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# Review on Alternate Materials for Producing Low Cost Lower Limb Prosthetic Socket

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## Abstract

Currently, several lower limb amputations occurred from different injuries caused by nature, accidents, and disease. From those harmed civilians, most of them not able to use artificial limbs or prostheses due to the high cost of the orthopedic prosthesis. This review aims to find out different types of materials used in the production of lower cost lower limb prosthetic sockets. Various related articles from 1984 to 2020 were collected from the database of Science Direct, google scholar, and other websites. A total of 112 research papers were obtained and out of them, 26 papers were selected for this review. Studies indicate that prostheses can be produced possibly from metal and polymer composites as well as natural fiber reinforced composites. It has been also reported that prosthetic sockets produced from synthetic fiber reinforced composite can be made to be durable and strong by changing the fiber orientation and by adding Nanoparticles with different volume fractions. However, they are more costly, stiff, and rigged. Prosthetic sockets made from biodegradable natural fiber reinforced composite are less costly, less stiff compared to conventional synthetic fiber polymer composite, and more comfortable for patients. Studies showed the good mechanical properties of Ramie, kenaf, pineapple, and Banana fiber reinforced polymer matrix composites made these materials the promising candidate for prosthetic socket applications.

**Keywords:** Amputation • Artificial limb • Prosthetic socket • Lower limb prosthesis

## Introduction

War, serious conflicts, land mines, numerous natural disasters, such as floods and earthquakes, along with chronic diseases, such as vascular diseases including diabetic complications, and arteriosclerosis are all the major causes of amputations. The study conducted in Brazil from 2010 to 2016 indicates lower limb amputation is two times as frequent in diabetic persons as compared to in non-diabetics, which accounts for 70% of non-painful lower limb amputations. Also, 85% of these amputations appear after the occurrence of ulcers, which affect 25% of those diabetics' person [1,2]. According to the review of Wakjira et al. in 2019, in Africa 60-80 million people were living with disabilities and among them, 78 million population are approximately Sub-Saharan Africa people. Likewise, the data received from public hospitals of Santa Catarina from 2010 to 2016, there were more than 1,200 lower limb amputation cases distributed around 20 micro regions in the state of Santa Catarina, Brazil [1]. The current review is supposed to know ways, materials, and methods to develop prosthetic socket devices. At present, the number of lower limb amputees keeps on growing in developing countries, and hence demand for orthopedic prosthetic devices yet unmet [3].

For centuries, different prostheses were made from specific types of wood or leather after they were shaped and stitched and sealed into the form of prosthesis. After dried and sealed, prosthesis makers proved the durability of the device. According to the survey of Rosalam et al. [4,5], initially, leather socket prostheses were usually suspended in a wood frame or structural metal to have the required shape and aesthetic value. Later, light metal and composite material become more popular for constructing different artificial limbs [5]. Especially synthetic fiber reinforced composite materials such as carbon fiber, glass fiber, and plastic materials were used as raw materials [6]. However, rather than cost, these materials have their own Side effect in air circulation, heat exchange, stress shielding [6-8]. To achieve the clinical requirements, many researchers studied the properties of different materials and improved the accessibilities as well as the durability of prosthetic devices made of metals and synthetic composite material. However, the expensive costs of the product burdened the wearers financially and have difficulty paying for these prosthetic legs.

## Objective

The main objective of this review was to document different types of materials used in the production of lower limb prosthetic sockets, external prosthetics, orthotic interfaces, and their functional requirements.

## Review Technique

For this literature review, a search was carried out on polymers used for the manufacture of prosthetic and orthotic lower limb interfaces and sockets, their functional requirements. The search was made from the database of Science Direct, google scholar, and other publications found in google to find related literature from 1984 to 2020. A total of 112 research papers were obtained. The keywords used for the search were prosthesis, amputation, lower limb, transtibial, prosthetic socket, modeling prosthetic socket, and interface. The review was made in Mar 2021.

