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Review article

HALLMARKS IN THE HISTORY OF ORTHOPAEDIC IMPLANTS FOR TRAUMA AND JOINT REPLACEMENT

GLAVNA OBILJEŽJA POVIJESTI ORTOPEDSKIH IMPLANTANATA KOD TRAUMA I ZAMJENE ZGLOBOVA

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Summary

This manuscript represents an attempt to review orthopaedic implants and reconstructive orthopaedic surgery for lower limbs lesions or trauma mainly in the 20th century. We emphasized on the type of implants, the biomaterials and their evolution, and we also engaged in a special reference for the pioneers of orthopaedic implant surgery and the innovative designers of those implants, in such a way to understand the ways and the stages through which they evolved to their present forms, as well as the scientific principles that affected their design and progress.

A correlation between the evolution of implants and several relevant disciplines (biomaterial chemists and engineers, biomechanics) that developed simultaneously with orthopaedic reconstructive joint surgery is present since the first attempts to reconstruct a damaged joint.

In the future, further progress is anticipated in the use of biomaterials, more compatible towards human biology, with minimally invasive applications and a perpetually increased life

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span. This progress depicts a phenomenon directly related to a multilevel, multifactorial and interdisciplinary scientific and technological field with many expectations.

Key words: *orthopaedic implants; trauma; arthroplasty; lower limb; joint; biomaterials.*

Introduction

In this historical review an attempt was made to present the evolution of orthopaedic implants for trauma and arthroplasty during the 20th century. It will be demonstrated that surgical implants had a parallel evolution with other scientific fields that are related to them like biomechanics, bioengineers and material processing, like metallurgy. These were proved to have a vital role in the attempt to manufacture new implants, more durable, that cause less biological immune reaction and are capable of simulating the natural function of the parts they replace with supreme accuracy.

All pioneer surgeons and designers of artificial implants are cited in order to prove the progress towards the achievement of the present form of the implants and the scientific principles that defined their design, evolution and application. Surgery's textbooks, medical publications, and international medical press, were thoroughly revised for the suitable information to be accessed.

Special reference will be made in particular for the implants for the replacement of the hip, the knee, the elbow, the shoulder and the small joints of the hand and foot.

Trauma, the early era

It was during the 1860s, when the aseptic surgical technique had been pointed out by the British surgeon Joseph Lister (1827-1912), combined with the use of anaesthesia that had been generalized by the American surgeon and pharmacist Crawford Long (1815-1878) since the mid of 19th century that boosted more complicated surgical methods and made possible performing longer, more invasive operating procedures [1,2].

At the beginning of the 20th century the attempts to use implants in orthopaedic surgery were still scarce and relatively rare, as medical community had not been persuaded for the use of artificial parts, metallic, or non-metallic. Surgeons of that era are thought nowadays as the pioneers of this field and the main feature of this period is the direct involvement of surgeons in the designing of implants.

The first attempts were related to the reconstruction of fractures of the long bones and their joints. Sir William Arbuthnot Lane, British surgeon and physician (1856-1943), together with the first orthopaedic nurse, also British Dame Agnes Gwendoline Hunt (1866-1948) and Belgian surgeon Albin Lambotte (1866-1955) designed a fracture plate made of stainless steel [3]. Some years later, William Sherman of Pittsburg and almost simultaneously F. Pauwels in 1935, modified Lane's method in order to reduce concentration of high pressure forces by elimination of the acute plate angles. They used a mixture of Vanadium-Iron, instead of steel, due to its stamina and elasticity. Stellite, a mixture of chromium and cobalt, was found to be biologically more inert for implantation, as introduced by Adalbert Zierold, with his research that started in 1924 (Figure 1). Soon stellite prevailed and was accepted by most surgeons by the late 30s [4]. The next step in the evolution of the implants, was Molibdenium, a material that contained stainless steel due to its resistance in reacting with organic compounds and biologic fluids. Later on, another material was used, named Vitallium, containing chromium and nickel [4]. The post Lister era, was marked by the fact that implants and biomaterials could not been correlated to success or failure as prosthetics and it was a common practice to remove an implant soon after its original purpose of use was achieved. Even though newer materials were manufactured, the use of stainless steel remained extensive and it was augmented by the work of Martin Kirschner (1879-1942) from Greifswald, a German surgeon, who used pins and wire to reinforce the connection of the implant to the bone, a method that still carry his name ever since, K-wire, or Kirschner wire [5].

Figure 1: Internal fixation of the tibia by means of plates and screws.

