RTD2015

21ST CENTURY MAKERS AND MATERIALITIES

Proceedings of the 2nd Biennial Research Through Design Conference | RTD 2015

Guy, B., Stevens, R., Challies, Z., Gillingham, W. 2015. Synthetic Anatomies, Co-designing desirable 3D printed facial prosthetics. In: Proceedings of the 2nd Biennial Research Through Design Conference, 25-27 March 2015, Cambridge, UK, Article 32.
DOI: 10.6084/m9.figshare.1327991.

Synthetic Anatomies, Co-designing desirable 3D printed facial prosthetics

Bernard Guy[1], Ross Stevens[1], Zach Challies[1] and Wayne Gillingham[2]

[1] School of Design, Victoria University of Wellington
Wellington, New Zealand
{Bernard.guy; Ross.stevens}@vuw.ac.nz
zschallies@gmail.com

[2] Welloral Ltd
Wellington, New Zealand
wayne@welloral.co.nz

Abstract: Desirable prosthesis is an early stage investigation formulated to explore the creative potential of 3D scanning and 3D printing in designing alternative facial prosthesis. The loss or disfigurement of a person's facial feature such as a nose or an ear is typically supplanted with a hand crafted silicon prosthesis designed to replicate the person's face pre surgery. Our research sets out to counter the traditional medically orientated art of camouflaged reconstructive silicon prosthesis and explore the design of 3D printed distinct and desirable prosthesis.

Together, the participant, designers and a maxillofacial surgeon explore ways to think about how new prosthesis might fit, feel, empower and be made. In conjunction to this we explore 3D laser scanning and the Objet Connex multi-material 3D printer to build prosthesis which allow greater facial expression and personalisation for diverse social activities. Designing desirable facial prosthesis proposes a shift from localised hand craft to a global digital process where prosthetic clients from around the world can interact, design and print personal prosthesis on 'state of the art' machines at a cost well below those hand crafted. Potentially enabling individual expression in performance, fit and aesthetics rather than the predominately ill-fitting attempts at camouflage currently prevalent.

Keywords: Prosthesis; facial; 3D printing; anatomy; digital craft.

Rationale/Aim

Facial prosthetics are relatively rare yet they have a critical role in allowing patients to confidently interact with the world which can lead to a life less full (Chang, 2005). Eggbeer's thesis 'computer aided design and fabrication of facial prostheses' (2008) and the applied research centres Cartis and PDR are examples of the capability of emerging and advanced digital technologies in 3D scanning and printing to alleviate the challenges of economies of scale and quality of individually manufactured facial prosthesis (Eggbeer, 2012). This research aims to offer consistency and support for the dramatic increase in facial prosthesis at the professional and demanding front end of healthcare. As designers we intersect the world of engineering and art, and as such offer a specifically aesthetic understanding and sensitivity to the possibilities of these new technologies.

This research is a practice based response to current methods of prosthesis creation that conspire to hide both tissue damage and arguably the person. The project was inspired by our research into the variable densities of the Objet Connex multi-property 3D printer, where materials are laid down layer by layer in a range of material qualities from hard (bone) to soft (flesh) that mimic the pre-existing physical anatomy. A tangible demonstration of design potential for 3D printing to mimic human anatomy was explored in an earlier design experiment, where a human ear was printed from MRI scans in multi-property materials (Fig.1). This

Figure 1. 3D printed ear in multi-property material.

example of simulated anatomy and timeliness with 3D printing and digital customisation was seen as an alternative manufacturing method, with conversations with medical practitioners producing an explorative debate around facial prosthesis – what could the patient have, rather than what would the patient want?

Expanding this question through practice demonstrates an argument for developing more individual, empathetic and desirable prosthetics. The aim is to exhibit how 3D scanning and 3D printing can allow the production of digitally tailored prosthetics that fit more exactly to the individual both physically and emotionally. This approach brings a human dimension to digital technologies. While technology inspires and shapes us, it is also the role of design to shape technology for the benefit of humanity. It is at this

Figure 2. 3D scanning to gather a digital map of the face.

point - where the social, behavioural and cultural insights meet technology - that truly innovative, unexpected and meaningful design opportunities emerge.