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## Overview of Prosthesis and Orthopedic Device

The word prosthesis comes from the Greek word's pro, meaning in front of, or forward, and thésis, meaning placement. Therefore, this term refers to a part that replaces an affected or absent part of the body [9]. Over a few decades, the socket is anatomically formed and usually constructed from laminate material, which is composed of thermosetting or thermoplastic resin with strengthening such as glass, Kevlar, and/or carbon fiber [10]. To ensure accurate fitting, sockets are produced from a plaster mold of the person's stump (residuum). It is usual to reuse the modular components, such as the pylon, suspension, and foot, while only replacing the socket [10]. The main objective of the prosthesis is to withhold the opportunity of reinstating functional inabilities to people with amputations and they are an extension of the user's limb [9]. The extension can be the upper or the lower limb as illustrated in Figure 1. The upper limp extension (upper limb prosthesis) is designed to replace the upper lost limb of the body whereas the lower limb extension is designed for replacing the lower lost limb of the bodv and detailed bellow.

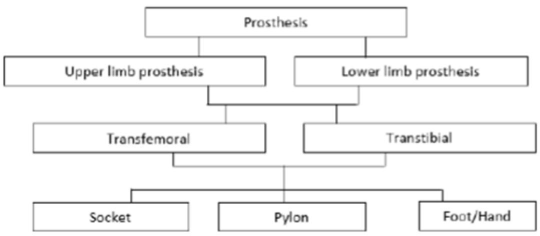


**Figure 1.** Classification of prosthesis and accessories

**Lower limb prosthetics**

Lower limb prosthetics is an artificial part of the body that is designed to substitute the form and function of the absent limb as the loss can alter a patient's quality of life. The devices are designed to supplement, support, or augment the function of an existing limb [11] The comfort and good quality of the prosthetic socket could govern the daily duration for the wearer and could prevent the destruction of soft tissues such as ulcers and blisters. The demands on prostheses are as a state of physical easiness and freedom from any constraints and pain to the user, high performance, and versatility to assist the user to have a normal life as possible [11].

There are different types of lower limb amputation that need special attention to fit prostheses to the stump of the patient, such as ankle disarticulation, partial foot, transtibial, knee disarticulation, transfemoral, and hip disarticulation. But the most common are transtibial and transfemoral [11].

Trans femoral: Transfemoral prosthesis is a device that replaces a lost leg above the knee and has a rigid and soft part, which is assembled to the residual limb of the patient as indicated in Figure 2.

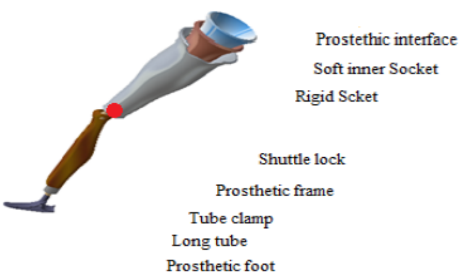


**Figure 2.** Transtibial prosthesis with liner and other components (authors' elaboration)

Transtibial: Transtibial prosthesis is a device that replaces a lost leg below the knee. Transtibial amputee prosthesis consists of a socket, adapter; to connect the socket to the shank, and artificial foot; besides, this also contains auxiliary suspension to join the residual limb to the socket as indicated in Figure 2. For transtibial amputations, the prosthetic socket is connected to a foot by titanium, stainless steel, aluminum, or carbon pylon [10].