Surgical treatment of the fracture of the femoral neck was the next achievement in implant surgery, when during 1926, Ernest William Hey Groves (1872-1944) first used common carpentry screws, and Norwegian surgeon Marius Nygaard Smith-Petersen (1886-1953), in 1931, who designed the first metallic nail with hinges (three-winged nail) in order to prevent rotational movement of the femoral head, by using stainless steel, which was later replaced by Vitallium [6]. Thornton, in 1937, adapted the idea of a metallic plate in the distal edge of the Smith-Petersen nail and secured it with screws for better support, while McLaughlin completed this newly evolved method with the use of plates with multiple angles [7]. The multiple angle device was adopted by Johansson and Thornton and later on by Bousquet. E.L. Jewett, in 1941, manufactured a three-winged sliding nail with a plate and a fixed angle system [8]. During the same period, Smith-Petersen, in 1939, used an artificial head surrounding the femoral head in order to create a new articular surface for the damaged joints. He had used glass, Pyrex, Bakelite and Vitallium. Vitalium was proved most biologically tolerant, resulting in 30% to 40% of the patients to gain once again usable joints. Thus came in use the basic dogma of arthroplasty, which is simply the replacement of a decayed joint by a strong artificial one [6]. Similar pioneering surgical techniques were also used by the Judet brothers in France, who had used the first biomechanically designed implant made from an acrylic compound, methyl-methacrylic, an invention that was meant to dominate orthopaedic implants ever since [8]. In the field of the screws and plates special reference must be made to the work of C.S. Venable and W.G. Stuck during the 30s, while in the field of the intrafracture compression a special note for Robert Danis is necessary [9,10].

The intramedullary nailing was the field for research by Ernest Hay Groves, who was the first to use metallic rods. In 1912, using his experience of treating open fractures of the femur during the 1st World War, he had described the first intramedullary nailing as an easy technique, which allowed the osteosynthesis by means of very small wounds without additional damage to the periosteum. He had noticed that the fracture healed without the use of plaster or a traction device, a real breakthrough in the history of Orthopaedics [11, 12]. The "real" intramedullary nailing was developed during the 1930s. The Rush brothers from Rochester, Minessota and simultaneously but independently Gerhard Kuntscher in Hamburg Germany developed similar techniques. It seems that the pioneers of the intramedullary nailing had limited communication and exchange of information due to the conditions of the mid-war era between Germany and the U.S. that made the communication of those scientific communities difficult [13,14]. Kuntscher showed with his work that the stabilization of the osteosynthesis is enhanced by the amplification of the medullary canal. Thus, using this idea, he could stabilize fractures of the femur distant to the canal. In order to achieve this, he had developed a hollow intramedullary nail at the beginning of triangular cross section and later a clover-shaped (figure 2). By this innovative way the

Figure 2: Kuntscher-type intramedullary nailing of the tibia.

use of intramedullary nailing in multifragment and metaphysial fractures was made possible [14].

External fixation methods were also developed, in the U.S. by Clayton Parkhill (1860-1902) from Denver, professor at Colorado and Dean of the Medical School, who had presented a device to the American College of Surgeons in 1897. Parkhill became the father of this technique, and his method was extremely popular during the 1st World War. In 1906 a surgeon from Antwerp, Albin Lambotte, developed a device for external fixation similar to that of Parkhill, working independently. In a time of war vast experience is acquired by surgeons and innovations are introduced in a short period of time that take decades to develop in a time of peace, but during the 2nd World War, scientists revealed that the external fixators didn't always produced good results and thus this method was reluctantly rejected by most surgeons [12].

Trauma in the post war era

In the years that followed 2nd World War, orthopaedic surgeons tried to perfect the methods of fracture fixation mainly by using wires and pins as developed by German surgeon Martin Kirschner (1879-1942). After a thorough research, the use of more sophisticated and refined mixtures of materials, a new generation of implants and prostheses prevailed in the treatment of arthritis and complicated fractures. A new boost was given by the advent of antibiotics, a fact that made possible prolonged operations with a reduced risk for infection. The vast progress in imaging techniques, like CT scan, made possible a closed visual access to regions of the body, that previously had been accessible only after an open surgical exposure.