3D scanning and generative software now make highly customisable and financially viable prosthetics a reality (Fantini 2012). The scanner maps facial morphology as an anatomical landscape from which we can both generatively model underlying support structures to fit location abutments and create novel facial contours (Fig. 2). These digital models can then be built as 3D printed multi-property structures with variable densities and rigidities. Vibrant colour multi-property printing using the Objet Connex system has been explored by Neri Oxman. Oxman (2011) has investigated the complexity of material mixing in a variety of visual and performance based artefacts. However, it has been applied predominantly in industrial design as a method of prototyping for traditional manufacturing technologies rather than a designed outcome in itself. This method of making has received little investigation for its potential to mimic anatomical tissue in both compliance and colour.

In this paper we describe the practice of creating an unconventional prosthetic nose. The work began with design experiments founded on conversations, demonstrations, and photography with three parties, a Maxillofacial Surgeon and Maxillofacial Prosthetic/Technologist, a participant who had lost his nose due to skin cancer, and a group of industrial designers. The aim of designing an alternative facial prosthesis that defies the aesthetic goals of facial normality is sensitive. To envisage alternatives meant that this project was speculative, requiring a very personal context and confidence in our group practice.

Opportunities of non-look-alike prostheses to enhance satisfaction of the wearer and emotional value of the product have been previously explored. Scott Summit of Bespoke Innovations creates prosthetic limbs (mainly legs) that take into account the wearers' personality and interests, designing with the 'face, name and story' behind the person, not around society's expectations of what a prosthesis should look like (Summit, 2010). He also talks about shape, materiality and context being an important way of adding value to transform a prosthetic, usually a utilitarian device, into an extension of the wearer's personality.

A contextual precedent is corrective spectacles, a condition of necessity and, in contemporary society, style and identity. We use the example of spectacles as an informal hypothesis, that to create desirable prosthesis a precedent for acceptation is required. Early spectacles were wire edged and crafted to reduce apparent disability to a minimum, and later became fashion items styled according to function, activity, facial shape and aspiration. The acceptance of desirable facial prosthesis may come through design where function and technical benefit is signalled and aesthetics preferences are hinted, later to become tailored to compliment both activity and occasion.

The nose is an anatomical mass of bone, cartilage and tissue that assists respiration, humidity and contains a host of sensory functions, and yet its form, contour and proportion is a highly visible characteristic. Rhinoplasty, the surgical reformation of nose shape for aesthetic beauty is one of the foremost and popular cosmetic procedures (AAFPRS 2014). These operations attend to perceptions of beauty, correctness, and self-consciousness (Gilman, 1999). Opposed to purchasing beauty, in New Zealand facial prosthesis is often the result of skin cancer. Skin cancers typically manifest on the face and nose, and in New Zealand and Australia are the fourth most common cancer and the sixth most common cause of death from cancer (O'Dea 2009). The occurrence of rhinectomy, the removal of the nose is uncommon; however, in advanced cases of melanoma it is often the only method of rehabilitation and with new and advanced methods of diagnosis the call for the procedure is increasing. However, rhinectomy is classed as non-debilitating and receive little financial support. The cost is substantial and the silicon prosthesis has a life of 6 to 12 months as the colours fade, the face changes colour with seasons and age, and the material degrades from handing and time. During this degradation process the capacity of the prosthetics to effectively camouflage the deformity greatly reduces resulting in the prosthetic nose appearing increasingly foreign to the face. Each new prosthesis requires time consuming face to face consultation, making, fitting, and painting.

Currently facial prosthesis are created by hand using an impression of the face and artistic interpretation and skill to craft the outward aesthetic. The cavity between is cast in silicon with tonal pigments matching the patient, which is then attached to the face with either an adhesive, clips or surgically fitted magnetic abutments (Thomas 2006) (Fig. 2). The procedure has changed little since the tin mask innovations during WW1 (Biernoff, 2011), where hand painted copper plate skins were attached to spectacles.

The Wellcome Trust with Fripp Design and Research (2012) have digitally harnessed the art and craft of facial prosthesis, producing anatomically correct, 3D printed full colour silicon prosthesis prototypes (Xiao 2014). However, in moving to a digital process that reduces the personal interaction between the experienced prosthetic technician and the patient there is a real risk of creating a technically efficient yet humanly insensitive process.

Figure 3a. Exploring attributes in products and searching for design cues.

Evidence in our process revealed design opportunities where digitisation can promote individualism and endeavour to integrate product to person. Such an alternative desirable prosthesis may also place the ownership of craft with the person rather than the medical community.