Besides transfemoral and transtibial, other less prevalent lower extremities that are included in prosthesis are

**Hip disarticulations**: This signifies the removal of the entire lower limbs through the hip joint.

**Knee disarticulations:** This refers to the knee separating the femur from the tibia bone.

**Symes:** Partial foot and foot amputations.

The other parts of lower limb prostheses are sockets. A socket is the most important part of the prosthesis. It enables the artificial limb to connect and fit the residual limb/residuum or stump. In amputation, a good fit with a prosthesis is critical. The contoured sockets should be fitted closer to the remaining muscles, bones, and soft tissues to provide better support and relief for the patient. The pylon (shank) resembles the anatomical structure of the lower leg and is used to join the socket with the ankle foot assembly. In an endoskeletal shank of a transtibial prosthesis, a central pylon is embedded inside a foam cosmetic cover. The prosthetic components are realigned and adjusted using an endoskeletal system. In an exoskeletal shank, the hard shell which is either hallow or filed with lightweight material provides the strength for the shank. The exoskeletal systems are more durable and robust compared to endoskeletal systems; but they are heavier, and the alignment is fixed which makes adjustment difficult.

**In general, according to the level of amputation, orthopedic prostheses can be categorized as:**

**Prosthesis:** As seen in Figure 3. Prostheses again can be classified into two parts, thus are rigid and soft sockets. Rigid sockets are used to distribute the bearing loads generated during the gait cycle [9], whereas soft sockets (prosthetic liners) are parts that enclose or cover the residual limb of the patient. Mostly, they are designed to fit perfectly with a prosthesis;

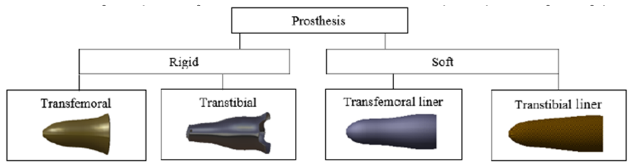


**Figure 3.** Lower limb sockets and prosthetic interface (authors' elaboration)

Orthosis: Orthoses are devices that are applied externally and used to adjust the structural and operational characteristics of the skeletal and neuromuscular system. They usually consist of a rigid socket and soft interface. The rigid socket is used for achieving the clinical goals of patients and soft interfaces are used to cushioning and distributing the pressures and efforts generated during the gait cycle. In most cases, orthoses are manufactured according to the shape of the residual limp of each patient and the degree of mobility required during the gait cycle [9]. Both orthoses' interfaces and soft prosthesis liners are permanently attached with the skin of the residual limb and are vital for patient comfort. Generally according to the International Organization for Standardization. ISO 8549-1:1989 Prosthetics and orthotics are categorized based on joints and the anatomical segments they cover as indicated in Figure 4. Rigid prosthetic sockets and external orthoses are mainly made from plastic and composite materials which are solid polymers in their final state [9].

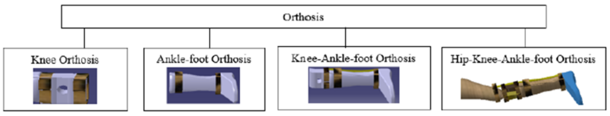


**Figure 4.** Lower limb external orthoses (authors' elaboration)

In the review of M.H. Nurhanisah 2017 et al., reported that the parts like foot, pylon, and other components are commonly purchased through the catalogs [11] and prosthetic manufacturers assembled these components by following the patient's special interest. However, the socket should be a custom made fabrication according to the patient's residual limb and it is impossible to produce the part as mass productions. Therefore, the prosthetic leg socket is the most entity and custom made component, and its importance is based on the production and functionality. Consequently, the quality of the socket has a major impact on the ability to control the prosthetic leg and on comfort for the patient. Therefore, the socket acts as a coupling between the stump and prosthesis and determines the comfort of the wearer. Hence, the materials, mechanics, and design aspects must be given attention to reassurance to the future prosthesis leg devices.

**Materials used for the production of orthoses and prosthetic devices**

The first prosthetic in the world started in ancient Egypt during 218 BC [12]. It is presently kept in a museum in Cairo, Egypt that is called "The Greville Chester Toe". It is a big prosthetic toe, fabricated from cartonnage, and is fastened onto the foot in a form similar to an Egyptian sandal. Cartonnage is a material constructed from layers of linen or papyrus wrapped in plaster [12]. The objective of prosthetics at that time was for spiritual and religious purposes. It was vital for the ancient Egyptians to keep up physical wholeness to attain spiritual wholeness during alive and in the afterlife. After centuries, in the ancient Greece and Rome civilizations, the first prosthetic device was recognized [12].

