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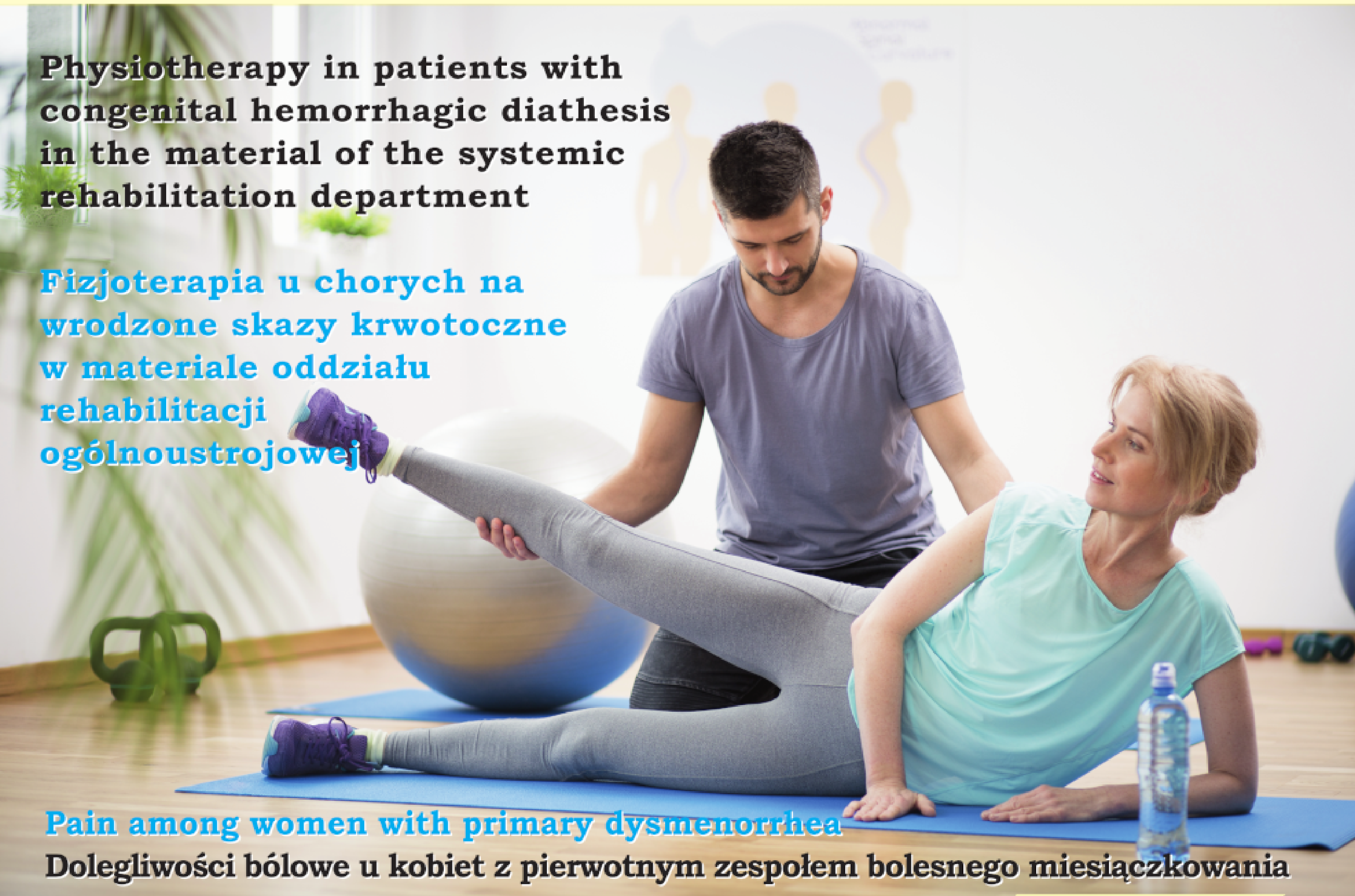

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Overcoming the disability – brief history of prosthetics and mechatronics of overcoming barriers

Pokonać niepełnosprawność – krótka historia protetyki i mechatronika w pokonywaniu barier

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Abstract

The oldest found and identified prosthesis was the Egyptian mummy's wooden big toe from approx. 3000 B.C. With the invention of gunpowder and the use of firearms, the number of limb amputations increased significantly, which consequently increased the number of disabled people. A field surgeon in the French army, A. Paré, designed movable prostheses that were very modern for those times. Simple machines used in their construction made it possible to perform bending and straightening movements, and his artificial hand called: 'Le petit Lorrain' with movable, spring fingers, even to perform a grip. Presently 15% of the population are people with disabilities. This is the biggest yet the most diverse minority in the world.

Modern technologies allow the human brain to be used to control the prosthesis by connecting it to the nervous system. The innervation of the amputated limb is introduced to any muscles on which electrodes are placed that receive signals sent from the brain, activating the motors in the prosthesis responsible for its movement. To move such an advanced prosthesis, it is enough to think about the movement as in the case of a healthy limb. There are reports that in the future it will be possible to prosthetics the brain and lost memory, but research involving humans in this area remains a vision of the future. This study aims to present a brief history of prosthetics and the use of mechatronics in overcoming disability.

Key words:

disability, history of prosthetics, modern prostheses

Streszczenie

Najstarszą odnalezioną i zidentyfikowaną protezą był drewniany duży palec nogi egipskiej mumii z ok. 3000 roku p.n.e. Wraz z wynalezieniem prochu i zastosowaniem broni palnej znacznie wzrosła ilość amputacji kończyn, a w ślad za tym liczba osób niepełnosprawnych. Chirurg polowy francuskiej armii, A. Paré, projektował bardzo nowoczesne jak na owe czasy protezy ruchome. Zastosowane w ich konstrukcji maszyny proste umożliwiały wykonywanie ruchów zginania i prostowania, a jego sztuczna ręka o nazwie „Le petit Lorrain" z ruchomymi, sprężynowymi palcami, nawet wykonanie chwytu. Obecnie niepełnosprawni stanowią prawie 15% ludności świata. Jest to największa, ale i najbardziej zróżnicowana mniejszość na świecie.

