"Advancements in Assistive Technology: Myoelectric Elbow-Wrist-Hand Orthosis Fabrication Using 3D Printing Technology"

BACKGROUND AND OVERVIEW

Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO) is a revolutionary assistive device designed to provide enhanced functionality and independence to individuals with upper limb disabilities. This abstract provides an overview of the key features, working principles, and potential benefits of the MEWHO.

The MEWHO is a custom-designed orthotic device that utilizes advanced myoelectric technology to detect and interpret the user's residual muscle signals from the forearm. These signals are then translated into precise movements, allowing the orthosis to mimic natural joint motions of the elbow, wrist, and hand. The system's sophisticated sensors and algorithms enable seamless and intuitive control, making it a user-friendly and efficient tool for daily activities.

The key components of the MEWHO include an elbow joint with adjustable flexion and extension, a wrist joint providing pronation and supination, and a multi-articulated hand with finger flexion and extension capabilities. The device is lightweight, durable, and comfortable to wear, encouraging prolonged use and minimizing fatigue for the user.

The primary application of the MEWHO is to assist individuals with conditions such as brachial plexus injury, spinal cord injuries, stroke. By restoring hand dexterity, enabling object manipulation, and supporting various grasping patterns, the orthosis empowers users to perform a wide range of activities, from simple tasks like eating and dressing to more complex actions involving tools and instruments.

In addition to enhancing functional independence, the MEWHO has shown promising results in rehabilitative settings. It can be used as a valuable tool for upper limb rehabilitation, promoting motor learning, and providing proprioceptive feedback to the user. Therapists can customize the orthosis settings to suit individual needs, tailoring the training process for optimal outcomes.

Despite its many advantages, the MEWHO also faces some challenges, such as cost, availability, and the need for skilled training for both users and caregivers. However, ongoing research and advancements in technology are continuously addressing these limitations, making myoelectric orthoses increasingly accessible and affordable.

In this chapter, we have tried to propose a novel 3D-printed Elbow wrist hand orthosis that is controlled by electromyography (EMG) signals.

In conclusion, the Myoelectric Elbow-Wrist-Hand Orthosis represents a significant step forward in the field of assistive technology, offering a comprehensive solution for individuals with upper limb disabilities. As the device evolves and becomes more widely available, it holds the promise of transforming the lives of countless individuals, granting them newfound independence and a higher quality of life.

KEYWORDS

Myoelectric Elbow-Wrist-Hand Orthosis, Upper limb disabilities, Residual muscle signals, Joint motions, Lightweight, Durable, Comfortable, Brachial plexus injury, Spinal cord injuries, Stroke, Object manipulation, Grasping patterns, Functional independence, Upper limb rehabilitation, Motor learning, Proprioceptive feedback, Cost, Availability, Skilled training, Assistive technology.

OBJECTIVES

The objectives of the chapter on myoelectric elbow-wrist-hand orthosis made using 3D printing technology are as follows:

1. Provide an Introduction to 3D Printing in Orthotics: The chapter aims to introduce the concept of 3D printing technology and its relevance in the field of orthotics, highlighting the unique capabilities and advantages it offers in designing and fabricating myoelectric elbow-wrist-hand orthoses.

2. Explain the Need for Customization: The chapter will emphasize the importance of customization and personalization in orthotic devices, specifically in the context of myoelectric elbow-wrist-hand orthoses. It will discuss how 3D printing enables the creation of patient-specific orthoses to ensure a better fit and improved functionality.

3. Discuss the Design Process: The chapter will detail the steps involved in designing a myoelectric elbow-wrist-hand orthosis using 3D printing technology. This includes aspects such as patient assessment, 3D scanning, computer-aided design (CAD) modeling, and integrating myoelectric sensors and actuators into the design.

4. Explore Material Selection: The chapter will delve into the different materials available for 3D printing and their suitability for myoelectric orthotic devices. It will discuss the importance of choosing biocompatible, lightweight, and durable materials for optimal patient comfort and safety.

5. Present Case Studies and Clinical Applications: To showcase the real-world application of 3D printed myoelectric elbow-wrist-hand orthoses, the chapter will present relevant case studies and experiences of patients who have benefited from these customized devices. It will highlight the positive impact on their functional independence and quality of life.