During the Dark Ages, a serious of progress was made on prosthesis when it was made for the extension soldiers' lower limb once they lose their limb in the battle and hiding deformity [12]. During the time, demand was heavy, and technology was inaccurate and most of the devices were made of wood, leather, and metal. Ambroise Pare, the one who invented both upper and lower limb prostheses have used these materials to construct prosthesis. Thus, for the first time, mechanical hand operated by mechanism was worn in the battle. Then, subsequent improvements in surgery and prosthetic science greatly enhanced amputation surgical treatment and the function of prostheses. What began as a modified walking aid (crutch) with a leather or wooden cup and improved through various metamorphoses has nowadays developed into a greatly sophisticated artificial limb made of space age materials [12].

The beginning of the 20th century saw the preamble of lightweight metals such as magnesium and aluminum and other functions design. Considering weight and impact forces that can carry much greater forces becomes the criteria for prosthesis design. Therefore, at present a variety of metals are used for orthopedics and prosthetics limbs; Aluminum, Copper, Titanium, Magnesium, Steel, and others have all been used for the load bearing structure in the past. Especially, Titanium, which was discovered in the late 18th century, has been used as the primary load bearing structure and current favorite material in the biomedical field.

The other prosthetic materials that are currently used to fabricate prostatic devices are polymers. These materials are mainly used as the load bearing structure of limbs. Phalanges, joints, and other smaller body parts are mostly made from these materials. Polymers are common materials for the smaller components or specialized features of prostheses. Conventional polymers that are used as raw materials for prosthetic manufacturing are polyoxymethylene (POM), pliable polyurethane (PU), and polyvinyl chloride (PVC). Polyoxymethylene is a hard polymer, whereas pliable polyurethane is much softer. The detailed classifications of prostheses and orthoses materials are detailed in Table 1.

| Polymers used for orthoses and lower limb prostheses | | | |
|---|---|---|---|
| **External orthoses and prosthetic devices (Rigid sockets)** | | **Liners for prostheses and orthotic devices (Soft sockets)** | |
| **Thermoplastic** | **Thermostable** | **Thermoplastic** | **Elastomer** |
| -High and low-density polyethylene (PE) Nylon & Teflon<br>-Polymethyl methacrylate (PMMA)<br>-Polypropylene (PP), Nylon6,<br>-Polyethylene & - Formaldehyde (CH2O) terephthalate (PET)<br>-Polyvinylchloride (PVC). | -Unsaturated polyester resin<br>-Epoxy resin<br>-Vinyl ester resin | -Polyurethane (PU)<br>-Plastazote<br>-Pelite | -Silicone (Silicone gel, & elastomer) |

**Table 1.** Polymer material for prostheses and Orthoses application

Waterproof prosthetic devices are made in larger quantities from polyethylene plastic which is a more flexible form of plastic [12]. PVC has emerged in the early part of the 20th century, and it was one of the most significant plastics. Polyvinyl chloride is used as a coating material, and it is very stable but has a restricted color range. When PVC is exposed to heat and light, it is unstable and requires the addition of stabilizers [12].

Carbon fibers developed in the 20th century when engineers and medics were looking for a strong and lighter load bearing material. Some of the mechanical properties of carbon fibers are high tensile strength, high stiffness, low weight, high temperature tolerance with low thermal expansion, high chemical resistance, high specific elastic modulus, and strength. It is very strong even it can carry a heavyweight amputee. Materials with a high modulus of elasticity are usually not very ductile. For instance, the specific modulus of elasticity of wood is equivalent to that of steel, titanium, magnesium, or aluminum, whereas carbon fiber reinforced polymer composites is about three times as high as wood. Carbon fiber reinforced polymer matrix composites also have high specific compressive and tensile strengths, as well as approachable elastic deformation [12] but carbon fiber is expensive compared to other materials with similar properties.

