A century of advances in prostheses

Prostheses today can trace their roots to the rudimentary designs of the First World War, but since then there have been significant advances that have improved the quality of life of amputees.

A century ago on the 11th hour, the guns fell silent and fighting ceased on the Western Front. Soldiers would no longer be required to leave the relative safety of their trenches to go 'over the top' and traipse through barbed wire across no man's land while taking on enemy fire. For the fortunate, returning home finally seemed to be a reality. However, in the aftermath of the Armistice of 1918, although there were no longer battles to be fought, the effects of the conflict were still physically evident as a large number of soldiers and civilians suffered the loss of limbs. As mentioned in an interview with Emily Mayhew, a historian in the bioengineering department at Imperial College London, amputations were often carried out as a surgical intervention generally due to necessity as a result of infections and gangrene in this pre-antibiotic era. Suddenly, many countries affected by the war had to figure out a way to rehabilitate the veterans and civilians with amputations in order to allow them to return to the workforce and live independent lives. This sparked a need to mass-produce prosthetics.

Due to their clumsy designs and low uptake rates, prostheses were largely seen as a medical stopgap rather than a permanent solution for amputees. It was clear that the peg-leg that was developed from a split tree trunk and attached using leather straps was not satisfactory. This led to the development of more sophisticated prostheses that were made from the latest alloys and had hinged joints that targeted above-knee amputations. There were also significant advances made by the aviator Marcel Desoutter in the use of aluminium for prostheses, due to their lighter weight, and also in the use of a pelvic suspension system for better comfort[1]. Decades later, more advances were made particularly for upper-limb prostheses such as the Bowden body-powered prosthesis, which permitted a greater range of motion[2]. The creation of myoelectric prostheses ushered in a new era of prostheses that permitted greater degrees of freedom in articulation. These were introduced in the 1960s by Alexander Kobrinski and were able to amplify electromyography potential in order to stimulate the movement of prosthetics[3].

WWI veterans practising with prostheses. Credit: dpa picture alliance/Alamy Stock Photo.

More recently, in 2004, a revolutionary surgical technique was developed — targeted motor reinnervation — that involves rerouting spare nerves from the amputated limb to specific target muscles that can be contracted or relaxed simply by the amputee 'thinking' about flexing their limb[4]. Targeted sensory reinnervation has also enabled the development of prostheses that offer sensory feedback to amputees in order to allow them to 'feel' and distinguish between objects, ultimately permitting the user to adjust the strength of their grip[5]. Other significant advances have been made in lower-limb prostheses such as the microprocessor knee, which is a computer-controlled pneumatic joint that permits normal gait by adapting to resistance in flexion and extension[6]. Advances in materials science have also contributed significantly to prosthetic design, and materials such as carbon fibre have been widely used in body-powered prostheses such as the Flex-Foot Cheetah, due to their enhanced shock absorption. Despite these advances, a major issue with these prostheses has been the significant financial cost associated with them.

Equally important are the issues related to the comfort and fit of the prosthesis. As stated by Mayhew, some of the problems with pain and discomfort of the residual limb within prosthetic sockets experienced over a century ago in the Great War are still relevant today. Soon after receiving their prostheses, usage of these artificial limbs by amputees drops significantly due to complications such as sores and infections. However, research projects that focus on improving socket design are ongoing in many research groups.

The aesthetics of prostheses are also a stumbling block. While the majority of lower-limb amputees would prefer prostheses of any kind that allow them to navigate life on their feet rather than using a wheelchair, for others, the psychological burden of using a prosthesis that does not match the skin tone or shape of their limbs is a major barrier. Therefore, the aesthetics of prostheses can make a significant difference for amputees in reconciling with the loss of their limbs during the arduous period of rehabilitation. Engaging with the public can also play an enormous part in social and psychological rehabilitation. Events such as the Paralympic Games, which evolved from the Inter-Spinal Unit Games, and the Invictus Games, a competition by wounded ex-service personnel, have all played a significant role in changing societal views on disability.

Other conflicts around the world such as the American Civil War and more recently in the Middle East have inevitably also played a part in driving progress in the care of wounded victims. Indeed, over the last century innovations in materials science and electronics have unquestionably contributed towards the development of better prostheses. As a result, these advances in technology, as well as transforming public discourse, have improved the quality of life for amputees. They will undoubtedly also play a significant part in the rehabilitation of patients with other complications, such as neurological disorders, who could benefit from neural prosthetics to aid not only in motor function but also in sensory and cognitive modalities. ❐

Published online: 23 October 2018
https://doi.org/10.1038/s41563-018-0218-y

References

1. Fliegel, O. & Feuer, S. G. *Arch. Phys. Med. Rehabil.* **47**, 275–285, http://www.oandplibrary.org/op/pdf/1966_04_313.pdf (1966).
2. Zuo, K. J. & Olson, J. L. *Plast. Surg. (Oakv.)* **22**, 44–51 (2014).
3. Sherman, E. D. *Can. Med. Assoc. J.* **91**, 1268–1270 (1964).
4. Kuiken, T. A., Dumanian, G. A., Lipschutz, R. D., Miller, L. A. & Stubblefield, K. A. *Prosthet. Orthot. Int.* **28**, 245–253 (2004).
5. Hebert, J. S. et al. *IEEE Trans. Neural. Syst. Rehabil. Eng.* **22**, 765–773 (2014).
6. Sawers, A. B. & Hafner, B. J. *J Rehabil. Res. Dev.* **50**, 273–314 (2013).