6. Address Advancements and Innovations: The chapter will explore recent advancements and innovations in 3D printing technology for

myoelectric orthotics. It may cover topics such as multi-material printing for complex hand articulations, integrating sensory feedback systems, and exploring the potential of soft robotics.

7. Discuss Cost-Effectiveness and Accessibility: The chapter will assess the cost-effectiveness of 3D printed myoelectric orthoses compared to traditional manufacturing methods. It will also discuss how local production using 3D printing technology can enhance accessibility and reduce waiting times for patients.

8. Evaluate Challenges and Future Directions: The chapter will identify and evaluate potential challenges and limitations associated with 3D printing myoelectric orthotic devices. It will also discuss ongoing research efforts and future directions to overcome these challenges and further enhance the technology.

9. Offer Recommendations and Guidelines: Based on the findings and discussions, the chapter will provide recommendations and guidelines for clinicians, researchers, and practitioners regarding best practices for designing, fabricating, and fitting 3D printed myoelectric elbow-wrist-hand orthoses.

10. Conclusion: The chapter will summarize the key takeaways and implications of utilizing 3D printing technology in the field of myoelectric orthotics. It will underscore the potential of this technology in revolutionizing orthotic care and improving the lives of individuals with upper limb disabilities.

INTRODUCTION

The Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO) stands at the forefront of innovative assistive technologies, offering a ground breaking solution for individuals with upper limb disabilities. As advancements in medical science and technology continue to transform the landscape of rehabilitative and assistive devices, the MEWHO represents a significant milestone in empowering individuals to regain functional independence and enhance their quality of life.

Upper limb disabilities, resulting from various conditions such as spinal cord injuries, stroke, or congenital limb deficiencies, can severely limit an individual's ability to perform essential daily activities and impede their overall autonomy. Traditional orthotic solutions have addressed some of these challenges, but they often fall short in providing the level of precise control and natural movement that users seek.

The MEWHO takes a transformative approach by integrating myoelectric technology into a sophisticated orthotic design. By harnessing the residual muscle signals present in the forearm, the MEWHO can accurately interpret the user's intended movements, effectively translating them into seamless actions of the elbow, wrist, and hand joints. This myoelectric control mechanism allows for more intuitive, fluid, and natural movements, closely resembling the motions of a fully functioning limb.

As we delve deeper into the world of the Myoelectric Elbow-Wrist-Hand Orthosis, it becomes evident that this assistive device has the potential to revolutionize the lives of countless individuals, enabling them to reengage in everyday tasks, pursue vocational opportunities, and participate more actively in social interactions. By blending cutting-edge technology with human-centric design, the MEWHO opens new avenues for progress and independence, propelling the field of assistive technology toward a brighter, more inclusive future.

Advancements in assistive technology have revolutionized the lives of individuals with upper limb disabilities, providing them with newfound independence and improved quality of life. Among these innovations, the Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO) stands out as a remarkable solution designed to restore functional capabilities and enhance the daily activities of users with impaired upper limb functions.

3D printing technology offers unprecedented flexibility in fabricating complex geometries and customizable components, making it an ideal manufacturing process for the MEWHO. The orthosis is tailored to each user's specific anatomical measurements and functional requirements, ensuring optimal fit, comfort, and performance.

The core components of the MEWHO, including the elbow joint, wrist joint, and multi-articulated hand, are intricately crafted using 3D printing techniques. The integration of sensors and myoelectric electrodes is seamlessly incorporated into the design, enabling accurate detection and interpretation of the user's residual muscle signals to control the orthosis intuitively.

The use of lightweight and durable materials in 3D printing ensures the orthosis is ergonomic and easy to wear for extended periods, reducing fatigue and discomfort for the user. The aesthetic appeal of the MEWHO is also considered, promoting acceptance and confidence during its use in various social settings.

The advantages of 3D printing extend beyond the manufacturing process. Rapid prototyping allows for efficient design iterations and continuous improvement, accelerating the development of future iterations and personalized upgrades for individual users. Additionally, 3D printing enables cost-effective production, addressing affordability concerns associated with custom-made orthotic devices.