Nowoczesne technologie pozwalają wykorzystywać mózg człowieka do kontroli protezy poprzez połączenie jej z układem nerwowym. Unerwienie amputowanej kończyny zostaje wprowadzone do dowolnych mięśni, na których umieszcza się elektrody odbierające przesyłane z mózgu sygnały, włączające silniczki w protezie odpowiedzialne za jej ruch. Aby poruszyć tak zaawansowaną protezą, wystarczy więc pomyśleć o ruchu, jak w przypadku zdrowej kończyny. Istnieją doniesienia, że w przyszłości możliwa będzie protetyka mózgu i utraconej pamięci, jednakże badania z udziałem ludzi w tym obszarze pozostają jeszcze wizją przyszłości. Celem pracy było przedstawienie krótkiej historii protetyki i zastosowania mechatroniki w pokonywaniu niepełnosprawności.

Słowa kluczowe:

niepełnosprawność, historia protetyki, nowoczesne protezy

Introduction

According to World Health Organisation (WHO), approximately 15% of the population, meaning over a billion people is facing a disability. Even up to 2-4% of them is struggling with everyday tasks [1]. This is both the biggest and the most diverse minority in the world. The research suggests that the number of disabled people would raise to 2 billion by 2050 [1]. The reason behind those numbers raising lays in population aging and linked to this risk of injuries, accidents, and effectively disabilities in old age. Another reason is the globally increasing frequency of occurrence of chronic diseases causing disability, such as diabetes, cardiovascular diseases, and mental disorders. In the countries of low and mid national income, chronic diseases are estimated to be even at 66,5% of all the diseases [2].

In Poland, according to the Study of People's Economic Activity of in 2018, the number of people with disability at the age of 16 and more, has reached over 3 million. It is however speculated, that the given number might be lower than the actual number, and in fact, the number of those people can be much higher, i.e. over 4 million [3].

These days people with various functional limitations, have access to numerous solutions and modern technologies, enabling them to be almost fully functional. However, man used to struggle with disabilities limiting his functioning in the community since the beginning of his existence. In the event of loss of some organs or their functions, he constructed simple aids that allowed them to be rebuilt or replaced.

Aim

This study aims to present a brief history of prosthetics and the use of mechatronics in overcoming disability.

A brief history of prosthetics, or how the disability used to be handled in the past

The first amputation was probably performed in prehistory. This is indicated by the outlines of hands on the cave walls in France and Spain. They are dated around 5000 BC. In addition to injuries and frostbite, many amputations were probably a kind of ritual at that time [4].

The history of prosthetics began before the advent of writing and is based on only a few fragments discovered by archaeologists. The oldest record of the prosthesis dates back to 3500 B.C. In the Hindu books of 'Vedas' mention is made of the amputation of Queen Vispala's leg and a metal prosthesis constructed especially for her, enabling her not only to walk but even to participate in battles [5]. The Greek historian Herodotus of 424 B.C. wrote about a Persian prisoner of war who amputated his own leg to escape captivity. He made an artificial leg out of wood and walked 30 miles before being caught [4]. The mosaic from the cathedral in Lescar in France shows probably the mentioned prisoner after amputation – Figure 1. A fragment of an ancient vase unearthed near Paris in 1862 also shows a person after a similar amputation, whose limb was replaced with a wooden stick – Figure 2 [6]. In Aztec mythology, there was the god of creation and vengeance Tezcatlipoca who lost a foot in the fight against the Earth Monster. He was depicted with an artificial foot made of obsidian – Figure 3 [4].

Fig. 1. Mosaic from the cathedral in Lescar in France showing an amputee prisoner
Source: Fundación Lebrel Blanco, http://www.lebrelblanco.com/anexos/a0299.htm

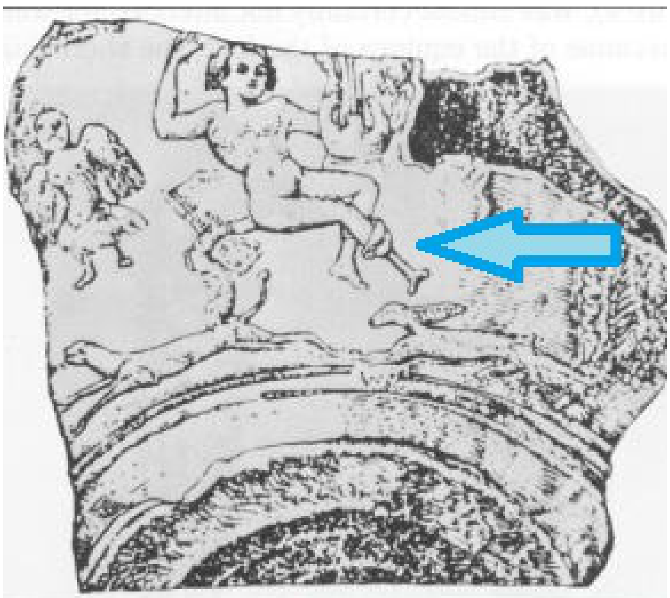

Fig. 2. A fragment of an ancient vase unearthed near Paris in 1862 with a drawing of an amputee whose limb has been replaced with a wooden stick. *Source: Sellegren K.R. An Early History Of Lower Limb Amputations And Prostheses. The Iowa Orthopaedic Journal 1982; 2: 13–27.*