Experiences and Explorations

As practice based research within a university, ethical approval was sought and gained, and in doing so issues of the participant's open and visual disclosure in publication were raised. As our practice crosses disciplines, exploration and publication would be very different from medicines' evidence-based research, and thus require an understanding of the designers' goals by the participant, and the surgeon's comprehension of the design's intentions. Moreover, we argued that design is about the person and the artefact, with both being paramount in the contextualising of any design achievement. The nature of this project, and how desirable prosthetics are explored, evidenced, communicated and experienced, is inexplicably tethered to its context, the face. Our practice is thus a design process to draw out the relationship between a person and an individualised method of desirable atonement.

Figure 3b. Exploring attributes in products and searching for design cues.

Figure 4. Observing the art of the maxillofacial prosthetist.

Our participant was recruited through the maxillofacial surgeon and showed interest in participating in the project after experiencing a variety of crafting and fitting procedures that varied widely in satisfaction. This intimate awareness of prosthesis procurement, fitting and wearing is vital to the design process.

To gain an initial affinity and gather aesthetic thoughts we spent some time with our participant. Together we browsed shops of interest where designed and styled consumer products were handled and discussed, including a sports shoe department, a fishing shop, and a sunglasses store (Fig. 3). This experience provided some prompts towards our particular participant's aesthetic preference for activity, performance and function. We photographed these experiences and conversed about material qualities, colour, and brands, then of the activities soccer, fishing and cooking. We then discussed the loss of a defining facial feature and the activities that could no longer be pursued. We also spent a day observing the crafting, casting, fettling, fitting and painting of a prosthesis on our participant to understand the limitations of current silicon prosthesis, which further developed our confidence in the project (Fig. 4).

To further our comprehension we took a series of portrait photographs. Portraits have the ability to share and subjectively understand character. The activity and images captured a key design insight - our participant smiled without his prosthesis (Fig. 5). On analysis we understood that the wide smile deflected the face to such an extent as to risk the dislodgement

Comments from particapant: 'Initially after having the nose removed I was advised that I'd be up for a total reconstruction but would have to wait for a year to make sure that all the tumour had been removed. So the best I had was a plaster covering the hole! Then I was advised that the best way forward would be to get a prosthetic nose. So I went to a technician and it was hopeless. So it was decided that he would try and get me to see someone who could do a better job. This took quite a long time, eventually they managed to work it that I would see the technician privately. All good until I had to go up to get some more noses made. At this stage the noses were applied using a special glue (better than a plaster) and only really lasted 4-6 months. What really annoyed me was that there was nothing in place for people like me to say what the costs are (plenty), what is involved and what to expect.'

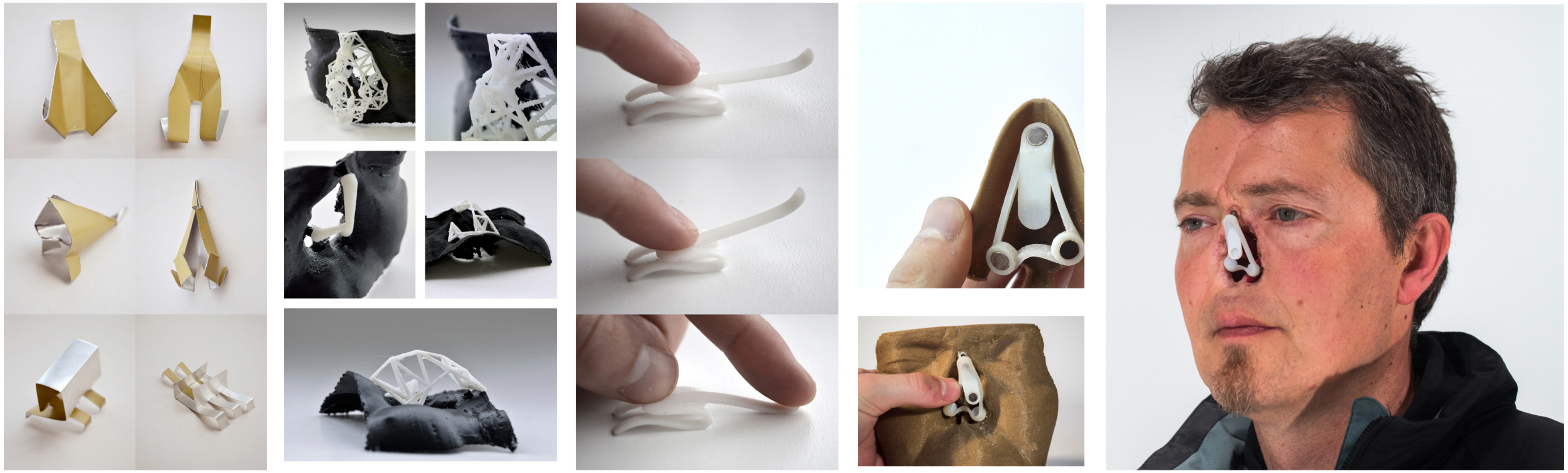

Figure 5 (left). Capturing the visual story.
Figure 6 (above). Sketch models of prosthetic shock absorber.