Preliminary studies evaluating the usability and effectiveness of the 3D printed MEWHO have shown promising results in terms of enhanced functional independence, improved grasping capabilities, and increased user satisfaction. The personalized nature of the orthosis has facilitated a more profound integration into the user's daily activities and has showcased its potential as an invaluable tool for upper limb rehabilitation.

While 3D printing technology holds immense promise for the MEWHO, challenges remain, including the need for further research, refinement of materials, and optimization of printing processes. Additionally, addressing regulatory considerations and standardization in 3D printed medical devices is vital for wider clinical adoption.

In conclusion, the integration of 3D printing technology into the development of the Myoelectric Elbow-Wrist-Hand Orthosis marks a significant milestone in the field of assistive technology. This personalized and versatile orthosis offers a transformative solution, elevating the functional capabilities and overall quality of life for individuals with upper limb disabilities. As 3D printing technology continues to evolve, the future holds immense potential for even more sophisticated and accessible orthotic solutions.

NEED FOR THE STUDY:

In some critical cases like diplegia due to stroke where person's upper limbs get paralyzed, to overcome this we can harness signals from the part which is in normal state and try to coordinate with it for paralyzed part to give the mobility and stability to it.

Spinal cord injury (SCI) is a major disorder that causes sensory, motor, and autonomic dysfunction in parts of the body served by the spinal cord below the level of injury. Unfortunately, there is no treatment to completely recover the functional status for patients with SCI at present.

Brachial plexus injury (BPI) is one of the most devastating injuries from the point of view of the patient. It effectively cripples function in one and rarely two upper limbs, causing significant loss of function and ability to perform tasks of daily living as well as delivering in his/her workplace. Potentially this can lead to unemployment, economic hardship, depression and in rare instances even suicidal urges.

Three-dimensional (3D) printing is a computer-aided manufacturing method that can create 3D objects using various materials such as plastic, metal, liquids, or even living cells.

As technology develops, the desire for new hand orthoses is growing. Myoelectric hand orthosis using 3D printing that provides functional grip for patients with cervical SCI and Brachial plexus injury (BPI) using the tenodesis principle.

By using 3D printing technology, we could manufacture a low-cost orthosis suitable for each individual while maintaining essential functionality.

FACTORS TO CONSIDER BEFORE PRESCRIBING MEWHO

Prescribing a myoelectric elbow-wrist-hand orthosis (MEWHO) requires careful consideration of various factors to ensure its appropriateness, effectiveness, and user satisfaction. Some key factors to consider before prescribing a MEWHO are:

1. Medical Diagnosis: Assess the underlying medical condition that necessitates the orthosis. Determine if the user's upper limb disability is suitable for myoelectric orthotic intervention, such as spinal cord injuries, stroke, congenital limb deficiencies, or other neurological conditions affecting motor control.

2. Level of Upper Limb Impairment: Evaluate the extent of impairment in the elbow, wrist, and hand joints. MEWHO is most beneficial for individuals with moderate to severe impairment who have some residual muscle activity that can be used to control the orthosis.

3. Functional Goals: Clearly understand the user's functional goals and expectations from the orthosis. Different MEWHO models offer varying degrees of dexterity and features, so it's crucial to match the device's capabilities to the user's specific needs.

4. User's Cognitive and Psychological Status: Assess the user's cognitive abilities and psychological readiness to use a myoelectric orthosis. Training and adapting to this technology may require motivation, patience, and active participation from the user.

5. Muscular Residual Signal: Determine if the user has sufficient residual muscle activity to control the myoelectric sensors effectively.

Some individuals with severe muscle atrophy or very limited muscle activity may not be suitable candidates for a MEWHO.

6. Skin Condition: Check the skin condition of the user's arm. A myoelectric orthosis requires good skin health and sensitivity since it involves direct contact with the skin through electrodes and sensors.

7. Training and Skill Development: Consider the user's ability and willingness to undergo training and skill development to effectively control the orthosis. Adequate training and practice are crucial for optimal use and to harness the full potential of a MEWHO.

8. Occupational and Lifestyle Considerations: Assess the user's daily activities and occupation to ensure that the MEWHO will be a practical and beneficial tool in their routine. Different professions and activities may have varying demands on the orthotic device.

