



Workshop Report

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The Future of Facial Prosthetics

In the advancement of facial reconstruction, facial prosthetics remains an important treatment modality as it offers opportunity to patients through patient selection of care, delay of other care options or for rescue where no other treatment options exist. For facial prosthetics to advance and keep pace with other rapidly evolving fields of facial reconstruction, there is an urgent need for facial prosthetics to be propelled into the domains of personalized medicine, advanced biotechnology and regenerative medicine.

In its evolution, facial prosthetics has been provided through a manual art-based approach. To remain in context and to be able to contribute to future care in facial reconstruction, facial prosthetics must transform to be driven by biotechnology, regenerative medicine and transplant medicine developments. This is a tremendous challenge for a treatment modality that has had a history limited largely to a manual art-based approach. The exploratory work undertaken by the report “The Future of Facial Prosthetics” is critical step in appropriate development of facial prosthetics.

A point of departure will be to understand the future care need and how this is to be technologically met. In this regard, there is a very long overdue need to see facial prosthetics understood as a bioengineering challenge that is driven by clinical need. From this flows the design and delivery of care. These issues should be considered in terms of Clayton Christensen’s constructs of disruptive and catalytic innovation. To become truly relevant to health systems and health economics, facial prosthetics requires technology development so as to be able to deliver care to broad populations, on demand and at substantially decreased cost. This can only happen when facial prosthetics is considered as a bioengineering technology development. This will involve advanced materials, advanced manufacturing technologies, imaging, color science and a range of other disciplines collaborating at a high level. It is thought that three stages are likely to occur in this journey:

- Stage 1. Transformation of facial prosthetic construction processes to advanced digital manufacturing processes
- Stage 2. The development of active, robotic prostheses with advanced materials
- Stage 3. The integration of intelligent facial prostheses with biological systems for facial reconstruction and facial transplants

Facial Prosthetics has much to deliver but this cannot be realized for the future without facial prosthetics transforming to a bioengineering development.

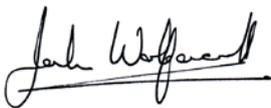
A critical element for the future is that facial prosthetics must demonstrate health economic utility. The level of hierarchy of strength of evidence related to facial prosthetics is particularly poor. The consequence is that there is little health economic justification for advocacy of facial prosthetic care. In a world evermore dominated by health economic consideration, this will ensure the continuing marginalization of facial prosthetic care. Similarly, this also causes facial reconstruction clinicians who are decision makers in the care pathway to regard facial prosthetics as only of value in rescue and last resort.

An important aspect in transforming facial prosthetics will be for those presently involved in delivering care to develop a strong translational role and engage basic scientists and clinician scientists in a structured approach to development. Core will also be to involve industry in this process. In bringing about transformative change, those presently involved in care delivery will need to clearly articulate the need for change to a bioengineering and health economic model to

create Christensen's Catalytic change. This will require accompanying substantive shifts in facial prosthetic clinical education processes.

Transformative change cannot occur without the involvement of industry to deliver the promise internationally. To convince industry partners to participate and to encourage public and private fund holders to contribute, a clear signal of a new and potentially transformative direction is essential. This must be accompanied by data to support an understanding of the market that would need to access facial prosthetic care internationally. Understanding the potential market will be key to moving the field forward. The value of this is that, as a biotechnology with broad application and processes that can be used in other biomedical applications, this represents a strategic opportunity for national and industry interests.

The report on "The future of Facial Prosthetics" is an important document. It is important as this is the first known attempt to begin the process of addressing the issues that are important to the future development of facial prosthetics. Each of the issues touched on above were considered in the report. For anyone with an interest in development of facial prosthetics, this report is the first known non-industry driven attempt to systematically consider how to approach developing facial prosthetics for the future. The authors and participants are to be congratulated on taking on this much overdue and vitally important work. The very unfortunate individuals in need of facial prosthetic care are so well deserving of this initiative.

A handwritten signature in black ink that reads "John Wolfaardt".

John Wolfaardt
BDS, MDent, PhD



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INTRODUCTION

On the 12th January, 2012, an EPSRC funded workshop with the aim to clarify a research strategy for developing state of the art clinical practice in maxillofacial prosthetics was held at Loughborough Design School, Loughborough University. This report outlines the need behind a workshop in this area and concludes the findings from the workshop that provide direction for further research.

BACKGROUND TO FACIAL PROSTHETICS AND THE NEED FOR A WORKSHOP

Maxillofacial prosthetics is a specialised profession that seeks to meet the needs of patients with various degrees of facial deformity by restoring aesthetic and functional portions of missing tissue using artificial materials (usually silicones). Figure 1 shows a patient who requires an orbital prosthesis. The practice of restoring lost tissue with prosthetic replacements precedes surgical attempts and even with recent advances in surgery there still remain many cases where prosthetic rehabilitation is more suitable and desirable to the patient involved.



Figure 1: A patient who requires an orbital prosthesis

Maxillofacial Prosthetists & Technologists, Anaplastologists and Prosthodontists are three professional groups that share a common interest in the provision of facial prosthetic care, treating a wide range of patients with conditions resulting from cancer treatment, traumatic injury, congenital deformity and other diseases that cause significant tissue damage. In the UK, this work is typically undertaken by Maxillofacial Prosthetists & Technologists (MPTs). Not

all of the work undertaken by MPTs is facial; it also includes fingers, hands, feet, toes, breasts and nipples since the construction techniques involved are similar. MPTs are also typically involved in fabricating surgical guides, cranioplasty plates, obturators and other custom head and face related devices. In many cases, they will also be involved with planning maxillofacial surgery. Figure 2 shows an orbital reconstruction plate, computer-aided surgical planning, a surgical guide and cranioplasty plate.