The use of intramedullary nailing in both multifragment and metaphyseal fractures of the long bones was made possible due to further improvement of the materials by the German surgeon Gerhard Küntscher (1900-1972). Nails, should be locked in their proximal and distal ends. Kuntscher himself, understood the lock 's value [14]. This technique was firmly established by the work of Klemm K, Shelman WD, Grosse A, Lafforgue D and Kempf I during the 70s. [12]. The amplification of the medullary cavity resulted in the destruction of the endosteal microcirculation having as a consequence the destruction of the callus and prolonged calcification with an increased risk of infection. This approach deterred many researchers from using intramedullary nailing in Gustilo type 3 fractures, using mainly external fixators for such injuries. Another disadvantage of intramedullary nailing was the increased risk of fatty embolism and Adult Respiratory Distress Syndrome, especially in multitrauma patients with lung injury. Pape et al showed the significant increase of the pulmonary pressure during the amplification of the intramedullary canal, resulting in an increase of the phenomena that finally lead to Adult Respiratory Distress Syndrome (ARDS) [12].

Intramedullary nails without prior amplification of the canal, used in the last decades of the 20th century, are not related to such results and they can be used in the treatment of open fractures. In comparison with external fixators, these nails are more patient friendly and they allow easy exposure in treating problems of the soft tissue during reconstruction. With those nails that do not require reaming, the circulation of the bone is not compromised in the same degree, infectional risk is minimal but there are no evidence supporting faster bone healing [11]. In bibliographical references there is a disagreement concerning the time required for callus formation in nailing with or without canal reaming. Although Kuntscher supported the use of the wider nail possible after reaming, there are contrary based on animal models views [12]. Thus, in experimental models with mice, Olav Reikeras found no difference [15]. Schemitsch EH, in addition, found no difference in healing, in revascularisation and the quality of callus in experimental studies with sheep [16]. Christin Runkel, on the other hand, in experiments with sheep found faster healing if reaming was not used [17]. Melcher AH, in experiments with rabbits found a greater damage in bone circulation with an increased risk for infection [18]. In fact, bone healing is a multi-cause procedure and it is different regarding the stage and the phase. It is possible to enhance the vascular phase of callus formation, which is not that significant in early stages when endocrine mechanisms prevail. It was from this correlation, that the history of implants was affected significantly from breakthroughs in histology and physiology (basic science) and that designers tried to invoke certain basic biological principles in the advent of new materials.

In another field, significant progress was made in the post war era as far as external fixation is concerned. In Europe, an amateur carpenter Raoul Hoffmann (1881- 1972) who had a degree in theology, in his spare time developed his own popular method of external fixation [19]. After modifications by Vidal J and Adrey J, it was made one of the most popular devices in traumatology, mainly because of its easy application [20].

During the decade of 1970 De Bastiani G developed the axial dynamic external fixation which was more tolerable by patients than the Vidal-Adrey external fixators. Axial compression and walking with full load were made possible by the micromovement supported fracture healing, as biomechanics had recently proved [21].

During the 60s, Gavriil Abramovich Ilizarov developed his circular osteosynthesis device that since then carries his name and allowed fixation of fracture fragments and furthermore made possible the three-dimensional realignment.. For many years the application of this device was limited in Kurgan, Siberia, but in 1980 this technique was introduced to the western world due do the Italian orthopaedic surgeon Carlo Mauri. Carlo Mauri was successfully treated by Ilizarov for septic nonunion of the tibia [22]. Mauri introduced this method in the Western world something that Ilizarov could not do due to restrictions by the Soviet regime. Nowadays external fixation is still in use for the treatment of fractures with significant soft tissue damage (Gustilo 3), for the immobilization of pelvic and long bone fractures especially in multitrauma patients, although there is a difference of opinions for its use as final treatment. Disadvantages were considered the limited joint flexion, the increased risk of nonunion and the infection in the pins entry sites (10% of cases). On the other hand, replacing an external fixator with an intramedullary nail, increases the infection risk [10].

The goal of rigid anatomic reduction was achieved with the use of internal fixation with plates and screws that compress the bone fragments against each other. It was demonstrated and spread by Muller ME. In order for this result to be accomplished, compressors were used and later on establishing the principle of dynamic compression (DCP). In this way, primary bone healing was made possible [10, 11]. In 1967 Schenk PR and Willeneger H, showed that under anatomic reduction and intrafracture compression, bone necrosis and re-absorption were minimal and there is simultaneous bone creation from the ends of the bone fragment. In this way, intrafragmentory compression leads in primary bone healing without radiologic evidence of callus formation [10,11]. During the following years the disadvantages of the method were made visible.