of the nose and for that reason the participant had trained themselves to not smile. This sad realisation illustrates the critical importance of the facial prosthetic role in sustaining the emotional wellbeing of the person. These images also revealed the highly confrontational appearance of a face without a nose that created a very real and valid fear of exposure by the wearer. Just how easy prosthetic dislodgment could occur was demonstrated with a sideways stroke of the finger. This shows that the empathic understanding of proximity to others is very different with the fear of losing your nose from another's touch.

Our exploration revealed that in the hands of highly skilled maxillofacial technicians, artistry and patient empathy continue to remain a constant and professional goal. Moreover, in referring to our participant's comment quoted in figure 5, the time consuming search for satisfaction and knowledge places anxiety on the patient directly after the surgery when they least need it as they reintegrate into their normal lives.

Process and Procedures

From our experiences, prosthesis fixation, revelation, junctions and form were identified as design prompts for crafting new anatomy.

To counter the concerns around suddenly losing the nose we explored various alternative methods of connection to the face that were sympathetic with the surgeon's recommendations. The silicon nose

Figure 7. Explorations into a visual and practical guard modelled from 3D scans.

would dislodge itself with ease and had no inherent properties to counter unexpected contact but couldn't be firmly fixed for fear of damaging the surgically implanted magnetic abutments. This led to a series of small bent metal experiments around suspension and the mount of the prosthesis. These ideas were integrated into the early prototypes as integral 3D printed springs between abutments and prosthetic. 3D scans of facial morphology allowed us to specify areas to flex and others to remain ridged using multi-property printing as an extension of anatomical compliance into a shock absorbing system that could control any sudden movement of the prosthesis (Fig. 6).

Figure 8. Making - 3D printed prototypes.

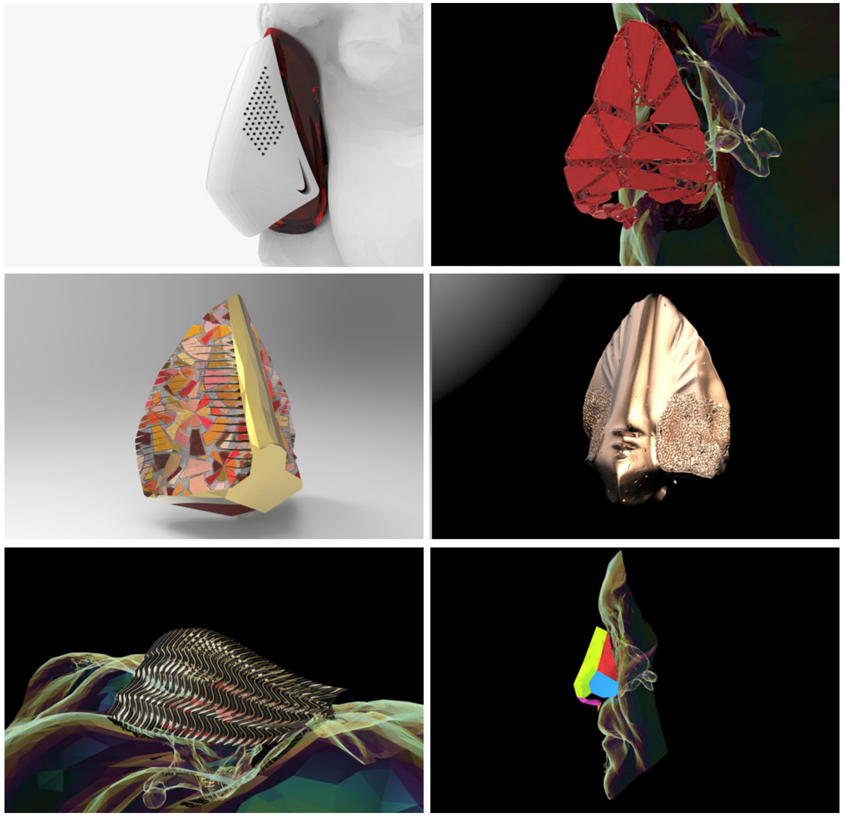

Figure 9. Complex computer generated forms.