Figure 2: Other devices and procedures that MPTs have active role in developing

Maxillofacial prosthetics has a history dating back hundreds of years, but became a specialist profession after the First World War when many soldiers survived with terrible facial injuries. This history is intertwined with the development of pioneering plastic surgery techniques. Although the specialty has a long history, technological advances have been relatively slowly adopted. Many of the fundamental techniques used today were developed during the First and Second World Wars to deal with the high number of casualties with facial wounds. Even with the widespread introduction of silicones in the 1980's, the construction methods changed very little and are still in use today.¹

The demand for facial prosthetics has dramatically increased with the improved detection and surgical intervention of diseases such as cancer, which can leave patients with significant portions of missing facial tissue. This places significant strain on National Health Service budgets. This is further compounded by the labour intensive, highly skill dependent techniques used in prosthesis production. Multiple, lengthy visits are required for the patients, which often involve long periods of sitting and waiting. This is both economically

¹Eggbeer D. PhD thesis. Published 2008. Available at Cardiff Metropolitan University library or in electronic form by request.

inefficient for prosthetist and patient and can be particularly difficult for patients, many of whom will have undergone traumatic surgical procedures. The outcome is also largely dependent on the individual prosthetist's experience and skill, which can vary significantly.

These issues have been raised in previous doctoral research, publications by the workshop organisers and other research groups.^{2,3,4} With the issues in mind, the workshop was organised based on the fact that the world-wide maxillofacial prosthetics field is faced with challenges that must be tackled in order to meet patient and health service expectations.

The challenges were initially perceived as:

- Increased patient numbers with fewer new staff entering the profession.
- Reliance on time consuming, hand craft-based techniques.
- Difficulty for some patients to access prosthesis construction services.
- The high technical complexity of facial prosthesis production.
- Barriers to training in the preceding surgical techniques and the application of new technologies.
- Lack of investment.

A limited number of researchers across the world have attempted to tackle the design and production issues faced in maxillofacial prosthetics. However, previous work has not provided a common clinical, technological and economic perspective on effectiveness; they have concentrated on either clinical aspects or the technology. In addition, little attention has been given to parts of the world where prosthesis provision is uncommon and less developed. As well as a lack of coherent direction, previous research has been hindered by lack of involvement by a broad spectrum of stakeholders, including: patients, companies and technology developers and related, translational specialties.

There is a need for a more structured approach to research in the area. A one-day workshop with defined objectives was considered an appropriate foundation on which to

² Wolfaardt J., Sugar A., Wilkes G. (2003), "Advanced technology and the future of facial prosthetics in head and neck reconstruction", *International Journal of Oral Maxillofacial Surgery*. **32**(2), 121-3.

³ Bibb R, Eggbeer D, Evans P. Rapid prototyping technologies in soft tissue facial prosthetics: current state of the art, *Rapid Prototyping Journal*, 2010; 16(2): 130-137

⁴ Eggbeer D, Bibb R, Evans P. Digital Technologies in Extra-oral, Soft Tissue Facial Prosthetics: Current State of the Art. *J Institute of Maxillofacial Prosthetists and Technologists*, Winter 2007, Vol. 10: 9-18.

build future research projects that will meet targeted needs for this sector. The workshop also formed the first in a series of three EPSRC funded workshops organised by [Ian Campbell](#) of Loughborough Design School.

ORGANISATION COMMITTEE

The workshop was jointly organised by researchers from the Centre for Applied Reconstructive Technologies in Surgery ([CARTIS](#)), [Dominic Eggbeer](#) and [Richard Bibb](#), and [Russell Harris](#) from the Additive Manufacturing Research Group at Loughborough University.

Dr. Dominic Eggbeer. Dr. Eggbeer is a Research Officer at PDR within Cardiff Metropolitan University with particular interests in the application of rapid product design and development technologies in surgery, prosthetics, dental technology and medical device design. Dominic has presented at conferences around the world, contributed to book chapters, courses and workshops and published 20 peer reviewed articles. Dominic's roles at PDR also include the management and development of commercial medical modelling services and PDR's patient-specific design centre. This provides a unique link between clinical and surgical specialists, industry and medical product users.

Dr. Richard Bibb. Dr. Bibb is Reader in Medical Applications of Design. He graduated from Brunel University with a BSc in Industrial Design in 1995 and then moved to the National Centre for Product Design & Development Research (PDR) to undertake doctoral research in Rapid Prototyping. After obtaining his PhD, he remained at PDR to conduct research into the medical applications of product design and development technologies such as 3D scanning, 3D CAD, Rapid Prototyping and Additive Manufacturing. In 1998, he established the Medical Applications group at PDR, which developed a medical modelling service for hospitals, which continues to supply the vast majority of the UK's medical models. He moved to Loughborough University in June 2008 to teach industrial and product design and continue his research. His collaborative applied research has been presented at international conferences in the UK, Belgium, Germany, Spain, Japan, South Africa, Canada and the USA and in more than 50 peer-reviewed publications. He is a co-founder and member of CARTIS.

Prof. Russell Harris. Prof. Harris is Professor of Medical Engineering and Advanced Manufacturing at the Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University. Prof. Harris specialises in materials and manufacturing process research, conducted through European and nationally funded research projects. His

achievements in these areas of research are demonstrated by various sources, including 70+ publications. He has received grant awards from EPSRC (IMCRC), EC Framework Programme, and Department of Health. Loughborough University is recognised worldwide for their research in Rapid/Additive Manufacturing technologies. Dr Harris has previously developed bespoke Additive Manufacturing techniques for medical applications. He has been awarded the IMechE Donald Julius Groen Prize for research in Structural Technology and Materials (2003), the IMechE Professional Engineering Publishing Award for research in Engineering in Medicine (2007), and the Institute of Mechanical Engineers SAGE Publishing Award for research in Materials Design and Application (2011). He has presented his research, by invitation, at the Royal Society's Technology Innovations in Healthcare conference, 2007. He holds an Honorary position at Nottingham University Hospitals (NUH) NHS Trust.

WORKSHOP FORMAT

The workshop was held at Loughborough Design School at Loughborough University. Four primary objectives were used to facilitate discussion. These were:

1. Benchmark clinical practice and research achievements to date
2. Identify priority needs within the profession
3. Identify key researchers, organisations and translational sectors that could help to address needs in the profession
4. Identify avenues for funding and facilitating ongoing collaboration

Discussions were broken down based on the major objectives. The workshop began with themed headings based on the objectives placed on the wall, with the objective to fill them out with appropriate information using post it notes as discussions progressed. A dedicated note taker was also available to ensure information was captured. These objective themes and deliverables are listed in Table 1.

Once recorded, the information gathered was written up into a draft report for circulation firstly to the workshop facilitators and then to the participants. The CARTIS website (www.cartis.org) was used to host a discussion forum and documents relating to the workshop in a secure environment. Feedback from this report will be used to provide a consensus on the profession's needs and priorities, which can in turn be used to direct and prioritise appropriate research and subsequent funding proposals. This process is illustrated in figure 3.