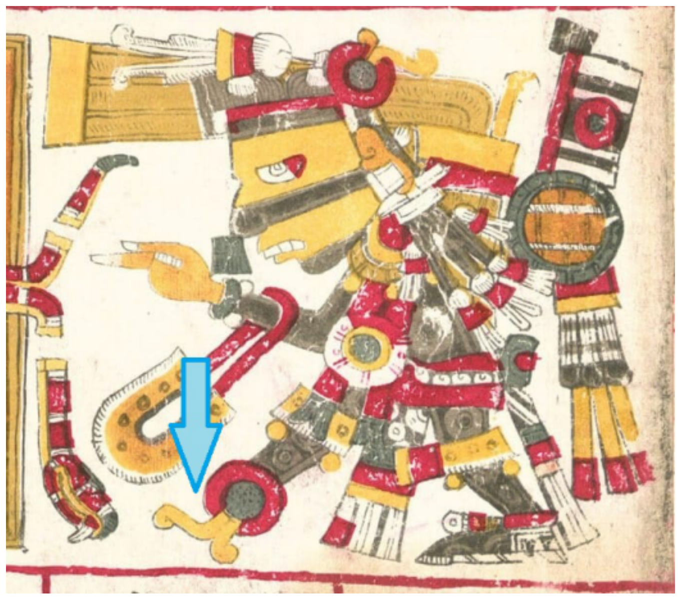

Fig. 3. Aztec god Tezcatlipoca with obsidian prosthetic foot.
Source:
https://www.amputee-coalition.org/history-prosthetic-leg/

Prostheses in ancient times were usually made of perishable materials and the death rate from amputation was extremely high, so only a few exemplars from this period have survived. Ancient Egyptian religion emphasized ‘wholeness’. It was believed that the lack of a limb would continue to disturb the deceased in the afterlife, therefore prostheses were also placed in the coffin [4]. Egyptian artificial limbs were made of fibre and designed to not only replace the missing part of the body, but also its function: the big toe of the foot is needed for balance, but in ancient times it was also necessary for wearing traditional Egyptian sandals. Dating from 1069-664 B.C. 'The Cairo Toe', designed for an Egyptian noblewoman, is made of wood and leather. The prosthesis shows signs of use, so it was not only attached to the owner's body after her death, but it was probably used during her lifetime – Figure 4 [4, 7, 8].

Fig 4. The oldest surviving prosthesis 'Cairo Toe' - wooden big toe belonging to an ancient mummy.
Source: Svitil K.,A. Walk Like an Amputated Egyptian
http://discovermagazine.com/2001/apr/breakwalk/#.Ua2U3Zw_TIV; https://www.amputee-coalition.org/history-prosthetic-leg/

Another example of an ancient prosthesis is the 'Grenville Chester Toe', dated between 1295 and 664 B.C. It was made of a paper-like material, consisting of flax, glue, and plaster – Figure 5. This prosthesis also shows signs of use [4, 8, 9].

Fig. 5. 'Grenville Chester Toe' – an ancient finger prosthesis made of linen, glue and plaster.
Source:
https://www.britishmuseum.org/collection/object/Y_EA29996

The oldest preserved full leg prosthesis, 'Capua Leg', was discovered in Capua, Italy, and is dated 300 B.C. It was found in the tomb with the remains of its owner. The lower leg prosthesis was attached to the body with a metal belt. It has numerous signs of use – Figure 6 [4, 10].

Fig. 6. 'Capua Leg' - the oldest full-leg prosthesis found in Italy.
Source: https://collection.sciencemuseumgroup.org.uk/objects/co84549/copy-of-roman-artificial-leg-london-england-1905-1915-artificial-leg

In China, a prosthetic leg made of poplar wood with a horse hoof instead of a foot was found. It comes from approximately the same period as the Capua Leg and was also found along with the remains of its owner with a deformed knee. The prosthesis was attached to the leg with leather straps and enabled the owner to walk and ride horses – Figure 7 [4].

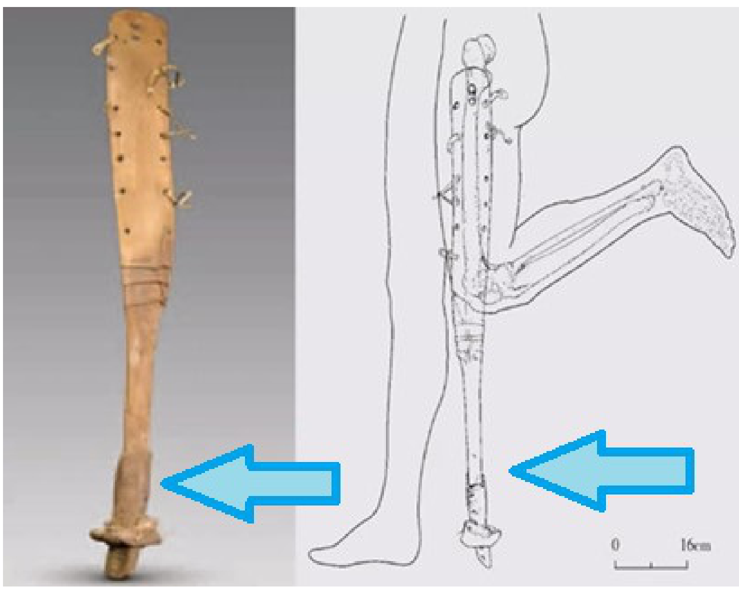

Fig. 7. A prosthesis with a horse hoof instead of a foot found in China.
Source: https://www.livescience.com/53321-ancient-prosthetic-leg-with-hoofed-foot-discovered.html

The Peruvian figurine from around the 1st-2nd century AD shows an amputee with a primitive cup-shaped prosthesis placed on the stump – Figure 8 [6].
The Middle Ages did not go down in any particular way in the history of prosthetics. During that period, only the wealthy could afford a prosthesis, and amputation procedures were still