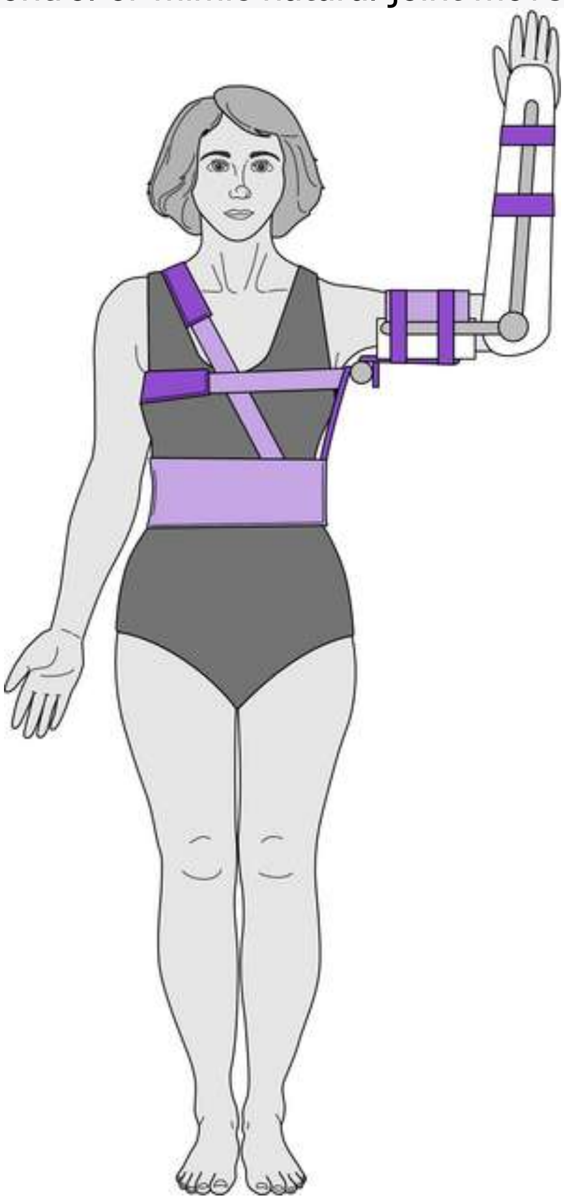
9. Cost and Insurance Coverage: Evaluate the cost of the MEWHO and the availability of insurance coverage or funding options for the user. Myoelectric orthoses can be relatively expensive, and ensuring financial feasibility is essential.

10. Follow-up and Support: Plan for ongoing follow-up and support to monitor the user's progress, make necessary adjustments, and address any concerns or issues that may arise during the use of the orthosis.

By carefully considering these factors, healthcare professionals can make informed decisions and prescribe the most suitable myoelectric elbow-wrist-hand orthosis that best meets the user's needs and enhances their functional independence.

ORTHOTIC INTERVENTIONS BEFORE MYOELECTIC ELBOW-WRIST-HAND ORTHOSIS.

1. Conventional Elbow-Wrist-Hand Orthosis: Traditional orthoses used in the past were typically rigid, non-powered devices designed to provide support and stability to the upper limb. They often lacked the ability to enable fine motor control or mimic natural joint movements.



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2. Body-Powered Orthoses: Body-powered orthoses relied on cables and harnesses attached to other parts of the body, such as the opposite shoulder, to activate the movements of the elbow, wrist, and hand. The user would engage their body's movements to control the orthosis.

It's important to note that the design and capabilities of these previous orthotic interventions may have varied significantly, and advancements in technology have likely improved their effectiveness over time. The MEWHO represents the culmination of research and development efforts to create a more sophisticated, compact, and user-friendly myoelectric orthosis with enhanced functionality and control capabilities.

3D PRINTING TECHNOLOGY IN ORTHOTICS

The field of orthotics has witnessed significant advancements in recent years, with the introduction of 3D printing technology revolutionizing the design and fabrication of assistive devices. In particular, 3D printing has shown immense promise in the development of myoelectric elbow-wrist-hand orthoses (MEWHOs), offering a patient-centric approach that emphasizes customization, efficiency, and improved functional outcomes. This chapter explores the application of 3D printing technology in orthotics, specifically focusing on the design and development of myoelectric elbow-wrist-hand orthoses.