Other supporting materials used in prosthetics are glass fiber, Kevlar, Spenco, Nickel plast, Poron, and Nylon reinforced silicone, to name a few. These materials are all mostly used and have been cautiously tested and selected based on their resistance during compression testing [9,12]. Nevertheless, Nylon reinforced silicone composite prostate was not tested for the reason that it gets to crack when a shear load is applied. Since Spenco becomes very thin after short term loading, it was impossible to test the material [12].

The other recent materials that are used as prosthetic devices are natural fiber [6,11-17]. Natural fiber materials are popular and used as multipurpose materials in orthopedics. Especially natural fiber based polymer composites have been reported to possess exceptional strength to weight ratio, high impact resistance, and superior biocompatibility [6]. Prosthetic sockets that are produced from these materials have good strength and comfort for the wearer [11,13]. Some of the materials that are used as prosthetic materials are ramie fiber reinforced composite, bamboo fiber composite, rattan fiber composite, and banana composite materials [11,13-15,18].

## Review on Prostheses Development

Many significant types of research have been performed with synthetic and natural fibers to develop fiber reinforced polymer matrix composites for the application of lower limb prosthetic sockets. Andrew I Campbell et al. reviewed some natural fibers for prosthetic socket applications and showed their inimitable advantages over other materials, like non-corrosive in nature, high strength to weight ratio, renewability, high fracture toughness, and sustainability [10]. Researchers [13-15,19] revealed good mechanical properties with Ramie, pineapple, and Banana fiber reinforced polymer matrix composites for prosthetic socket applications and hence, partially replaced metals, plastics, and synthetic fiber polymer matrix composite part of the prosthesis.

Banerji and J.B. Banerji (1984) studied the use of bamboo and cane trunks as basic construction of prosthetic and orthotic device. They used field trials to prove the viability of the materials and found; cane and bamboo are very viable alternative materials for orthotic/prosthetic appliances and rehabilitation. Among the rehabilitation aids, they found wheelchairs, walkers, and crutches are remarkably useful and cheap. They also tried these materials for the construction of lower leg prostheses, but they didn't prove these prostheses experimentally.

M.H. Nurhanisah et al. (2017) reviewed the analysis and the numerical modeling of the prosthetic socket design related to the thermal comfort on the socket. They reported that the largest areas of elevated temperature were found at the lateral and posterior sides as well as at the distal end of the stump. The researchers proposed natural fiber based biocomposite materials for the development of a prosthetic socket due to the biocompatibility of these materials with the skin [11].

Polyester composite finally, tensile and flexural tests were applied to a specimen. The result observed from the ramie fiber reinforced epoxy composite prosthesis socket was with the highest tensile and flexural strengths compared to ramie fiber polyester resin and Agustinus Purna et al. (2015) studied the characteristics of Rattan fiber reinforced epoxy composite prosthesis, and they developed a prototype of lower leg prosthetic socket made from Rattan Fiber Reinforced Epoxy Composites. To assure the durability and the comfortability of the prosthesis, they did three tests as the compressive, failure test, and gait analysis by using the Six Minute Walk Test Method (6MWT) and psychophysical analysis by measuring the pulse rate of the respondents before and after gait analysis. Finally, they found a prosthetic socket that can carry a compressive load of more than 4KN, (almost equal to the ISO 10328 standard suggested for prosthetic socket test) with deflection of 1 mm and low pulse rate compared to the former synthetic prostheses which indicate, the lower leg prosthesis is comfortable for the patient [20].

Andrew I Campbell et al. (2012) investigated the feasibility of natural fiber reinforced plant oil reinforced resin matrix composite prosthetic socket. They collected different available natural fiber materials and prepared specimens for mechanical testing and using an Instron 5800 tensile test machine, they determined the tensile strengths of the test pieces and found ramie fiber with high strength compared to other natural fibers. Lastly, they manufacture the ramie fiber reinforced oil plant resin composite lower limb prosthetic socket prototype according to ISO 22523 and obtained a strong prosthesis socket that exceeds the ISO 10328 standard requirement of structural testing for lower limp prosthesis [10].