It was clear that the only way to accomplish fixation was by the use of a rigid and bulky material. A large exposure was required with iatrogenic injury of muscular and periosteal structure. Applying a plate on the bone, invokes delayed union and in some cases even non-union. Primary callus, on the other hand, without the formation of healing bone is not very powerful and it is a cause of refracture after the removal of the planted materials. These disadvantages have lead to biological osteosynthesis with plates [10,11].

As far as special hip fractures are concerned, in comparison to the pre-war era, the invention of nails capable of withstanding the absorption of the femoral neck and intratrochanteric line like the three-winged telescopic nail of Pugh and the respective screw nail of Charnley followed. For treating such hip fractures angular hip nails- plates with angles of 130 degrees and 95 degrees were used. At the same time, the technology of dynamic hip screw of Richards was developed, a method that even today is approved for treating hip fractures. Surface osteosynthesis for treating fractures of the hip seems to recede nowadays in favor of intramedullary nailing, locked or not, like the different kinds of gamma-nail [10].

Trauma, biological osteosynthesis and contemporary developments

Special reference must be made to the concept of biological osteosynthesis, a term used to include a new approach in practical osteosynthesis. The primary goal is to achieve rigid fixation of bone fragments without soft tissue or periosteal injury. Free bone fragments are stabilized by the use of screws without damaging vascularisation if possible. When this could be accomplished, fracture healing is similar to the closed treatment of fractures with the creation of callus. Devices that provide this possibility are the waving and the limited contact plates (LC-DCP). The waving is a bent plate, whose metallic body is not in contact with the bone at the fracture site. The space between the plate and bone is filled with autologous cancellous bone grafts. These materials are used in multifragmentory fractures of the femoral diaphysis, when there is destruction of the medial cortex. Healing is taking place towards the creation of callus resulting in rare refracturing after the removal of materials [10, 11]. LC-DCP represents an improvement of dynamic compression plate invented by Stephan Perren in 1969. Stainless steel was replaced by biologically tolerant titanium mixtures combined with changes in the designing of the plate. Due to its shape, bending the plate is easier, vascularization of bone edges is minimally affected and callus formation is favored. Trapezoid shape of plate allows formation of circle edges at the rim of plates which are not overlooked during removal. Plate holes have the same formation with that of classic dynamic compression plates and so intrafragmentary compression is possible [10,11].

Another improvement in biologic osteosynthesis was the invention of locking screws. This technique allows better material attachment amplified if screws are placed in a non vertical position. Screws need to anchor in only one cortex, as internal locking on the material replaces stabilization of anchoring on the second cortex. In that way, limited contact osteosynthesis plate in combination with locking and/or non-locking screws could be used [10,11]. Eventually, the theory of biologic fixation leaded to the invention of LISS, a system resembling a plate and acts as an internal form of external fixation guided through a small hole distal to the fracture site with a closed introduction of cutting screws. An internal locking of that kind maintains the advantages of external fixation but with a potential for final treatment. Elastic osgteosynthesis helps the creation of callus without additional injury and allows healing by preservation of the blood supply. The main disadvantage of this technique is that it requires skill during the closed application of the plate and the screws. It is scientifically accepted that the advantages of biological osteosynthesis are simplicity, callus formation and resistance to infections [10].

During the modern era, since 1990, new systems made of bioabsorbable nonmetallic materials became popular. In that case conventional metallic plates and screws were succesfully replaced by similar devices made of PLA (polygalactic acid) or PGA (polyglicolic acid) or a combination of both in PLGA. The greatest advantage of these implants was that they are progressively absorbed and do not remain in situ like those that are metallic, and therefore a second operation for the removal of materials after the fracture healing is avoided. Their disadvantages are the reaction of the immune system due to their recognition by the macrophage cells of the body and their inability to support early mobilization. Therefore, those materials can still be used in special cases and indications in fracture repairing that will not be mobilized early after their osteosynthesis [10,11]. It is still considered idealized and unreal to construct implants that will combine the endurance of the metallic and the biotolerance of the synthetic, that is a combination of useful properties of both categories of biomaterials in a new innovative implant [11].

The hip

The idea to replace an abnormal or destroyed joint with implants had been materialized even before the 2nd World War by the technique of

Smith-Petersen and others. But most innovations boosted alongside with the scientific progress of the post war era [23]. During the 50s, two American orthopaedic surgeons, Moore AT and Thompson FR, had an important impact in this field with the solution they proposed to the problem concerning the femoral head. They had invented two stable metallic implants that satisfied the anatomical, functional and mechanical demands of the hip in a better way. Those plates were consisted of a head similar to normal with a neck and a collar with a long intramedullary stem with a neck- shaft inclination angle of 135 degrees for more natural distribution of forces. Moore had already used the first implant during 1940 replacing the proximal end of the femur of a patient with a malignant tumor in the vicinity of the trochanters but the result was not satisfying. In 1950 he had designed the implanted head in such a way as it is known today, with two portals in the proximal part of the stem, which he filled with grafts of bone he took from the extracted femoral head in order to create a bridge of bone and thus achieve the desired stability [24, 25].