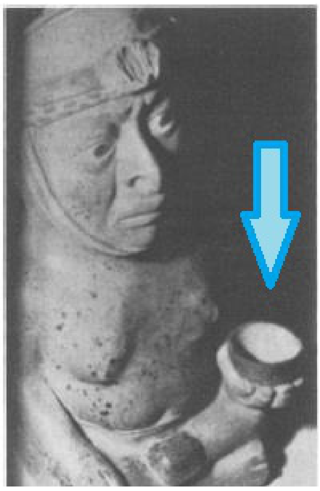

Fig. 8. Peruvian figurine depicting an amputee with a primitive 'cup' shaped prosthetic leg. *Source: Sellegren K.R. An Early History Of Lower Limb Amputations And Prostheses. The Iowa Orthopaedic Journal 1982; 2: 13–27*

very primitive and often performed by a hairdresser or a ship's cook [4]. A common substitute for limbs lost during war or battle was the so-called 'Pegleg' or 'wooden leg'. Waste wood was easy to obtain and any trader or armorer could transform it into an artificial leg. Knights who lost their limbs were likely to be equipped with iron artificial legs enabling them to ride a horse but had no other use [4].

With the invention of gunpowder and the use of firearms, the number of limb amputations increased significantly, which consequently increased the number of disabled people. A field surgeon in the French army, and later a royal surgeon, Ambroise Paré (c. 1510-1590), who is considered the father of modern surgery, designed movable prostheses which were very modern for those times. Simple machines used in their construction made it possible to perform bending and straightening movements, and his artificial hand called: 'Le petit Lorrain' with movable, spring fingers, even to perform a grip – figure 9 [4, 5, 11, 12].

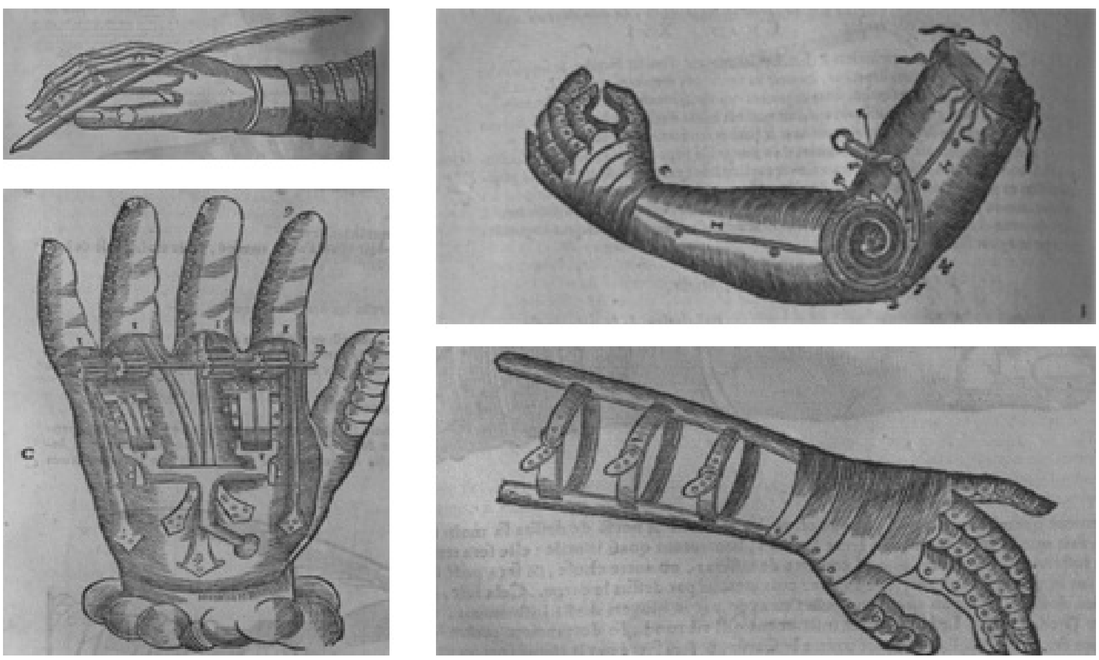

Figure 9. 'Le petit Lorrain' – hand prosthesis designed by A. Paré. *Source: https://nyamcenterforhistory.org/tag/ambroise-pare/*

He was also the first to develop a knee prosthesis with an adjustable harness and a lock-on knee hinge, which became a model construction for modern prostheses. He also substituted wood with much lighter materials, such as leather, paper, and glue – Figure 10 [4, 5, 11]. Paré also developed artificial noses – Figure 11 [4, 11].

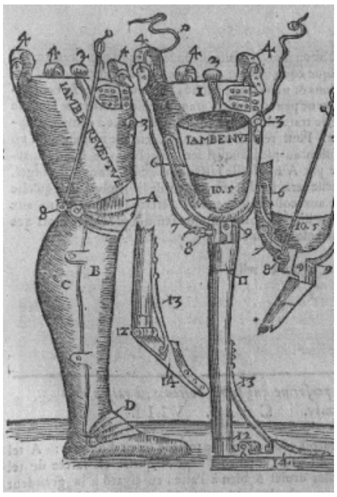

Fig. 10. Prosthetic leg designed by A. Paré
Source: https://nyamcenterforhistory.org/tag/ambroise-pare/