Objectives	Deliverables
Benchmark clinical practice and research achievements to date	<ul style="list-style-type: none"> ▪ A list of techniques, processes and technologies commonly used in clinical practices in busy maxillofacial units ▪ A list of known state of the art techniques demonstrated in research
Identify current and near future priority needs within the profession	<p>Identify, prioritise and document</p> <ul style="list-style-type: none"> ▪ Patient needs ▪ Healthcare trends ▪ Training requirements ▪ Budget considerations
Identify key researchers, organisations and translational sectors that could help to address needs in the profession	<p>Identify:</p> <ul style="list-style-type: none"> ▪ Who has published in the area ▪ Centres of world-wide expertise ▪ Current conferences & workshops ▪ Charities and companies active in the area ▪ Translational and complementary specialists (e.g. materials experts, designers, surgeons, manufactures, etc.)
Identify suitable methods of funding and facilitating ongoing collaboration	<ul style="list-style-type: none"> ▪ List of funding avenues and strategies for approach ▪ Agreement on hosting an online collaborative resource to facilitate future meetings ▪ Targets for the dissemination of activities and outcomes ▪ Agreements on collective needs and network opportunities

Table 1: Objectives and deliverable outcomes of the workshop



Figure 3: Illustration of the workshop process

ATTENDEES

The workshop brought together a number of the UK's leading maxillofacial prosthetists and researchers to discuss major themes that will help to develop a structured approach to research in the area. Major prosthetics labs with a demonstrated record of research engagement from England, Scotland and Wales were represented. Further major labs were invited, but could not attend. In addition to the organisers, the workshop was attended by:

- **Peter Evans:** Morriston Hospital, Swansea. Peter is renowned in the field of Maxillofacial Prosthetics, being part of a team that pioneered the use of Osseointegrated craniofacial implants in the UK for retention of maxillofacial prosthetics. He is presently Head of Prosthetic Maxillofacial Rehabilitation at Morriston Hospital, Swansea. His main areas of interest include facial prosthetics for children, craniofacial implantology and 3D modelling and imaging. He has published extensively in on the integration of digital technologies into facial prosthetics and implants. Peter is a full member of the Institute of Maxillofacial Prosthetists & Technologists (IMPT) and a founder member and secretary of CARTIS.
- **Jason Watson:** Queens University Hospital, Nottingham. Jason worked as Chief MPT at the Northern General Hospital until 2002 when subsequently moved to Queens Medical Centre (QMC) in Nottingham to head a new unit as Consultant MPT. QMC unit undertakes a diverse service in all aspects of maxillofacial prosthetics (facial prosthetics, cranioplasty, implants, surgical planning, cleft, trauma) restorative, orthodontics and dental prosthetics. Jason's Research interests include 3 dimensional modelling and specialist surgical modelling techniques. Current research funding totals £900,000 (DTi). Jason has sat on the IMPT council since May 2006 and has been an Editorial Board member of the IMPT Journal since 1998. He also won the national award, Chief Scientific Officers Award for Leadership in 2010.
- **Dr. Muhanad Hatamleh:** Dr. Hatamleh is a clinical practitioner, lecturer and researcher who has split positions between the University of Manchester and Queens University Hospital, Nottingham. He has particular research interests in the mechanical properties of silicone materials and widely published and presented in this area.
- **Steve Worrollo:** Consultant Maxillofacial Prosthetist Maxillofacial Prosthetics Department Manager, University Hospital Birmingham NHS Trust. Steve is a fellow of the IMPT who originally started his career in Dental Technology, with the intention of specialising in Maxillofacial Technology. He has worked in a number of

specialist units within the UK. He has also gained experience in the USA and Sweden. He started at UHB in 1989 and was instrumental in setting up the extra oral implant program for facial prosthetics and Bone anchored hearing aids (BAHA). This now has one of the world's largest clinical series of patients with osseointegrated facial prosthetic reconstructions. Steve has extensive experience of working with patients who have facial disfigurements and complex soft tissue and bony defects. His main interest is the management and rehabilitation of patients with head and neck cancer, working in collaboration with reconstructive surgeons to compliment and increase the options available to maximise patient choice to obtain optimum aesthetic/functional results. He has organised workshops/conferences and courses in maxillofacial prosthetics, contributed to scientific meetings at national and international level, author numerous book chapters in surgical text books, and scientific papers. He is also Editor and member of editorial boards for peer review journals in the UK and internationally.

- **Peter Jeynes:** Queen Elizabeth Hospital, Birmingham. Peter completed 5 years training in Dental Technology and has worked in private practice in the UK and Germany and is now based at the Queen Elizabeth Hospital in Birmingham. The progressive team at the QE Hospital are internationally recognised and Peter has presented at conferences globally. Peter also teaches at Birmingham Universities and is a faculty member to a number of course. He has recently of the recently established partnership between Birmingham University and University Hospital Birmingham who are undertaking research and development into new technologies to improve reconstruction and rehabilitation in the head and neck.
- **Pauline Paul:** Principal Maxillofacial Prosthetist, West of Scotland Regional Maxillofacial Prosthetics and Technical Service at the Southern General Hospital, Greater Glasgow and Clyde NHS Trust. Pauline started her career in 1987 in Dental technology. After qualifying, she went on to specialise in Prosthodontics and Orthodontics before moving into maxillofacial prosthetics. In 2000 Pauline moved to Canniesburn Hospital (Glasgow) to become part of the team in the Regional Maxillofacial Unit. Since then she has become a member of the IMPT and has gained experience nationally and internationally. She was part of the team that provided technical input and services for the first course on Distraction Osteogenesis at the Craniofacial Surgery and Research Centre, Dharwad, India. Pauline's main interest is Dentofacial deformities (orthognathic model surgery) and has presented nationally and internationally and organised various scientific courses and conferences in this field. She was awarded a Master of Science research degree graduating from Glasgow University in 2010. Since then she has published scientific papers in peer-reviewed journals.