The modern era of hip arthroplasty is inaugurated by the invention by McKee GK of a stainless steel cup on a Thompson type head [26]. This arthroplasty was modified in 1960 in collaboration with Watson Farrar with the addition of teeth like hinges in order to gain more stability in the acetabulum [27]. What followed, was the use of acrylic cement P.M.M.A. for the stabilization of implants by Charnley J during the same year. In 1963 the use of polyethylene as material of friction between head and acetabulum was established [28, 29]. In Switzerland, Muller ME presented his own implant for hip replacement made of protasul and friction material plastic [30]. The "low friction" arthroplasty of Charnley (figure 3) with a smaller metallic femoral head of a diameter of 22,225 mm articulated with a polyethylene cup with the use of cement was the milestone in the evolution of arthroplasty [29]. This method was modified and the lateral approach with a trochanter osteotomy was replaced by a posterior (Moore), anteriolateral (Watson-Jones), posteriolateral (Gibson) or lateral (Hardinge) approach. In order to increase the range of motion and decrease friction and the risk of dislocation, the diameter of the head initially was increased to 40 mm (modular: in two parts) and eventually set to 28 mm (conventional) [29]. Overall,

Figure 3: X-ray of a Total Hip Replacement. Such devices have revolutionized orthopaedic surgery and medicine in general.

there were 3 methods of stabilization of implants in total hip replacement: a) With the use of acrylic cement, a method with results proved satisfactory, b) With porous fixation with the use of hydroxyapatite, and c) With press-fit fixation. The use of acrylic or biological cement (polymethylmethacrylate – P.M.M.A.) made the direct mechanical fixation of the implant, the early mobilization of the patient and the long survival of the joint possible. The purpose of its use was to increase the fixation surface of the implant to the bone and to decrease the pressure on the surface [23].

In 1933, it was the German chemist Otto Rohm that invented and reserved the name "PLEXIGLAS" as the first form of industrial use of P.M.M.A., although chemically it was firstly invented during 1877 by the German chemists Fitting and Paul [4]. Nowadays this polymer is available in the following types: a) with a radiolucent factor (eg barium sulfate), and b) with antibiotic (usually gentamycine 0,5-1gr that reduces its rigidity but has an important role in infection prevention). Proximally bulky long circular stems are used in the cemented arthroplasties. Their specially shaped surface with vertical and perpendicular ridges intends to modify the linear forces into compression in the cement-implant surface [4].

The invention and use of cement also modified the biomaterials of the implants. It has been proved that chromium-cobalt alloys mixed with other minor metals had assisted in better application of forces, stabilizing the area, and so they prevailed. In the cementless techniques, titanium is still preferred because of its excellent rigidity and biocompatibility [23]. In the cementless techniques, another progress has been the use of a layer of hydroxyapatite which, by means of its absorption, increases the contact forces between metal and bone. Finally, as far as the acetabular cup is concerned, metal-on-metal contact had been used. Two parallel progressive efforts were the use of ceramic insert between the surfaces that also decreases friction compared to metal-on-metal contact having a similar result [23], and secondly the surface replacement arthroplasty of the hip, which was the most conservative choice of treatment for young adults without an indication for osteotomy. Wagner and Freeman, who were the pioneers of this technique during the 70s, reported failure in 35-58% within 6 years of follow up. Complications concerned mainly acetabular loosening and bone loss because of increased frictional forces and further more fractures of the femoral neck were also reported, in a lower frequency. A new boost was given to this technique after 1990, with the use of a cemented metallic head and press-fitted acetabular component and more recently with the advent of biotechnology of materials in order to reduce osteolysis and metallosis [31].