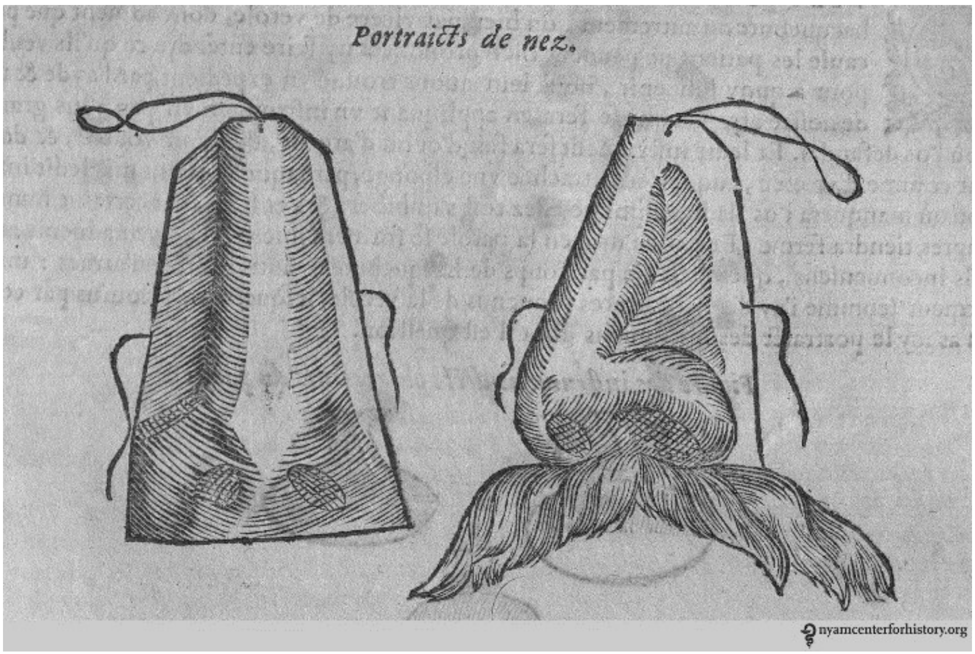

Fig. 11. Artificial noses designed by A. Paré. *Source: https://nyamcenterforhistory.org/tag/ambroise-pare/*

Another figure worth mentioning was Pieter Verduyn (c. 1625-1700)- a Dutch surgeon who invented the non-locking knee prosthesis in 1696. The device had external hinges and a leather thigh socket – figure 12 [4, 11].

During the American Civil War, the demand for limb prostheses increased. During this time, almost 80 different designs of prostheses were introduced that allowed to increase the mobility of the amputated limb [4, 11].

Londoner, James Potts, who emigrated to America, invented a knee prosthesis with a wooden calf and thigh and a flexible

Fig. 12. Prosthetic leg designed by P. Verduyn
Source: https://nyamcenterforhistory.org/tag/ambroise-pare/

foot attached to a steel knee with catgut 'tendons'. This design was considered more aesthetic than the prostheses produced so far [4]. In turn, Douglas Bly invented a spherical ankle joint made of ivory and a rubber thigh socket. Bly published information about his prosthesis in brochures all over the country, however, the US government found it too expensive to deliver it to injured soldiers [11].

James Edward Hanger (1843-1919) was an American engineer who first experienced amputation during the Civil War. During his convalescence, he designed a prosthetic leg, then patented it and founded the company Hanger Inc. The aforementioned prosthesis was made of oak barrels. It had articulated knee and ankle joints for better mobility [4].

The Salem Leg Company manufactured articulated knee prostheses and below-the-knee ones. They were officially recommended by the US government for the army, and their sales materials contained quality certificates confirmed by eminent war veterans [4].

New York inventor Dubois Parmelee also made significant advances in the field of lower limb prostheses in 1863. In his design, the prosthesis socket was attached to the stump under atmospheric pressure [4].

After the World War I, the American Prosthodontics and Orthotics Association was established. Nevertheless, there has been no major progress in this area until after the WWII, when the U.S. government provided funds to military companies, which has led to the development of many modern used materials in prosthetics, such as plastics, aluminium, and other composite materials [4].

In 1945, the US National Research Council established the Committee on Prosthetic Devices, later called the Advisory Committee on Artificial Limbs. In 1954, the Committee published the book 'Human Limbs and Their Substitutes' describing such advances in prosthetics as the electric arm, new methods of knee stabilization, and adjacent femoral funnels [11].

In his book, 'Upper and Lower Limb Prostheses', author William A. Tosberg introduced a brief history of the materials used in prostheses. After the World War II, plastics dominated [11].

Modern prosthetics as a chance to regain independence

The aim of modern prosthetics is the functional restoration of partially or completely lost body parts and the restoration of maximum functional abilities. It also aims to faithfully recreate their natural appearance [13]. Limb prostheses are divided depending on the place where the amputation was performed. There are upper limb prostheses: transradial and transhumeral. The first one is a prosthesis placed below the elbow joint, the second – above. Similarly, in the case of the lower limbs: the transtibial prosthesis is mounted below the knee joint, and the transfemoral prosthesis – above [14]. In terms of functionality, a prosthesis can also be classed as cosmetic, mechanical, and biomechanical prosthesis.

The main function of cosmetic prostheses is to mask the defect caused by the loss of a given body part. During the production of the mentioned type of dentures, great emphasis is placed on aesthetics and a realistic appearance. The colour of the prosthesis cover should be as close as possible to the patient's complexion, and its shape and size must match the patient's body. Cosmetic prostheses are the simplest to build, they are complemented with silicone mass and plastic, which is why they are lightweight. They have very limited mobility, which makes them only a little help in carrying out the simplest activities of everyday life [15].

Mechanical prostheses are active prostheses. They work thanks to a special suspension system (lines or harnesses). The user controls the prosthesis with the muscles linked to it, located above the stump. Their disadvantage is that the patient feels the strength of the work performed – the muscles get tired faster than in the case of a non-disabled person [15].