A.P. Irawan et al. (2011) developed a ramie fiber reinforced epoxy resin composite prosthetic socket to replace the conventional prosthetic socket made from synthetic fiber reinforced composite Ramie fiber reinforced epoxy and polyester resin composite prototypes were produced by filament winding whereas, fiberglass polyester resin composite prototype by hand layup technique. The three test specimens were prepared by chopping from prosthesis socket prototypes made of ramie reinforced epoxy composite, ramie fiber polyester composite, and fiberglass reinforced fiberglass reinforced polyester resin composite materials with grater mechanical properties required by the ISO10328 standard [21].

Agustinus Purna Irawan et al. (2018) used promal composite software to analyze the failure mode of Ramie fiber reinforced epoxy resin composite material and validated the Ansys result experimentally (tensile and compression test) using a universal testing machine and Scanning Electron Microscope (SEM). The result showed the composite would not fall at 00 fiber orientation but in other angles of fiber orientation, the failure probability increases. The morphology analysis resulted from SEM showed, the failure was stimulated due to voids, fiber matrix interaction, and initial crack [18].

Abbas (2020) used finite element method to know the fatigue characteristics of the composite used to make a prosthetic socket above the knee after determining the ultimate strength of the composite using tensile and fatigue tests. For the experiment, two groups of composite specimens were manufactured with a sequence of layer N glass, carbon fiber, N glass from lamination resin 80:20 (group 1) and siegalhaz resin as a matrix (group 2) material respectively through vacuum pressure molding technique [19]. From ANSYS simulation the prosthetic socket manufactured from N glass, Carbon fiber, N glass with siegalhaz resin matrix composite (group 2) was found to be safer than group 1 which is produced from lamination resin 80:20. This indicates siegalhaz resin has better sticking properties than 80:20 [19].

Agustinus and Sukania (2015) developed banana fiber reinforced epoxy composite material for prosthesis application. The volume fraction of the samples was 10%, 20%, 30%, 40%, and 50% with 0/90 degree fiber orientation. After produced the sample via compressing and vacuum processes technique, tensile teste is done by a universal testing machine under ASTM D 3039 standard. The result obtained indicates, the tensile strength of the banana fiber reinforced epoxy resin composite is in the middle range of glass fiber epoxy resin composite. To be exact, banana fiber reinforced epoxy resin composite is (62.3 ± 0.67) MPa, whereas glass fiber reinforced epoxy resin composite is 60-109 MPa [22].

Saif M. Abbas and Ammar I. Kubba (2020) carried out the study by using finite element modeling and experimental test to develop a prosthetic socket for chopart amputation. The specimens were prepared from three types of composite fibers: Perlon (p), glass fiber (f), and carbon fiber (c) with a different combination. The sequences of the layup of the fibers in the composite were, for groups 1, 2, and 3 are 3p, 2c, 3p; 3p2f3p, and 6p respectively. The experimental test result from these composite prosthetic socket materials was used for finite element simulation [23]. The result obtained from finite element simulation indicates, group 1 with 3p2c3p staking sequence is more strong, durable, and safe.

Kahtan Al Khazraji et al. (2011) studied the effect of particle reinforcement on fatigue characteristic of the transtibial prosthetic socket. To validate the results, five samples with different stacking sequences were prepared using vacuumed molding method [24]. From the experimental test and ANSYS result, they obtained the hybrid (carbon+glass) fiber composite socket material with better tensile strength and fatigue compared to particle reinforced hybrid (carbon+glass) fiber composite and others.