- **Michael O'Neil:** Principal Maxillofacial Prosthetist, West of Scotland Regional Maxillofacial Unit, Southern General Hospital, Glasgow. Michael has worked for nearly 30 years in various areas of this technology, has set up and managed laboratory services for both NHS and commercial laboratories. He has provided placement training for students nationally and internationally. He has organised courses in Orthodontics and Maxillofacial technology in Scotland and overseas. Michael dedicated himself to a research MSc in 2007 at Glasgow University graduating in 2010. He was invited to present at the University of Glasgow's Post Graduate prize seminar, obtaining 1st prize for his research. He was also awarded the University of Glasgow's Robert's Travel Fellowship, allowing him to present his findings at various conferences. His research was published in the British Journal of Oral and Maxillofacial Surgery (January 2012). Michael supervises University of Glasgow MSc students from overseas and is a member of the Biotechnical and Craniofacial Sciences Research Group. Current projects involve image manipulation using Mimics, 3matic, Simplant, VRmesh, Dimensional imaging and Brain lab software. He has investigated and presented on how these software programmes can be used to predict superior levels of accurate surgery planning for head and neck cancer and trauma patients.

- **Leo Basil:** Technovent Ltd., Newport. Leo is a director of Technovent, who are a silicone materials development company who are also a major supplier to the field of maxillofacial prosthetics. His colleague, Prof. Mark Waters is a professor at Cardiff Dental School and is also a director of Technovent.

- **Sean Peel:** PDR, Cardiff Metropolitan University. Sean works within the Medical Applications Group (MAG) at PDR on patient specific medical design. His work applies product development technologies and techniques to help companies and NHS specialists introduce services and products tailored to individual patient needs. Sean also works on MAG's medical modelling service to manipulate CT and MRI scan data for the production of physical models of patient anatomy used in surgical planning. Sean graduated from Loughborough University in 2010 with a first class honours degree in Industrial Design & Technology. He is embarking on a PhD to investigate the effective introduction of digital product development technologies to hospital unit-based activities.



Figure 4: The Attendees (left to right) Sean Peel, Dominic Eggbeer, Leo Basil, Richard Bibb, Steve Worrollo, Michael O'Neil, Muhanad Hatamleh, Jason Watson, Russ Harris, Pauline Paul, Peter Evans, Peter Jeynes.

REPORT

The report has been broken down into a series of bullet points and short discussions that represent post it notes added to the themed headings during the day and general discussions during the sessions. The headings are:

- [Current state of the art in clinical practice](#)
- [Current state of the art in research](#)
- [Profession and patient needs](#)
- [Healthcare trends](#)
- [Training](#)
- [Individual researchers, research groups & translational specialties](#)
- [Charities, companies & representative organisations](#)
- [Funding avenues & research strategies](#)

Conclusions and a confirmation of the key priorities for a research strategy are provided at the end of the report.

CURRENT STATE OF THE ART

NOTES

- No consistency in manual crafting techniques
- Nobody knows if technology adoption is of benefit
- Evaluation of outcomes not standardised or rigorous
 - Outcomes are highly hospital/clinician dependent
- Nationwide records of cases are not harmonised and there are no statistics available
 - Difficult to establish number of patients – some centres are growing, some are shrinking
- Lack of research support in the area – underdeveloped research culture, little or no research resources
- Move towards 3D planning in major units
 - But a lack of time to learn and develop skill in the software
 - More technicians spending time at a computer rather than in lab
- “Workarounds” frequently used with digital technology
- Current service providers are too expensive (related to implants)
- Most units are too small to have a well-managed and resourced structure
- There is minimal involvement with trauma. This wasn’t always the case
- Many more patients and specialties requiring their services from the lab (Glasgow)
- Sharing equipment resources with other departments is a valuable method of justifying cost and sharing expertise (Morrison)
- Some units have access to clinical psychologists, others do not (assessment of outcomes)

DISCUSSION

Key points identified:

- Technology is still limited in clinical prosthesis application
- Lack of measurement in existing practices
- Lack of harmonisation between units

The vast majority of units use ‘conventional’ lab-based procedures in prosthesis construction. Despite the similarities in size, equipment in MPT units varies considerably.

Computer-aided technologies have been adopted by some of the larger units. Queen Elizabeth Hospital have surgical planning software, 3D scanning and a Rapid Prototyping (RP) machine in-house, Nottingham have RP in house, Morriston Hospital have surgical planning software, CAD design software & 3D scanning in house, Southern General Hospital have surgical planning software in house. However, the majority of UK labs do not have access to this.

The need to record cases and measure treatment outcomes was noted as critical. Although individual units record information on case numbers, types, outcomes etc., there is no UK-wide standard on doing this. The lack of consistency and harmonisation in record keeping is a major hindrance to understanding the requirements of the profession. It also means there is no baseline against which research outcomes can be measured against.

CURRENT RESEARCH STATE OF THE ART

NOTES

- A growing amount of disparate research on the application of technology.
- Hospital/University collaborative research focused on orthognathic planning
- Research to benchmark state of the art and specify future developments published
- Retention component design at Cardiff Metropolitan University and QMC Nottingham
- Prosthesis body production improvements (CARTIS) – evaluating the aesthetic and mechanical performance of digital and conventional techniques
- Research in related areas including:
 - High fidelity surgery simulation models and phantoms – RH research
 - Human surrogate and tissue simulation work – RH & RB research
 - Other wearable devices such as wrist splints – RB, DE and more research
 - User centric research – multiple centres
 - User experience research – noted by RB
 - Tissue simulation in computer environments

DISCUSSION

Key points identified:

- Need to structure future research around providing evidence of success.
- Ongoing research needs to involve multidisciplinary and multicentre researcher collaboration
- Share research with complementary and translational research areas in future research

There is a growing amount of research in the area of facial prosthetics, but much of it is disparate, resulting in duplication of effort and an uncoordinated, inefficient approach. The need to structure future research and encourage inter-department, multidisciplinary and multicentre collaboration was confirmed by all present. Furthermore, the need to measure research outcomes against the patient and profession needs was identified as critical throughout the workshop.

