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The Importance of Incorporating Technological Advancements into the Prosthetic Eye Development: A Perspective Commentary

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Abstract

Application of technology into healthcare has typically been targeted to high demand illnesses and treatments. However, with an increasing need to meet patient's expectations combined with increased accessibility and reduced costs, smaller healthcare fields are starting to investigate its function and usability. Services have historically been led by skills and expertise, and recent developments are being seen by ophthalmologists in the field of prosthetic eyes who acknowledge the potential benefit from technological advancement. Utilising the technologies recently investigated in maxillofacial prosthesis can start the evolutionary process where products are continually re-designed and re-developed to achieve excellent patient outcome and satisfaction levels.

Keywords: Prosthetic eyes; Technology in healthcare; Maxillofacial prosthesis; Artificial eyes

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Introduction

A focus on addressing the needs of the patient has resulted in the incorporation of technology in modern healthcare becoming increasingly widespread [1]. Healthcare interventions are often complex consisting of various components that may act both independently and inter-dependently [2]. It is important to understand the requirements of those involved with the product (the patient, their families and the health professionals) to ensure effectiveness, thus increasing success rate and limiting the need for modifications [2-4]. The end product not only needs to be functional, but also aesthetically pleasing and fit into the working and living pattern of the patient [3]. Although this knowledge creates greater insight for the developers, requirements often change over time and factors that were once important to a patient may have been forgotten or have changed, thus not all needs will be met [5].

High demand healthcare needs such as heart related conditions and diabetes often attract investment and funding allowing for significant technological advancement. Examples of this include an electronic stent for the heart, an artificial pancreas and 3D printed biological materials [6]. With reduced resources, research and development in small healthcare sectors is often

slow, sometimes remaining stagnant for a number of years. With changing patient expectations, products produced in these fields can result in reduced patient outcomes and satisfaction [1, 3].

However, the need to meet patient expectations within healthcare and increased accessibility to technologies has led to its recent application in small healthcare sectors [7]: One example of this is maxillofacial prosthesis. Investigation of technology into this field includes three-dimensional surface capture (3D scanning), three-dimensional Computer-Aided Design (3D CAD) and layer additive manufacturing processes/rapid prototyping and manufacturing (RP&M).

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In creating prosthesis, three-dimensional surface scanners are used to capture 3D images of the surface and the subsurface. This is followed by 3D CAD tools to analyse and fine tune the captured data which once processed generate an STL format used by all RP machines. RP is a form of layered or additive manufacturing process that allows small batch manufacturing with low initial capital investment.

Current incorporation of technology into maxillofacial prosthetics

Specific areas that have been researched in maxillofacial prosthesis include orbital prosthesis, ear (auricular) prosthesis and nasal prosthesis [8-13]. MRI, Laser or CT scans can be used to produce a three-dimensional image of facial anatomy. However, they are unable to produce fine details such as hair and wrinkles [7, 10]. To overcome these limitations, plaster replicas of the defect site such as the nose and ear have been produced for scanning purposes [7, 10].

The prosthesis is designed and manufactured using 3D CAD packages and RP&M technologies such as FreeForm CAD software and ThermoJet technologies [10]. 3D CAD packages are used to refine the roughly defined shapes to produce optimum levels of detail. Along with bringing time and cost saving benefits, both CAD and RP&M technologies produce good accuracy [10]. However, software limitations in representing and modifying complex anatomical forms results in the end product not being aesthetically pleasing [10, 11, 14]. The design in the fitting bar for the ear prosthetic lacked retention strength making the prosthesis apparent and the nasal prosthesis suffered from a noticeable margin resulting in a visible gap [7]. With facial anatomy consisting of various shapes and sizes, the technologies reliance on mathematically defined shapes makes visual judgement better at producing acceptable outcomes than the technology [10]. Consequently, additional stages such as the fitting and finishing methods currently employed in the conventional method are needed.

The incorporation of technology into maxillofacial prosthesis needs further development. This includes non-surface scanners that produce fine details of facial anatomy; software that can process scanned data, and for additional RP&M processes to produce wax-based materials [7]. The need for the above improvements combined with constantly changing costs of technology that can vary regionally and the addition of indirect costs such as technology maintenance, updates and training, results in its incorporation in maxillofacial prosthesis not currently making clinical or economic sense [7].