Rajnish Kumar et al. (2017) studied "the effect of kenaf fiber length with constant fiber loading on dynamic mechanical properties and its effect on loss modulus, storage modulus" [25]. The samples were prepared with compression molding technique from different fiber lengths and volume fractions with epoxy resin by completely mixing the fiber with a resin after treated the fiber with NaOH. Tensile, three bendings, and SEM tests were carried out using a universal testing machine. The result obtained indicates that the tensile and the young's modulus of the composites increases with an increase in fiber length and volume fraction as indicated. The fractography of the fiber matrix interface observed from SEM after tensile fracture showed deboning of fiber and matrix in the composite. This is because the folding of long fiber occurred in the sample. Also, the storage modulus decreases as temperature increases with a decrease in fiber length.

J. K. Odusote (2016) investigated the mechanical properties of pineapple leaf fiber reinforced epoxy resin composites as an alternatives material to replace the above knee glass fiber reinforced prosthetic socket. The study was carried out at ASTM standard using a universal testing machine to know the ultimate tensile strength, flexural and impact strength of the material. After treated the pineapple leaf fibers with sodium hydroxide and acetic acid, the fibers were mixed to epoxy and polyester resin at varying fiber loadings and produced specimens by using hand lay-up method. At the end, the mechanical strength of the pineapple fiber reinforced epoxy resin composite compared with 30% Glass fiber reinforced epoxy composite which has 65.72+_3.3 Mpa ultimate tensile strength and 7.3 elongations. The result obtained implies pineapple reinforced epoxy composite at 40% fiber loading has better tensile and flexural strength with minimum elongation. This minimum elongation of pineapple fiber reinforced epoxy composite gives more comfort for the wearer compared to glass fiber reinforced polyester composite [14].

Jamiu K. Odusote et al. (2016) studied the mechanical properties of banana fiber reinforced epoxy composite as a replacement for transtibial prosthetic socket. After the treatment of the continuous fibers with NaOH and acetic acid solution, the samples were prepared manually using a hand lay-up method with different fiber ratios. A universal testing machine was used to carry out the test according to ASTM standards. The result showed banana pseudostem composite had superior mechanical strength than glass fiber composite, as banana pseudostem fiber at 40 and 50% fiber loading with epoxy resin were higher than 30% glass fiber loading with polyester resin [15].

Agustinus Purna Irawan et al. (2016) investigated the mechanical characteristics of rattan reinforced fiberglass epoxy composites for shank prosthesis application. The objective of the study was to develop hybrid reinforced rattan fiber with fiberglass epoxy resin materials to enhance the mechanical strength especially in compressive, tensile, and flexural, impact strength that can be used as an alternative prosthetic material for shank prosthesis application. The method used to make the endoskeletal composite material was by using a layup process of fiberglass with rattan fiber and epoxy resin. After producing the prototype, Universal Testing Machine was used to determine the maximum strength of the composite produced from rattan and rattan glass fiber reinforced epoxy composite. The result obtained shows the prototype produced from rattan glass fiber reinforced epoxy resin composite has better mechanical results compared with pure rattan fiber reinforced epoxy composite [13].

Sulardjaka et al. (2020) investigated the mechanical strength of water hyacinth fiber methyl methacrylate polyester resin composite for socket prosthesis application [17]. The sample was produced by hand layup method in the mold prepared according to ASTM D 3039. A servopulser tensile test machine was used to determine the tensile strengths of the test pieces. NyGlas fiber reinforced composite material was used for comparison. The result obtained indicates water hyacinth with 00 fiber orientation and reinforced with nanoparticle has better tensile and compressive strength compared to nyglass fiber reinforced methyl methacrylate polyester resin composite.

Muhsin J. Jweeg (2020) used numerical simulation software to investigate the Nano effects on stress distribution in a Below Knee Prosthetic socket. Four synthetic fiber reinforced lamination composite prosthetic sockets combined with different weight fractions of Nano material composition were model. The simulation result showed synthetic fiber reinforced prosthetic socket combined with SiO2 Nanoparticles generate reduced stress distribution and deformation compared to prosthetic socket model made from synthetic fiber reinforced composite material without the combination of Nanoparticles [26].