Myoelectric prostheses work thanks to special electrodes that link them to the muscles of the stump. The contraction of the muscle transmits an electrical impulse to the electrode above it. This stimulation activates small motors that move the prosthesis. In this type of device, external battery power is used, so that the patient gets less tired during usage than when using a traditional mechanical prosthesis. The prosthesis enables precise hand movements, such as opening and closing it, as well as the variable intensity of clenching the fingers. Unfortunately, their downside is the price, which is often very high. An alternative is to manufacture prostheses with the use of 3D printers, significantly reducing their cost, enabling more people able to afford them [15, 16].

Bionic (biomechanical) prostheses are currently the most advanced type of prostheses, applicable when it is necessary to replace an amputated hand. Contrary to the myoelectric prostheses mentioned before, they also allow for the reception of tactile stimuli that enable recognition of the shape, texture, and hardness of the touched object. What's more, they allow you to adjust the strength and dynamics of the grip. The operation of this type of prosthesis is based on an attempt to recreate the physiological path of the nerve impulse, from the receptor to the effector. Thanks to the neuro-interface and electrodes communicated with the peripheral nervous system, a disabled person can perform a movement, only by thinking about it [15, 17].

In 2007, it was released for sale, developed by a team led by Stefan Schulz at the Research Center in Karlsrühe, in collaboration with the University Orthopedic Hospital in Heidelberg, Germany, 'Fluidhand' prosthesis – Figure 13 [18]. As the name suggests – 'Fluidhand' – is a prosthesis that replaces a lost hand. The fingers are moved due to a hydraulic system, which makes it different from other prostheses and makes it less noisy and smoother in operation. The miniature hydraulic pistons are connected with executive modules responsible for the flexion movement in the joints of the fingers. Connections are made of small, flexible pads filled with hydraulic fluid supplied from the tank, and the case covers the processor that manages the entire system. This allows the fingers to be flexed separately and for different types of grips.

Fig. 13. 'Fluidhand' prosthesis developed by a team led by Stefan Schulz
Source: Gaiser I, et al. The fluidhand III: A multifunctional prosthetic hand. JPO: Journal of Prosthetics and Orthotics 2009, 21: 91-96.

The gripping force can be adjusted by processing the force feedback signal. Resistance sensors on the index finger and thumb pick up the signal, which is then processed in a microcontroller linked to a vibration system. Depending on the signal strength, the vibration system changes, which is feedback for the user. Stefan Schulz has repeatedly emphasized that thanks to the hydraulic system used, the movement of the Fluidhand prosthesis is soft and flexible, unlike prostheses with built-in electric motors. As a result, the hand seems more natural and the grip is steadier [19, 20].

In 2017, another myoelectric prosthesis appeared on the market – 'TASKA Hand', whose introducer was Mathew Jury. It is characterized by a built-in flexible wrist and flexing fingers in various configurations. Its additional advantage is the great mobility of the thumb, which not only improves the grip but also has a positive effect on the naturalness of movement. 'TASKA Hand' allows you to perform grips of varying intensity, and as a result, the user can precisely grasp even small and delicate objects without risking their destruction – Figure 14 [21].

It is the first hand prosthesis in the world that is completely waterproof, which undoubtedly, is very important because it has enabled the disabled to adopt new ways of using it: they do not have to remove the implant, for fear of spills, when washing teeth, hands or bathing [22]. The creators of 'TASKA

Hand' have also created a special mobile application that allows the prosthesis to be controlled with a mobile phone. Thanks to it, it is possible to create personalized types of holds tailored to the needs of a specific person.

Fig. 14. 'TASKA Hand' prosthesis presenting a forceps grip. *Source: https://www.prostek.com.au/prosthetics/taska-hand.html*

Contemporary lower limb prostheses are also computerized. An example is 'C-Leg', i.e. a prosthesis with an automated knee joint - figure 15. Currently, the fourth, improved model of this prosthesis can be found on the market. It is designed for patients who have had lower limb amputation at the thigh level.

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Fig. 15. 'C-Leg' – prosthesis with an automated knee joint.
Source: https://www.thelondonprosthetics.com/prosthetic-solutions/lower-limb/microprocessor-knees/c-leg-4/

The above-mentioned prosthesis has a built-in microprocessor responsible for movements. During the entire gait cycle, the computer controls its phases, both in the support and transfer phases. Non-disabled people do not have to think about how to position the leg and foot while moving, as it is a physiological activity for them. People using C-Leg, unlike traditional prosthesis users, do not have to concentrate on their artificial leg with each step, because it adjusts itself in real-time to the gait, as well as to the type of surface and its angle [23]. Additionally, the scientists have proven that patients using C-Leg lose much less energy while walking than people using traditional prostheses. Another proven advantage of this prosthesis is a significantly smaller number of falls compared to traditional prostheses [24].

In ophthalmology, eyeball prostheses have been used for a long time, fulfilling mainly cosmetic functions, masking the lack of an eye. They do not restore the vision; they only make the patient feel better.

Recently, Second Sight 'Argus II' retinal prostheses, also known as the bionic eye, became available – Figure 16. They are used in the treatment of blindness caused by retinitis pigmentosa. The implant works by converting images captured with a small video camera attached to the glasses into a series of electrical stimuli. Then, the stimuli are sent wirelessly to electrodes previously implanted on the surface of the patient's retina. As a result of these actions, healthy cells of the retina are stimulated, causing the perception of light patterns in the brain.