NEEDS

NOTES

Profession needs

- National guidelines on expectations – e.g. NICE
- National MPT strategy & structure required
- Improved managerial skills for MPTs
- Better communication and collaboration between MPT units
 - Regular meetings between units are crucial
- Drivers for change identified include:
 - Decreasing numbers of invasive procedures – reduces risk and potentially, cost
 - Increasing accuracy
 - Reducing surgery time (noted that surgery costs in the order of £16/min)
 - Need to reduce costs
 - Need to reduce MPT learning and training time
 - Need to reduce clinical time (work hours per case)
 - Improve materials
- Audit urgently required to measure current practices and produce baseline data
- Need to improve the ‘minimum’ standard of production quality – more consistency across regions and hospitals, managing expectations
- Need to disseminate best practice for both traditional and new digital techniques
- Need to identify what the profession should and should not be doing – e.g. somato prostheses?
- Longer life prostheses are the ideal solution! Can they be made to last 5+ years for example? This would eliminate repetitive labour and materials costs for re-makes and frequent patient visits.

Patient needs

- Noted that we do not *really* know how patients feel – baseline data required
- Improved information for patients. Web-based and printed (based on the needs of patient groups treated, that includes the frail and elderly, but also the young). Hospital R&D funds have been used to create animations explaining treatments. [For example.](#)
- Longer life prostheses – see above
- Reduced consultation times (for patient benefit and reduce Did Not Attends – DNAs)

- Improved cosmetic results (needs evaluation standards)
- Easier to care for prostheses

DISCUSSION

Key points identified:

- The profession has a number of economic and outcomes based needs that drive the desire to improve practices
- The need for a national strategy was pertinent
- In general, patients would benefit from more efficient, faster services, with fewer visits

As identified in the original workshop proposal, there are numerous challenges facing the profession, revolving around the need to become more efficient and to minimise the impact of procedures to patients.

The workshop also acted to highlight the need for a nationally aligned research strategy that includes key research active units, researchers and translational specialists. This should be coordinated and based on practical, clinically viable research that can have genuine impact based on measurement – i.e. evidence-based practice.

HEALTHCARE TRENDS

NOTES

- Evidence-based practice required – currently presents a challenge since outcomes measurement is not standardised or commonplace.
- Oncology cases increasing.
- Move towards outsourcing of services.
 - There is a need to validate the quality of outsourced services
- The Western World represents a tiny proportion of the global needs for facial prosthesis provision. Increased efficiencies developed here could have a massive global impact.
- Improved screening for diseases such as cancer. This could allow for better planning of future provisions if number could be predicted.
 - How can improved screening and treatment planning be used to inform facial prosthesis provision in the future?
- Improved autogenous reconstructions.
- Move towards private provision. This is currently limited in facial prosthetics, but NHS cuts could result in more private cases.
- Cranioplasty – changes in neurosurgery practice results in more cases, larger defects, higher survival rates, more complex plates.

DISCUSSION

Key points identified:

- Move towards evidence-based practice is critical – a key research driver
- Large global demand with poor service provision in many areas
- Improved screening could provide an opportunity to plan prosthesis provision well into the future

Evidence-based practice is increasingly important. Evidence could be broadly categorised under: improved efficacy of procedures or improved economic performance. This further highlights the need to establish a baseline against which research outcomes can be measured.

The global demand for prostheses is significantly larger than just the western world. However, it would not necessarily be appropriate to apply a UK-approach to other cultures without sufficiently considering a suitable service backup that would ensure longevity and accessibility for those who require prostheses. Simply parachuting in a service based on UK-style services would not be appropriate.

Improved screening for diseases such as cancer could allow for better planning for prosthesis provision in the future by identifying patient trends and linking that to particular needs in training, resource allocation and service delivery.

TRAINING

NOTES

- Nothing above undergraduate level. Courses currently offered by [Kings College London](#) & Manchester Metropolitan University
- Primarily on the job training
- Cannot afford to have non-applicable or non-pragmatic research/training activities
- As yet the Scottish Government has not signed up fully to the MSc programme which is to be implemented south of the border. This matter is ongoing.
- Limited time available to develop skills in software and hardware
- Are new recruits joining the profession with the right qualifications – is dental technology the best background?
 - The need to identify future MPT skill requirements is urgent
 - There is a need to implement a national ICT strategy
 - There is a need to include digital technology etc. in current training
- Are dedicated research posts within major units a viable option?
- Should MPTs have an academic role? Especially pertinent in University / Teaching Hospitals.

DISCUSSION

Key points identified:

- A review of training needs to meet modern healthcare demands is required
- MPTs should be more research active

The profession has evolved into requiring new IT/computer-based skills combined with the more traditional materials and manual crafting aspects required to deliver prostheses. The future of efficient services will rely on teaching these skills and translating them into practice. There are questions as to whether dental technology remains the most suitable platform for maxillofacial prosthetics training or if it does, whether computer-based skill should be a more fundamental component at this level.

In general, a very small percentage of UK prosthetists are research active and of those, few are able to dedicate adequate time to research. There is an opportunity to improve the research credentials of the profession, particularly in major teaching hospitals.

INDIVIDUAL RESEARCHERS, RESEARCH GROUPS & TRANSLATIONAL SPECIALTIES

NOTES

A small number of those invited could not attend the workshop, but expressed an interest in the outcomes and future developments. There are:

- Dr. [Trevor Coward](#). Dr. Coward is a senior lecturer at Kings College, London. Trevor's research interests are based upon the use of digitised technology, its use in planning and creating prostheses using three-dimensional data from different methods of data collection (CT, MRI and Laser scanning) in maxillofacial prosthetics. Trevor was invited, but unable to attend the workshop.
- Liz Gill. Senior Lecturer in Prosthodontics & Maxillofacial Prosthetics & Researcher in Ocular & Facial Prosthetics. Liz took up a post as Senior Lecturer in Maxillofacial Prosthetics and Prosthodontics in 2007 at Manchester University and from June 2011. Liz is seconded to a new position as a Research Scientist for one year relating to innovative methods of rapid prototyping materials and methods in all aspects of maxillofacial prosthetics and head and neck reconstruction. Liz has a particular interest in translating prosthesis provision to the developing world via the [Mission Cure Bangladesh](#) project.
- [Ben King](#) – Industrial Designer, Canada. Ben is an industrial designer working in the “wacky world of reconstructive medicine.” He has experience designing and teaching courses on 3D modelling for medical visualization and surgical planning and works at [iRSM](#).

Practitioners

- John Beumer. John Beumer III, DDS, MS has been Chair of the UCLA Division of Advanced Prosthodontics, Biomaterials and Hospital Dentistry since 1998, and was formerly Chair of the Section of Removable Prosthodontics. He established the Residency Program in Maxillofacial Prosthetics at UCLA in 1977. Dr. Beumer's textbook, *Maxillofacial Rehabilitation – Prosthodontics and Surgical Considerations*, has been the standard text in the field for more than 25 years. His primary research interests have been focused on the effects of radiation therapy on oral structures and the rehabilitation of patients with large surgically-induced defects secondary to the removal of oral-facial cancers. From [this](#) website.