The cavity revealed without a prosthesis is deep and unnerving when first seen. The fear of public revelation is evidenced in our participant's apprehension around activities of close proximity, sport, a crowded bus, congestion. To minimise the fear of revelation a concept where the nose had two parts was considered. The first would adhere strongly to the face and form a visual and practical guard (Fig. 7). The contact boundary areas of this would be printed in a very soft and compliant mix to move with the face and the inner in a firmer grade to support the second part the formal nose. This would be attached magnetically, and if dislodged revelation would be of anatomical loss but not disfigurement.

Figure 10. Prosthesis fitting.

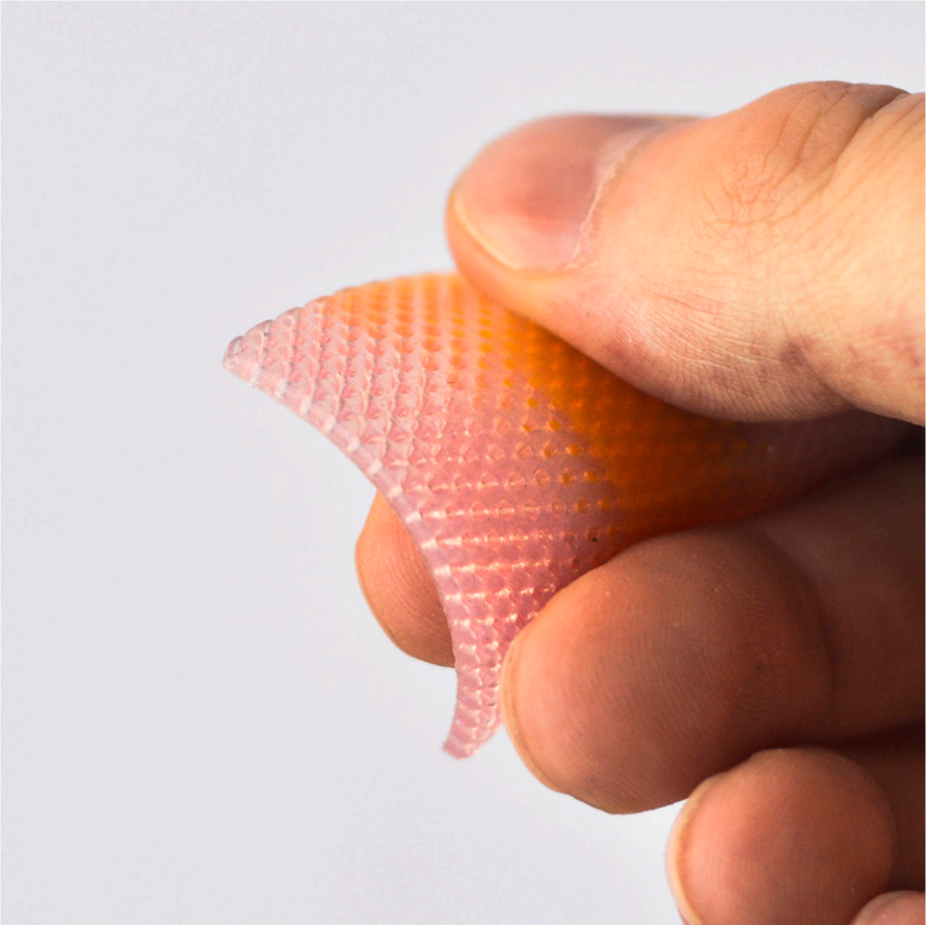

Figure 11. Colour swatch evaluation for Multi-property printing.

In a traditional prosthesis the junction between prosthesis and skin tissue is referred to as the margin, a very thin membrane of silicon that is tasked with making the face seamless. Facial expression and movement are counter to this procedure, facial muscles lifting and stretching in reaction to emotion and task quickly make evident the margin, refuting its intention. To overcome these issues and emphasise the potential in 3D scanning and multi-property printing the margin is treated as such. We respect the conspicuous junction and treat it as a design opportunity where a person's freedom to laugh, smile and be active is considered.