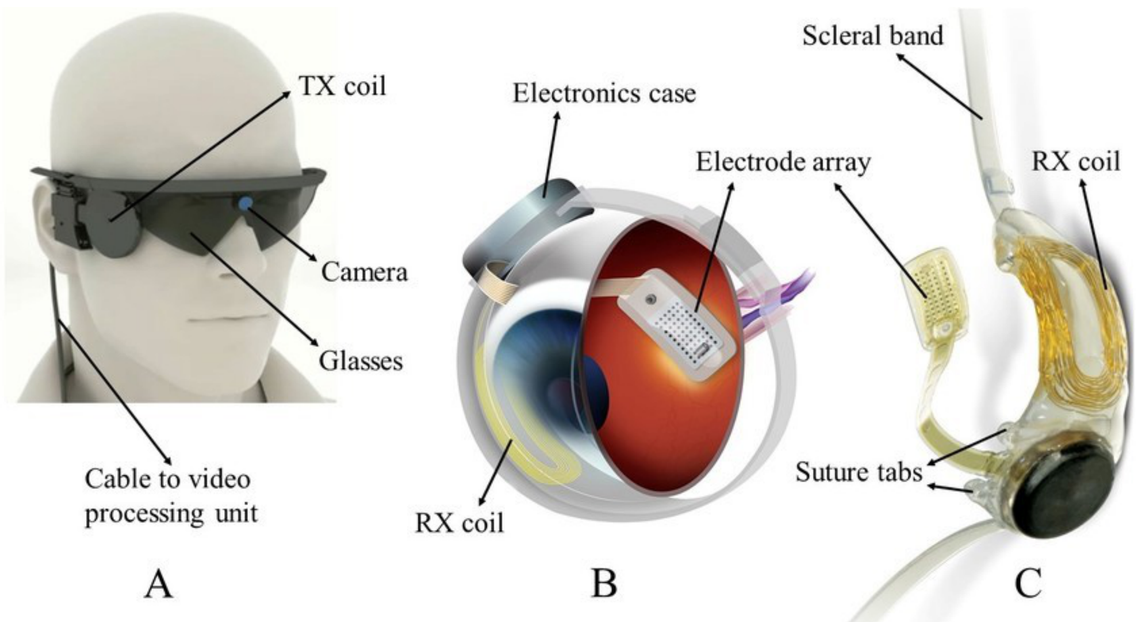

Fig. 16. 'Argus II' retinal prosthesis with the presentation of its individual parts. *Source: Agarwal K, et al. Wireless Power Transfer Strategies for Implantable Bioelectronics: Methodological Review. IEEE Reviews in Biomedical Engineering. 2017*

Even though patients do not fully regain their eyesight, some important visual functions are restored, such as identification of objects in the house (table, door, etc.) and motion detection. As a result, their comfort of life improves and reduces the dependence on help from other people [25, 26, 27].

From a biological point of view, the eyes are the most important sensory organ of most animals. In practice, thanks to the sense of sight, the human brain receives over 80% of information about the world around it. In 2020, the journal ‘Nature’ published information that scientists from the United States and Hong Kong have developed a prototype of the biomimetic eye ‘EC-EYE’, which may in some time be able to restore sight to the blind – Figure 17. The project is based on the light-sensitive implemented in solar panels – perovskite, used to create thin nanowires several thousandths of a millimetre long, mimicking photoreceptors found in the human eye. In ‘EC-EYE’ the density of nanowires is even greater than the density of photoreceptors in volleyball. Scientists have managed to precisely copy the natural curves of the eye – the semi-circularity of the retina and the roundness of the lens in the front of the eye. Moreover, the inside of the ‘EC-EYE’ was filled with a biomimetic substance – an ionic liquid. Nanowires generate charges, which are exchanged for ions – Figure 17. Therefore, it is possible to detect light and send a signal to external electronics, which transform it into an image. However, there is a lot of work to be done by the research and development team as there is not yet a safe way to connect 'EC-EYE' to the human brain, to interact with it, and create images. Moreover, currently, the ‘EC-EYE’ is supplied with energy from the outside, which disqualifies it as a prosthesis, as placing it in the patient's body could be life-threatening [28, 29].

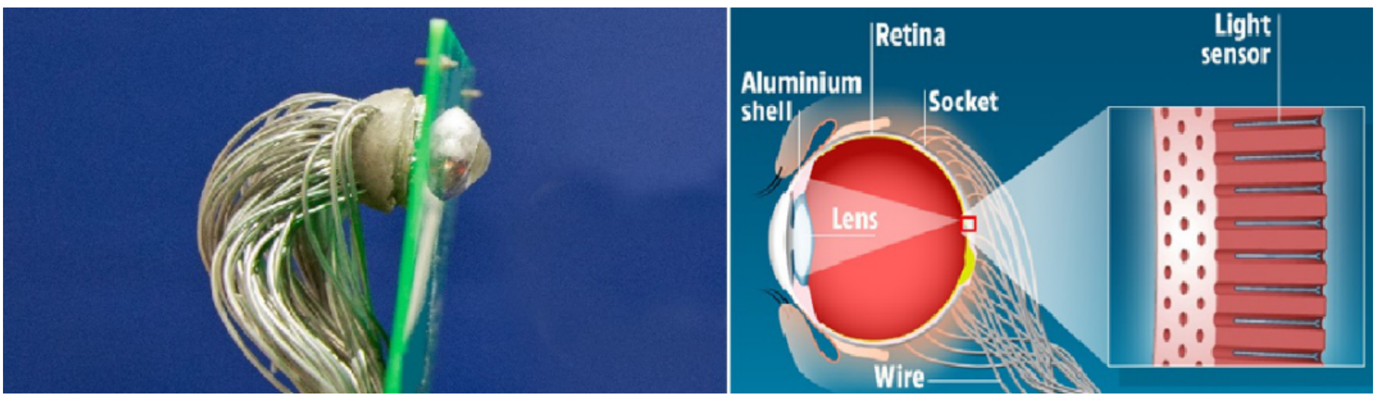

Fig. 17. ‘EC-EYE’ – modern eye prosthesis and its simplified flowchart
Source: https://businessinsider.mx/ec-eye-el-ojo-bionico-desarrollado-por-la-universidad-de-hong-kong/; https://www.thesun.co.uk/tech/11674074/bionic-eye-invention-night-vision/

A person's memory can be disrupted by medicines, diseases, and brain damages. Previous attempts to restore or stop the loss of memory function in humans have usually involved non-specific modulation of brain areas and nervous systems related to memory recovery. In 2018, scientists from the Wake Forest Baptist Medical Center and the Viterbi School of Engineering presented a neural prosthetic system that can improve memory by using space-time memory codes in the hippocampus via an electrode placed in it – Figure 18.