Technological development in prosthetic eyes

Despite these limitations and requirements for improvements, the investigation of its application and suitability for use in other fields is still warranted: one of which is prosthetic eyes. Prosthetic eyes are a type of artificial eye made from a thin, hard acrylic shell that covers the surface of the eye restoring it to a normal appearance [15]. Whereas prosthetic and artificial eyes

are manufactured using poly methyl methacrylate (PMMA) and occupy an anophthalmic socket, orbital prosthesis contain both PMMA and silicon components, retained by skin adhesives or by orbital bone implants. As such orbital prostheses are very different from prosthetic eyes which are more disguisable and easier to maintain. With technology being investigated in orbital prosthesis (such as 3D scanning and rapid prototyping and manufacturing), this perspective commentary will address the incorporation of technology for prosthetic eye development.

Advancements in prosthetic eye development have mainly been ocularist led, based on their experience and expertise. This includes digital imaging, creating ways of taking an impression of the eye socket and changing pupil size in different lighting conditions: created through the use of electro-active polymer technology.

Digital imaging involves taking a digital image of the patient's iris, which is uploaded to a computer to be evaluated and adjusted for correct colour, brightness, contrast and hue using graphics software such as Photoshop [16-19]. Once the iris is correctly colour-matched to the natural eye, it is printed on photo-paper before being attached to the wax pattern where the remaining stages of manufacturing are undertaken. Digital imaging is less time consuming than the traditional methods as it requires minimal artistic skills, and provides aesthetic quality as it closely replicates the natural iris with minimal colour adjustment and modifications [16-19]. However, requiring special digital photography equipment and computer software [16, 18-20], as well as experiencing colour fading as a result of the light instability of photographic dyes, has seen a return to the traditional methods of using paints and pigments to create the iris [21, 22].

A recent collaboration between industry and academia has seen the start of RP&M technologies being applied to prosthetic eye development. Despite being in its early stages, various limitations are emerging [7]. Firstly, despite 3D scanning making the accurate measurement, manufacture and fitting of the prosthetic eyes more achievable, the production method of RP&M technologies does not require 3D scanning as the prosthetic eyes are batch produced in three standard sizes of small, medium and large. Secondly, the prosthetic eyes are printed from powder with the iris being digitally created and overlaid into 3D form before being encased in resin. By using a standard list of hues, this method is unable to fully colour-match the iris. Thirdly, the end product does not include veining and tinting of the scleral, therefore does not represent the patient's natural eye. Although these limitations can only be currently addressed by adding additional man-made steps into the process, continual investment into this field has the potential to advance this technology through further research and development.

By not being able to produce individualised prosthetic eyes, the use of technology in this process is not viable. Further investigation is needed into how current technology can address the needs of prosthetic eye wearers. This includes scanning technologies that can capture the contours and fine details of the eye socket, 3D CAD software that can accurately represent the surface of the object and RP&M processes that use wax-based patterns to produce the prosthesis. Although a range of advanced

technologies exists that can accurately capture, represent, manipulate and reproduce soft and hard tissue, they require a level of investment that are difficult to justify in small healthcare sectors [7].

Essential components in the design and manufacturing of prosthetic eyes that are not yet met or have been investigated by technological intervention include the veining and tinting of the scleral and the polishing and fitting of the prosthetic eye in the patient's eye socket. A suggestion for future research based on these limitations is an investigation into how a 2D image of the vein can be mapped onto the scleral.

Conclusion

The focus on meeting the needs and expectations of healthcare patients has led to innovations in their treatment regime and after-care needs. Combined with increased accessibility, the patient centered approach has seen technological advancements being applied to small healthcare sectors. Yet, a lack of resources and investment means that its continual development is not promised. Small healthcare sectors that have started investigating the use

of technology into their current methods include maxillofacial prosthesis. Although the research has demonstrated the potential effectiveness that technology can bring, this potential cannot be fully exploited by current technologies without addressing the specific materials and process requirements in the design and manufacturing process [8, 11-14].

One area yet to be extensively investigated is prosthetic eyes. With a lack of investment and funding, developments have often been ocularist led, based on their skills and expertise. Requiring a starting point and being a similar field, the technologies investigated in maxillofacial prosthesis, can be applied to the prosthetic eye process. With an evolutionary element where processes are continually re-developed until the end product results in excellent patient outcome and satisfaction, understanding technological capabilities as they currently stand is of upmost importance.

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