- Jan De Cubber. Jan is a key researcher in the field of maxillofacial prosthetics and also runs a [Belgium-based lab](#) that delivers prostheses. He has published and presented widely on the use of computer-aided technologies in prosthesis construction.
- Dr. Harry Reitsema DDS PhD AIMPT
- Kirsten Bergström, Sahlgrenska University Hospital, Gothenburg, Sweden. Kirsten is one of the world's leading authorities on maxillofacial prosthetic rehabilitation and she has trained a significant number of professionals in the UK and throughout the world.
- Jane McPhail (Liverpool). Jane McPhail is a Consultant Burns and Plastic Surgery Prosthetist and Managing Director of [Prosthetic Innovations Ltd](#). She works both privately and within the NHS in Merseyside. Jane has worked in Burns and Plastic Surgery at Whiston Hospital since 1998. In 2011 she also took over the role of delivering technical services to the Maxillofacial Unit at Aintree University Hospital Trust. She is research active in facial prosthetics and related areas.

Prior Researchers in the sector (not previously mentioned, or participating in the workshop)

- [Prof. David Williams](#) - Professor of Healthcare Engineering, Director of the Research School of Health and Life Sciences, Loughborough University. Prof. Williams has research interests in Commercialisation of Regenerative Medicine; Manufacturing Technology for Cell and Tissue Based Therapies; Translational Research; Capture of Clinical Need; Medical and Drug Delivery Devices; Oro-maxillary Rehabilitation; Growth of SME's and Clustering; Exploitation of Healthcare Technologies; Manufacturing Technology and Design for Manufacture.
- [Prof. Ashraf Ayoub](#) - Lecturer in Oral & Maxillofacial Surgery at the University of Glasgow and Professor of Oral & Maxillofacial Surgery. He has specific research interests in areas of three-dimensional facial modelling to assess craniofacial malformations, bone biology and management of alcohol related facial injuries.
- [Prof. Steve Richmond](#) - Head of Applied Clinical Research and Public Health, Cardiff University. Prof. Richmond has particular research interests in epidemiology, clinical outcomes and clinical effectiveness in orthodontic provision, the use of three-dimensional imaging to assess facial growth in children and the use of biomechanical modelling to mimic facial structures.
- Prof. Joseph Barbenel – Research Fellow at Strathclyde, Glasgow University
- [Prof. Chee Kai Chua](#). Nanyang Technological University, Singapore. Dr. Chua has been involved in Rapid Prototyping (RP) since 1990. On-going research at NTU include development of new systems and techniques in biomedical applications (prostheses,

implants, devices and tissue scaffolds) using RP.

Translational researchers and sectors

- Lesley McNair – clinical psychologist
- [Prof. Nichola Rumsey](#) – Director at the [Centre for Appearance Research](#). Her portfolio of ongoing health service focused research projects currently includes: Assessing quality of life in people with appearance related concerns; establishing the factors associated with resilience in coping with visible difference; assessing the psychosocial needs of burn injured patients; the implementation of changes to the provision of care for patients with a range of disfiguring conditions; the psychological consequences of whole face transplantation.
- [Dr. John Winder](#) – Radiography, Ulster University
- [Dr. Stephen Golding](#) – Radiography, Oxford. Dr. Golding is the Course Organiser and a Consultant Radiologist at the John Radcliffe Hospital. He has undertaken extensive research in the field of radiology with particular interests in the reduction of radiation exposure.
- [Prof. Mark Waters](#) – Materials expert, Cardiff. Prof. Waters is a researcher in biomaterials within Cardiff University and a director of [Technovent](#), who develop materials for maxillofacial prosthetics. He has published extensively and has given significant focus to developing novel solutions in maxillofacial prosthetics. He was invited to the workshop, but was unable to attend. His Technovent colleague, Leo Basil attended in his place.
- [Prof. Nick Jones](#) – ENT surgeon, Nottingham. Prof. Jones is an ENT surgeon, but is also involved with maxillofacial surgery and prosthetics.
- [Prof. Adrian Bowman](#) – School of Mathematics and Statistics, University of Glasgow. Prof. Bowman has a particular interest in modelling the shape of the human face, in order to quantify any remaining unusual features present after facial surgery or to investigate characteristic associated with particular medical conditions. Methods for formulating the information presented in a facial scan and using this to provide statistical tools for analysis are the focus of the recently formed Face3D consortium.
- Statisticians
- Psychologists
- Health economists
- Radiology/radiography

Research Groups

- [CARTIS](#). CARTIS is a research collaboration between [PDR](#) and the Maxillofacial Unit at Morriston Hospital in Swansea. The collaboration is designed to facilitate ongoing research in the field of reconstructive surgery and prosthetics.
- [Queen Elizabeth Hospital](#), Birmingham. 2 representatives from QE hospital attended the workshop. QE are one of the UK's largest and busiest maxillofacial units and are one of a small number to have invested in their own rapid prototyping equipment.
- Glasgow Research Group
- [Queens Medical Centre](#), Nottingham Universities Hospitals. 1 representative from this hospital attended the workshop. The University Hospitals have been involved with research with one of the workshop organisers, Russell Harris and includes Jason Watson's maxillofacial lab.
- [iRSM](#) in Canada. The Institute for Reconstructive Sciences in Medicine is an internationally recognized clinical and research institute focused on medical reconstructive sciences. iRSM is a joint initiative of the University of Alberta, Caritas Health Group and Capital Health, based at the Misericordia Hospital in Edmonton, Alberta.
- [UIC](#). The University of Illinois, Chicago runs a postgraduate course in facial prosthetics and has a department that includes researchers, such as Rosie Seelaus, who has helped to pioneer the application of digital technologies in prosthetics.