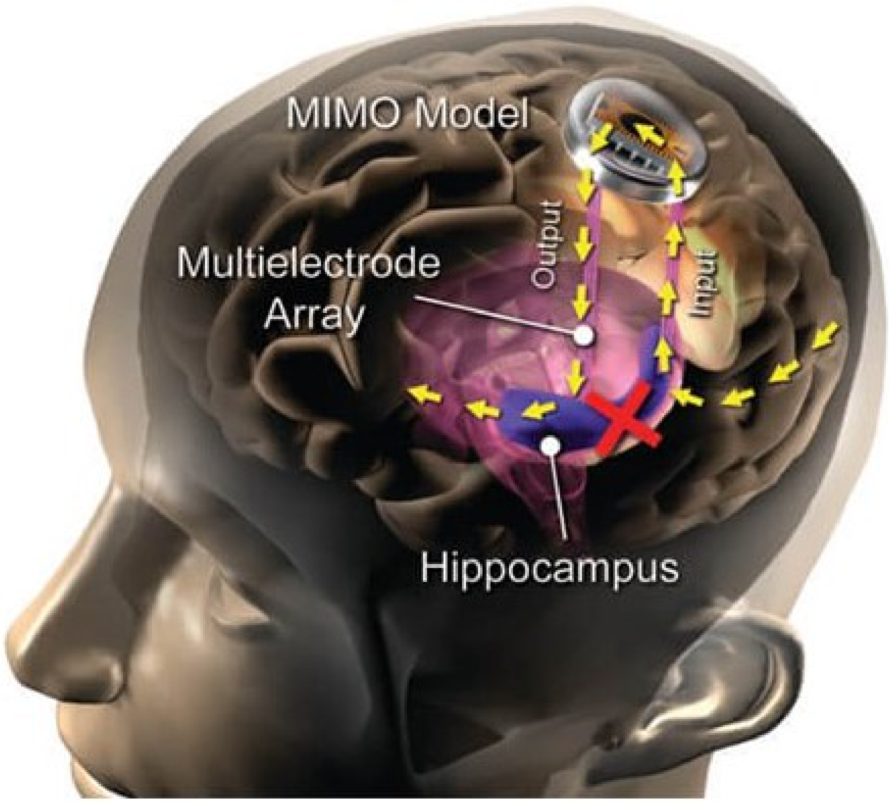

Fig. 18. Neural prosthetic system - simplified operation scheme.
Source: https://www.medgadget.com/2018/04/implanted-brain-prosthesis-helps-to-retain-new-memories.html

In the discussed pilot study conducted in a group of patients with epilepsy, the researchers proved that even when the memory of the examined person was impaired, it was possible to identify patterns of neuron discharge responsible for the proper formation of short-term memory. The aforementioned patterns were analysed, and then, thanks to the placed electrodes, returned to the patient, which did not directly replace short-term memory but strengthened it. The study showed an improvement in the short-term memory performance of the tested patients compared to baseline measurements by 35%. The researchers also expressed hope that in the future they will also be able to support long-term memory. Ultimately, the treatment procedure using the described system is to apply to people with neurological diseases such as Alzheimer's disease, post-stroke condition, or serious head injuries [30].

Currently, medicine is unable to manage the reconstruction of the spinal cord. Patients suffering from it depend, to various extents, on the help of third parties. Scientists from the Feinstein Institute for Medical Research in Manhasset performed a procedure on a patient with quadriplegia, which involved implanting a chip in the patient’s brain that receives and transmits information to the computer about the pattern of electrical activity that occurs when the patient is thinking of moving their arm. The signals obtained were analysed and sent to a specialized, flexible sleeve wrapped around the patient's forearm – Figure 19. Stimulations from the sleeve stimulated the previously inactive muscles and

Fig. 19. Stimulation sleeve placed on the forearm and reconstruction of movement patterns by the patient
Source: Bouton C, Shaikhouni A, Annetta N. et al. Restoring cortical control of functional movement in a human with quadriplegia. Nature 2012; 533: 247–250

allowed the patient to perform the missing movements [31]. In the future, this system may be used to restore the movement abilities of patients with spinal cord diseases or other neurological pathologies.

Conclusion

People with disabilities are the largest and most diverse minority in the world, and studies indicate that this group will double by 2050.

Disability was incorporated in the life of man from the earliest centuries, as evidenced by the preserved items, which include: the Hindu books of ‘Vedas’, where the Queen Vispala after an amputation is described; a mosaic in Lescar picturing a war prisoner; prosthetic toes of ancient mummies; and prostheses of whole legs. Probably, many prostheses were made in ancient times, but only a few of them were found, and based on them, an image of the prosthetics of that time has been created.

Another breakthrough stage for prosthetists were the inventions of Ambroise Paré: ‘Le petit Lorrain’ (hand prosthesis) with movable, spring-loaded fingers, allowing for gripping and a prosthetic leg with a knee hinge, which became a model construction for a modern prosthesis. Other researchers living with A. Paré only improved his prosthetic design.

Nowadays, people with various functional limitations have access to many modern solutions and technologies, enabling them to be almost fully functional. The state-of-the-art bionic prostheses are constantly improved thanks to new materials used in ‘joints’ enabling smoother movements and ensuring water resistance, and modern software allows them to ‘learn’ the user's movement pattern. There are also eye and memory implants that may give hope for the future for blind people and people with central nervous system diseases, but their use in humans remains a vision of the future.

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