With the participants face digitised we were able to construct and print prototypes that exploited the 3D printer's unique capacity to print in range of materials during a singular printing process (Fig. 8). This offers performance benefits that are only possible with a process that doesn't require post assembly and hand craft that could drastically reduce the cost of prosthetics while improving their performance. We explored a variety of aesthetic forms for the nose that ranged from complex computer generated geometries to aesthetics for activities. Many of our early attempts were propagated within a virtual context of the digitised face (Fig. 9). We reflected on the context and notion of respectful transition for our participant in order to alleviate some tangible problems such as movement and to formalise the aesthetic to that which is known. Debating success and failure through design practice and the use of many prototypes assisted in leveraging our design towards compositions our participant could understand and consider. We engaged all partners in the practice, the speculation required a rigorous technical and financial benefit with subtle aesthetic qualities.

In trialling the prototypes we revisited portraiture photography as a shared method of visualisation and as a vocabulary to complete our circle of thought and making (Fig.10).

Outcomes and Continuance

To apply experience and story to concepts we adopted a method of 3D scanning and computer modelling. In a 3D scan of the face the individual's characteristics are captured as data that separates both the logistics of needing the face to work off and the predisposition to replicate as normality. A 3D scan can offer back to the patient their own digital mirror capable of facial aesthetic orchestration, rather than a generic medical solution. Teamed with multi-property printing and methods of tailoring, the complex dynamics of facial expression are accommodated in materials that simulate anatomy and facilitate the seemingly simple and spontaneous act of a smile.

Our participant is now beginning to privately live with the prosthesis, to reflect outside of the practice and return with more detailed ideas around aesthetics and performance. We continue this project with further experiments in multi-property printing including colour and flexion (Fig. 11) and to open up the project to other participants with the focus on participant as co-designer.

While the project is at an early stage we plan to continue and envisage a project where people can manipulate and model the design over their data, select between options and order at a cost effective price. Changing the visual and performance characteristics of facial prosthesis is an example of research through design where individuals may take ownership of the design craft through exploitation of emerging digital technologies within an international arena.

Acknowledgements

Special thanks to Julian Goulding and Michael Williams (Maxillofacial Prosthetist/Technologist).

References

AAFPRS American academy of facial plastic and reconstructive surgery. Available from: http://www.aafprs.org/wp-content/themes/aafprs/pdf/AAFPRS-2014-Report.pdf [Accessed 12 October 2014].

Biernoff, S,. 2011. The rhetoric of disfigurement in First World War Britain.

Social history of medicine 24(3) 666–685.

CARTIS The centre for applied reconstructive technologies in surgery. Available from: http://www.cartis.org/ [Accessed 3 October 2014]

Chang. T,. Garrett, N,. Roumanas, E,. Beumer, J,. 2005. Treatment satisfaction with facial prostheses The journal of prosthetic dentistry 94 (3) 275-280

Eggbeer, D. (2008). The computer aided design and fabrication of facial prostheses. Unpublished thesis (PhD), University of Wales Institute Cardiff.

Eggbeer, D,. Bibb, R,. Harris, R,. 2012. The future of facial prosthesis. Workshop report Loughborough University, Engineering and Physical Sciences Research Council.

Fantini, M., De Crescenzio, F., Ciocca, L., 2013. Design and Rapid Manufacturing of anatomical prosthesis for facial rehabilitation. International journal on interactive design and manufacturing 7 (1), 51–62.

Gilman, S. L., 1999. Making the body beautiful: A cultural history of aesthetic surgery. Princeton University Press.

O'Dea, D,. 2009. The costs of skin cancer to New Zealand. The cancer society of New Zealand, Wellington School of Medicine, University of Otago.

Oxman, N,. 2011, Variable property rapid prototyping Virtual and physical prototyping 6 (1) 3-31.

Summit, S., Available from: http://www.bespokeinnovations.com/ [Accessed 1 August 2014].

PDR The national centre for product design + product research. Available from: http://pdronline.info/ [Accessed 12 October 2014].

The Wellcome News, 2012. Losing face: The symbolism and treatment of facial mutilation Wellcome Trust 14-19

Thomas, K. F. 2006. The art of clinical anaplastology. England: Samoza. S. Thomas.

Xiao, K., Zardawi, F., van Noort, R., & Yates, J. M., 2014. Developing a 3D colour image reproduction system for additive manufacturing of facial prostheses. The international journal of advanced manufacturing technology 70 (9-12), 2043-2049.