Conferences

- [ADT](#) (Advanced Digital Technology in Head and Neck Reconstruction). ADT conferences cover a range of topics that address advanced digital technology in relation to head and neck reconstruction. The conferences are a highly relevant dissemination route for best practice in facial prosthetics and offer an opportunity to engage with a worldwide audience.
- [IMPT](#). The Institute of Maxillofacial Prosthetists and Technologists hold a biennial, international congress that is the only one of its kind dedicated to the profession.
- [IAA](#). The International Anaplastology Association holds meetings approximately one time per year. At a meeting, you can expect to hear about the exciting developments in the field and stay abreast on the research in the field of anaplastology.
- [CARS](#). The Computer Assisted Radiology and Surgery congress is the yearly occasion where medicine and technology meet to present and discuss the key innovations that shape modern medicine on a worldwide basis.
- [ISMR](#). The International Society for Maxillofacial Rehabilitation holds regular

conferences to discuss and disseminate research in maxillofacial rehabilitation.

- [AAMP](#). The American Academy of Maxillofacial Prosthetics holds annual scientific conferences, usually in a prominent US city.

A [workshop](#) on digital technologies in facial prosthetics has been joint run by CARTIS, iRSM and UIC for two years. This represents the only course of its kind and has the potential to engage with post-workshop activities.

DISCUSSION

Key points identified:

- There are a limited number of research active groups in the UK, but they represent a good skill base, critical mass and geographical spread.
- There is a need to involve complimentary and translational specialties
- There are many individual researchers who could provide valuable research input

The consensus was that the workshop included key UK researchers and practitioners who have an interest in developing an appropriate UK research strategy. These research groups represented England, Scotland and Wales and were attached to University Hospitals. Beyond those who attended, a more comprehensive list of potential researchers, groups and translational specialties was generated. This further highlighted the need to involve different, but relevant people in future research projects.

It was agreed that there is a need to establish a network that would provide a long term foundation of expertise, from which a coherent strategy for research development could be formulated.

CHARITIES, COMPANIES AND REPRESENTATIVE ORGANISATIONS

NOTES

Companies

- [3DMD](#). 3DMD are a US and UK-based company who specialise in the design and development of 3D photogrammetry systems. They have particular strength in the medical sector and their systems are installed in hospitals and research units across the world.
- [Materialise](#). Through research, the Belgium-based company, Materialise have pioneered the use of computer-aided technologies since 1994. They specialise in creating software and providing services in patient specific device design including maxillofacial prosthetics.
- [SensAble](#). The US-based company, SensAble have developed a highly versatile and appropriate computer aided design software package called FreeForm, which has been used by researchers in prosthesis design for many years.
- [Renishaw](#). Renishaw are an international, research-led company with a growing interest in the development of novel software and hardware for the medical sector.
- [Delcam](#). Delcam are a UK-based, international company who have been involved with previous funded research to develop software for maxillofacial prosthetics.
- [Objet](#) and other RP/AM developers. There are numerous RP/AM developers who could be involved. Objet Geometries are an Israeli company who offer the only technology capable of producing parts in a soft material with properties close to those of facial prostheses. Objet Connex technology shows great promise and research links are being actively developed.
- [Synthes](#). Synthes are a multinational company involved with the research and development of novel implantable prosthetics devices, including patient specific implants.
- [Medtronic](#). Medtronic are a multinational company involved with six major businesses that focus their efforts around a condition or therapy type: Cardiac Rhythm Disease Management, Physio-Control, Spinal and Biologics, CardioVascular, Neuromodulation, Diabetes, and Surgical Technologies.
- [Cochlear](#). Cochlear are a UK-based, international company. They are developers of hearing aid devices, including bone anchored hearing aids. They have a strong research background and are present at many international conferences and workshops.

Organisations

- [IMPT](#). The IMPT is a registered charity with the aim of promoting study and practice and improving professional standards for the benefit of patients. Someone registered with the IMPT has followed extensive training to provide a variety of specialist services to patients and surgical specialists.
- [IAA](#). The International Anaplastology Association promotes quality patient care by supporting the development of best practices in anaplastology through educational conferences, networking, publication, and advocacy opportunities.
- [AAMP](#). The American Academy of Maxillofacial Prosthetics is an association of prosthodontists who are engaged in the art and science of maxillofacial prosthetics. Their mission is to accumulate and disseminate knowledge and experience; and, to promote and maintain research programs involving methods, techniques and devices used in maxillofacial prosthetics.
- [ISMR](#). The International Society for Maxillofacial Rehabilitation is dedicated to advance and promote the science of maxillofacial rehabilitation throughout the world.
- [BAOMS](#). The British Association of Oral & Maxillofacial Surgeons is a charitable organisation with objectives: (a) To promote the advancement of education, research and the development of Oral and Maxillofacial Surgery in the British Isles and (b) To encourage and assist postgraduate education, study and research in Oral and Maxillofacial Surgery. Maxillofacial prosthetists have a particularly close relationship with maxillofacial surgeons and are crucial in planning surgery that enables a suitable prosthetics outcome.
- [ADT Foundation](#). The ADT Foundation was set up as a trust to advance knowledge and research in advanced digital technologies in head and neck reconstruction. The establishment of a foundation came from the ADT conferences, which is a primary avenue for dissemination of state of the art in maxillofacial prosthetics.
- [Royal College Of Surgeons](#). The Royal College of Surgeons of England is committed to enabling surgeons to achieve and maintain the highest standards of surgical practice and patient care.
- The organisation and charity which represents cleft professionals is the Craniofacial Society of Great Britain and Ireland
- Scottish Oral and Maxillofacial Surgeons (SOMS)
- [The Centre for Applied Reconstructive Surgery in Medicine](#) (CARTIS). Details on CARTIS can be found here. The CARTIS website was cited as a suitable mechanism to facilitate ongoing, post-workshop collaboration and as a resource to prepare funding bids.