Santosh Kumar et al. (2020) investigated the viscoelastic properties of Flax Ramie fiber reinforced bio epoxy (formuLITE) resin composite for the application of bone grafting and Orthopedic Implants [8]. The three samples were fabricated from ramies, flax, and Flax/Ramie hybrid reinforced bio epoxy composite with three different volumes fraction by hand layup technique. After a mechanical test using a universal testing machine, the strength of the composite was compared. The natural composite with 15% Flax and 15% of Ramie showed better mechanical properties, such as tensile modulus and compressive modulus which is closer to cortical bone.

Jeetendra Mohan Khare (2020) studied the influence of different types of resin at a constant weight of glass fiber with varied hybrid jute and grewiaoptiva fiber loading reinforced epoxy, vinyl ester, and polyester matrix to fabricate a prosthetic limb [27]. After preparing the samples using the hand layup technique, they perform mechanical testing. The result obtained showed; the tensile, flexural strength and hardness of the composite get improved as the ratio of natural fiber increases in an epoxy based hybrid composite.

Agustinus Purna Irawan (2016) studied the mechanical characteristics of Rattan Reinforced Fiberglass and Epoxy Resin Composites. The objective of the study was to produce an alternative material for shank Prosthesis Application [13]. The samples were prepared with hand layup technique and the mechanical strengths (tensile, compressive, and flexural strength) were tested using a universal testing machine. The result obtained showed the hybrid glass/rattan fiber reinforced composite was increased in strength compared with rattan without lamination and less costly and more comfortable with glass fiber reinforced epoxy resin composite end skeletal shank prosthesis.

## Conclusion

The development of prosthesis started in the 218th B.C from an era of an ancient Egyptian prosthesis called "The Greville Chester Toe". Since then, for centuries, different prostheses were made from specific types of wood or leather after they were shaped, stitched, and sealed into the form of the prosthesis to replace the missed part of the body. At that time the aim of the prosthesis was only to withhold the opportunity of reinstating functional inabilities to people with amputations. Later to increase the functionality, durability, and aesthetic value of the prosthesis, the researchers developed prostheses from metals, polymers, and plastic materials. But these materials are extremely costly and uncomfortable. Most of the wearers remove the prosthesis made from these materials due to stress shielding occurred on the skin of the residual limb. Different studies were conducted to solve the problems regarding the cost and comfort issue by providing a variety of prostheses. Studies showed synthetic fiber like carbon fiber, E glass, and Kevlar fiber can be made strong and durable by adding Nanoparticles; but they are more costly, stiff, and rigged for prosthetic socket application. Nowadays, because of the advanced technology and inventions, it can be possible to produce prostheses from hybrid synthetic/natural and natural fiber reinforced polymer with different volume of fraction and types of resin matrix composites to provide cheap prostheses for those civilians who couldn't be capable to wear costly synthesized composite or metal prosthesis, especially in developing country. Studies also showed a selection of material is not only concerned with operational requirements for prosthesis but also the expense of the materials, availability of materials, manufacturing processes, maintenance, and the measure of aesthetic value is very important. Due to these reasons, different researchers have paid close attention to prosthetic socket development and currently, they can produce these devices from a biodegradable natural fiber reinforced composite material such as Ramie, pineapple, Retain, and Banana fiber reinforced polymer matrix composites. Studies have shown that when up to 40% of these fibers are added to the bio epoxy resin, the combined mechanical strength is equal to or better than that of glass fiber reinforced polymer composites Thus, prostheses made from these composite materials can replace metals, plastics, and synthetic fiber polymer matrix composite prostheses. In general, It can be understood natural fiber reinforced composite prosthetic sockets are less stiff and more comfortable for patients. So giving more attention to artificial limb development will allow the wearers to find coast effective, comfortable, and affordable prostheses easily. Therefore, with the help of specialists, innovative designs, and new measuring instruments, there is a possibility to come up with a better solution for socket design and suspension systems.

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