The knee

As far as the knee joint is concerned, an attempt to replace only the affected medial compartment of the joint had started before the total knee replacement during the 60s by MacIntosh AI and MacKeever D with the use of a metallic component unilaterally or bilaterally on the articular surface of the tibia. The main disadvantage of this technique was the implant loosening and its dip [32]. In 1976 Goodfellow J and O' Connor J presented an implant with harmonic and perpendicular articular surfaces between which a polyethylene movable miniscal-shaped insert was placed (the Oxford Knee) [33]. The procedure was possible with a small incision in the medial surface of the knee. Thus, the outcomes were impressively better. Total knee replacement was presented during the 50s by Leslie Shiers and Borje Walldius who used a metallic implant with rigid hinges which was stabilized not only on the articular surface but also in the medullary cavity of the femur and tibia. This implant offered correction regardless of the degree of distortion or instability, satisfactory range of motion and relief of pain. The uniaxial movement of this implant on the multiaxial motion of the human knee during gait was the reason of its limited use [34].

In 1971, Gunston FH presented the Polycentric implant that functioned on the principle of scrolling in a ringe and almost simultaneously Coventry MB in 1973, invented the Geometric system with total harmonic and perpendicular surfaces. The ratio of loosening was exceptionally high because of the overshearing and rotation during gait caused by the uniaxial motion of the knee [35,36]. The hinged joint implants became popular again during the late 70s (Stanmore, Guepar, Endolink). Initially, polyethylene was used for the reduction of friction but in the process linked joints permitting rotation during flexion-extension were also used (Spherocentric, Stabilocondylar, Attenborough, Sheehan). Loosening continued to be the main complication and the number of revision surgeries was increased dramatically [37]. Freeman MA and Swanson SA started using the condylar implant ICLH with non-perpendicullar articular surfaces during the 70s. This implant was totally, or partially controlled in moving against the plastic articular surface of the tibia [38]. Insall JN and Burstein HD modified this method in 1981 by means of a mechanism of posterior cruciate ligament replacement, the Posterior Stabilized Condylar Knee [39]. Implants that preserve the posterior cruciate ligament were characterized by the lack of harmony between the articular surface of the femur and the tibia. The discovery of the causes of failure guided to the attempt of stabilization of the tibial implant to the cortical bone of the tibia and the use of a stem that supports free movement of the plastic tibial component on a metallic platform in order to distribute loading in a better way (Insall and Burstein II, 1988), and also to the ability of posterior scrolling and rotation of the femoral condyles during flexion [41].

Thus, new implants were created in which cruciate ligaments are sacrificed (Total Condylar Prosthesis), the posterior cruciate ligament is preserved (Kinematic, AGC) or the ability of choice is given (Miller-Galante, Genesis, PFC, LCS). The use of a thin polyethylene insert in implants with flat articular surfaces (PCA of Hungerford 1983), as well as of a flat shaped polyehtylene insert (Kinematic), was accompanied with an extensive delamination of the plastic (figure 4). Towards the late 80s the use of implants with perpendicular, harmonic and extended surfaces of contact fixed bearing (Freeman-Samuelson 1985) began [41].

Figure 4: X-ray of a Total Knee Replacement. Over the years new designs and new implants have increased the efficiency of this technique and made it the most popularized in all Orthopaedic Surgery.

Conclusion

The progress made mainly during the 20th century boosted towards a grater future to come with an innovative evolution to be anticipated into more biologically tolerable materials, with minimally invasive techniques and continually increased life span. Hallmarks in orthopaedic implants will continue to make history as science progresses to beat medical barriers.

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Sažetak

Ovaj rad predstavlja pokušaj pregleda ortopedskih implantata i rekonstruktivne ortopedske kirurgije kod lezija ili trauma donjih udova većinom tijekom 20. stoljeća. Naglasak je na tipu implantata, biomaterijalima i njihovu razvoju, ali smo se posebice osvrnuli na pionire ortopedske kirurgije implantata i inovativne dizajnere tih implantata kako bismo shvatili na koji su se način i kroz koje faze razvijali do današnjih oblika, kao i na znanstvene principe koji su utjecali na njihov dizajn i razvoj.

Veza između razvoja implantata i nekoliko relevantnih disciplina (biomaterijalna kemija i inženjerstvo, biomehanika) koje su se razvijale paralelno s ortopedskom rekonstruktivnom kirurgijom zglobova prisutna je od prvih pokušaja rekonstrukcije oštećenog zgloba.

Anticipira se daljnji napredak u korištenju biomaterijala, kompatibilnijih s ljudskom biologijom, s minimalno invazivnom primjenom i stalno rastućim životnim vijekom. Stoga govorimo o fenomenu direktno povezanom s multirazinskim, multifaktorskim i interdisciplinarnim znanstvenim i tehnološkim perspektivnim poljem.

Ključne riječi: *ortopedski implantati; trauma; artroplastika; donji udovi; zglob; biomaterijali.*