Charities

- Individual Hospital research charities – most teaching hospitals have them
- [Cleft Lip and Palate Association](#). The Cleft Lip and Palate Association are the only national charity in the UK dedicated to supporting all those affected by cleft lip and/or palate. Maxillofacial prosthetists and surgeons often deal with patients with cleft lip/palate.
- [Let's Face It](#). Let's Face It is a charity and international support network for people with facial disfigurement, their families, friends and professionals. They would be a crucial partner in helping to understand the requirements of those affected by facial prostheses.
- [Changing Faces](#). Changing Faces is the leading UK charity that supports and represents people who have disfigurements to the face, hand or body from any cause. They would be another key charity to help direct research to meet the needs of patients.
- [Saving Faces](#). Saving Faces is a charity that carries out groundbreaking work in areas such as the role of selective neck dissection in early oral cancer treatment, the psychological factors in head and neck and gastrointestinal cancer, the prevention of smoking and binge drinking amongst teenagers and the use of microcytology to provide a non-invasive, in-vivo rapid detection tool for oral cancers. They currently support 4 Ph.D. studentships and facilitate ongoing research.
- [The Katie Piper Association](#). The Katie Piper Foundation is ultimately working towards the delivery of an advanced rehabilitation and burns clinic in the UK. This will in time, include residential facilities for patients, enabling them to benefit fully from treatments and from social interaction with other survivors. One of their aims is to “normalise disfigurement within society”. The charity has close relationships with a range of facially disfigured individuals, including those who wear facial prostheses.

DISCUSSION

Key points identified:

- Which company, charity and organisation to involve will be project specific.
- Company and charity engagement and support is crucial
- Patient representation is crucial

The scope and scale of future research will dictate the appropriateness of company, charity and organisational involvement.

FUNDING AVENUES AND RESEARCH STRATEGIES

NOTES

Potential projects

- Patient expectations study – could act as both a benchmark and target
- Research audit of major units:
 - Establish current level of prosthesis demand
 - Identify trends in case types and clinical conditions of patients
 - Cost current techniques using harmonised methods
 - Produce baseline data
- Materials research
 - Improving the longevity of existing silicone-based materials so they can last 5+ years
 - Developing alternative materials to silicones
 - Hydrophobic coatings (improved hygiene, longevity, etc.)
- Optimising design and manufacturing routes:
 - Developing new methods that would allow individuals to make their own prostheses or re-order them without an appointment
 - 3D printing of prostheses. Prior attempts have pursued inappropriate methods. Early stage research at Loughborough is establishing the feasibility.
 - Mould design – research underway, but needs developing
 - Re-design of retention structures that can be incorporated into digital processes more effectively. Research is underway at QMC Nottingham and CARTIS.
- Development of more suitable patient information

- Cranioplasty research (including orbital and facial reconstruction plates)
 - Costing current techniques (pilot research already underway has highlighted the variation across the UK)
 - Establishing the ideal design and material requirements for different case types – optimise production and create standards
 - Consideration of secondary trauma – is this a big problem?
 - Establishing agreed, evidence-based design specifications

Funding avenues

Funding avenues and funders are project dependent.

- UK research councils:
 - [EPSRC](#)
 - [AHRC](#)
- [Knowledge Transfer Partnerships](#) (TSB funded)
- Medical Research Councils – large scale projects only
- [FP7](#) – EU partners required
- [NIHR](#) Research for patient benefit, many applicable themes such as
 - [I4I](#)
 - [D4D](#)
- Research Charities
 - [Leverhulme](#)
 - [Wellcome](#)
 - Others
- Regional funds – e.g. European Regional Development Funds, local government. Funds for business and academic partnerships
- Hospital R&D funds. For example, [Morrison Hospital](#), [Queens Medical Centre](#), [Queen Elizabeth Hospital charity fund](#).

CONCLUSIONS

Clear priorities have been identified from the workshop under the headings below.

- [Current state of the art in clinical practice](#)
- [Current state of the art in research](#)
- [Profession and patient needs](#)
- [Healthcare trends](#)
- [Training](#)
- [Individual researchers, research groups & translational specialties](#)
- [Charities, companies & representative organisations](#)
- [Funding avenues & research strategies](#)

The application of computer-aided technologies in current clinical practice is gaining popularity, but is not widespread. The lack of access to training and time to develop efficient techniques hinders development. There are clear opportunities to develop collaborative research projects that would advance the efficient use of technology whilst ensuring clinical viability.

The lack of harmonised standards in measuring patient numbers, case types and clinical outcomes across the UK is currently a major barrier to demonstrating research impact. It was unanimously agreed that undertaking a research project to establish baseline data will be a fundamental prerequisite to defining a research strategy with demonstrable results. Linked to this is the disparate nature of research undertaken to date, which has resulted in a lack of consensus on whether newly attempted techniques are appropriate and whether their success can be measured. In order to address this, it was agreed that a network of researchers, practitioners and other leading specialists should be established to disseminate best practice, develop national guidelines, harmonise standards and foster a national approach to research strategy. The need to include translational specialties, such as healthcare economists, statisticians and others in a network was also highlighted as critical. In the short term, it was agreed that the CARTIS website would be a suitable mechanism to disseminate and follow up from this workshop, but more sustainable and inclusive mechanisms would be necessary in the future.

The workshop raised the issue of lack of patient information. Patients often attend treatment without a full understanding of what will happen and there are very few places where they can gain appropriate levels of information. Charities such as those listed offer patient support, but do not provide pre-treatment advice in an easy to understand and appropriate manner. Both the [IMPT](#) website and [CARTIS](#) provide some level of patient

information, but there is significant scope to improve this by making it more accessible using new technology and media. A project to address this shortcoming could be funded by a charitable organisation. Patients would also stand to benefit from advances in technology that would improve the experience of prosthesis delivery. Any such information would need to be nationally agreed.

The profession is in need of a national strategy and guidelines that govern service standards. This is another area where a specialist network could help to facilitate change.

The UK and worldwide healthcare sector is constantly undergoing change and reform, now more than ever. Whilst the increased privatisation of healthcare has not affected the MPT profession to a high degree currently, it may do in the future. If the trend towards privatisation continues, there will be a need ensure the consistency and quality of products and services from any and all providers. Nationally agreed minimum standards and expectations will be needed to ensure equality of service across the UK.

It was unanimously agreed by all present that a UK network to support research in MPT was critical to meeting the challenges ahead.

AGREED PRIORITIES

The short-medium term priorities can be summarised as follows:

1. **Establish a network** of researchers, clinicians and translational sectors to create a pool of expertise and the foundation for future research development.
2. **Establish baseline data** for a selection of representative major units on patient numbers, case types and clinical outcomes.
3. Pool resources to create **improved information for patients**.
4. Consider how prosthetics fits in with other MPT roles (such as implant planning and design) and **establish further workshops** based on these.

Medium to long term priorities can be summarised as follows:

1. Use the network and associated professional organisation **to establish a national strategy**.
2. **Develop appropriate research proposals** based on evidence generated through network activities and the national strategy

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