhD students. Dr Teh published papers with collaborators in Guangzhou University (China) on diagnostic markers (RASSF1A and FOX1) as predictors of malignancy in head and neck cancers (*Cell Death Disease 2020*). We have formal research agreements with Zagreb (Croatia) on bioactive glass composites, Harbin (China) on bone grafts and the University of South China on Air Abrasion. We have a MoU with the National University of Singapore to share 3D *in vitro* tissue engineering expertise (Hagi-Pavli). There are strong links with Tehran University Medical School on bone grafts and dental composites which have resulted in five visits and six papers.

Donos has developed a collaboration with the Swiss International Team for Oral Implantology, and the Osteology Foundation with both organisations providing funds for Scholarship Centres. Fleming has developed a collaboration with researchers from the Universities of Bern and Stanford resulting in numerous publications relating to Orthodontics and Research Methodology. Coulthard has collaborations with the Universities of Boston, Hong Kong and Barcelona. Hill was the UK representative of the EU network NewGen (Bone Grafts).

**4C. Wider benefits for key users of research**

The breadth and impact of our research has ensured that we have been pivotal in developing national and international policy.

Hutchinson led research on the surgical management of oral cancer. It is estimated that his findings will save at least 21,000 lives a year worldwide. The work led to a revised European Position Paper recommending a change in surgical practice. Hutchison also founded "Saving Faces" providing an expert helpline to support patients who are about to undergo or are recovering from facial surgery. Saving Faces provides a rapid telemedicine triage service for primary care practitioners relating to potentially malignant oro-facial lesions.

Coulthard working with Patients and Dental Public Health colleagues initiated regional Oral Surgery Referral Triage. An Online Referral Management and Triage System for all dental specialist referrals has been established across England (£670K NIHR).

Pine was appointed by PHE to review the evidence and inform national guidance for Delivering Better Oral Health. Pine obtained funding from Health Education England to upskill dental nurses across the NHS in a novel approach to reducing the risk of recurrence of dental caries.

Johal is the dental representative on the NICE panel for Sleep Apnoea which developed the national recommendations for the use of oral appliances.

Fortune is a Co-I on a project (£2.5m) across 8 African countries investigating the effect of asthma on children's oral health. She works with organisations including the Global Knowledge Network which, during Covid-19, supported African countries with teaching aids, videos and waterless soap. She is involved with the World Association of Sustainable Development providing health and education to developing countries.

**COVID Response.**

Since the start of the coronavirus pandemic, IoD staff and students have contributed to frontline clinical service and infrastructure. Clinical Academics, dental research nurses and dental students (Diploma, BSc and BDS and PG) volunteered to provide frontline care in intensive care and Covid wards. The Royal London Hospital was under extreme pressure and IoD staff including the Dean provided support to reduce Ventilator-Associated Pneumonia. Coulthard's first of 12 Covid articles in 12 months was the British Dental Journal's most accessed (82,000) and top cited article (55 citations). He demonstrated national and international leadership producing Position Statements as President of the British Association of Oral Surgeons with much needed PPE advice. Coulthard was an author of the, 'Mitigation of Aerosol Generating Procedures in Dentistry – a Rapid Review' published by the Scottish Dental Clinical Effectiveness Programme in 2020 and updated in 2021. Laboratory and technical staff supported the establishment and operation of the national Lighthouse laboratories.

The IoD provided essential support early in the pandemic by supplementing NHS personal protective equipment through the donation of masks and gloves. IoD designed and fabricated face shields using dental equipment and 3D-printing with consumables funded by the Barts Charity (£22K).