CHALLENGES IN CONVENTIONAL ORTHOTIC DESIGNS

Conventional orthotic designs, while effective for many patients, do face several challenges that can limit their functionality and patient satisfaction. Some of the key challenges in conventional orthotic designs include:

1. One-Size-Fits-All Approach: Conventional orthotic devices often follow a standardized design, which may not accommodate the unique

anatomical variations and functional needs of individual patients. This can lead to discomfort and inadequate support for some users.

2. Limited Customization: Due to the constraints of traditional manufacturing methods, customization options for conventional orthoses are often limited. Patients may not receive the level of personalization required for optimal fit and performance.

3. Cumbersome and Bulky: Some conventional orthotic devices can be bulky and cumbersome, hindering natural movement and causing discomfort during prolonged use. The weight and size of these devices may limit their practicality and acceptance in daily activities.

4. Lack of Aesthetics: Many conventional orthotic designs are functional but lack aesthetic appeal. The appearance of orthotic devices can impact a user's self-esteem and social acceptance, leading to decreased compliance with wear.

5. Difficulties in Joint Articulation: Certain conventional orthoses may struggle to replicate natural joint movements accurately. This limitation can hinder activities requiring fine motor control and precision, such as grasping small objects or typing.

6. Durability and Longevity: Traditional orthotic materials may not always be as durable as desired, leading to wear and tear over time. Frequent replacements can be costly and inconvenient for patients.

7. Skin Irritation and Hygiene Concerns: Conventional orthotic devices often have limited breathability and may cause skin irritation, especially in areas of prolonged contact. Maintaining hygiene and preventing skin issues can be a challenge for some users.

8. Limited Functionality: Some conventional orthoses may be designed to address specific impairments but lack versatility to cater to a broader range of activities. This can limit the user's ability to perform various tasks effectively.

9. Cumbersome Adjustment Process: Making adjustments to conventional orthotic devices may require multiple visits to the healthcare provider, leading to delays in achieving an optimal fit and function.

10. Cost and Accessibility: Customized conventional orthoses can be expensive, making them less accessible to individuals with limited financial resources or inadequate insurance coverage.

Addressing these challenges is essential to improving the effectiveness and user experience of orthotic devices. The integration of 3D printing technology in orthotics holds the promise of overcoming many of these limitations by offering personalized, lightweight, and more functional orthoses, such as myoelectric elbow-wrist-hand orthoses.

ADVANTAGES OF CUSTOMIZATION IN MEWHOs

Customization in myoelectric elbow-wrist-hand orthoses (MEWHOs) offers numerous advantages that significantly enhance their functionality, comfort, and overall effectiveness. Some of the key advantages of customization in MEWHOs include:

1. Optimal Fit: Customized MEWHOs are designed based on the patient's unique anatomical measurements and functional needs. This ensures an exact fit to the individual's arm, minimizing pressure points, discomfort, and the risk of skin irritation.

2. Enhanced Functionality: Customization allows orthotists to tailor the MEWHO to the user's specific impairment and functional goals. This results in improved joint alignment, optimal range of motion, and precise control over the orthosis, facilitating more natural and efficient movements.

3. Improved Grasping and Manipulation: Customized MEWHOs can be designed to accommodate individual hand shapes and grasping patterns. This level of customization enables users to achieve a more secure and functional grip on objects, enhancing their ability to perform various activities of daily living.

4. Personalized Control System: Myoelectric sensors in MEWHOs detect residual muscle signals to control the movements of the orthosis. Customization allows the control system to be tailored to the user's

unique muscle signal patterns, optimizing the accuracy and responsiveness of the orthosis.

5. Comfort and Compliance: A well-fitted and customized MEWHO is more comfortable to wear, leading to improved patient compliance and long-term usage. Patients are more likely to incorporate the orthosis into their daily routines when it is tailored to their individual needs and preferences.

6. Aesthetics and Social Acceptance: Customization can address aesthetic concerns, allowing the MEWHO to match the user's preferences and blend seamlessly with their clothing and appearance. This fosters increased social acceptance and confidence in public settings.

7. Faster Rehabilitation and Adaptation: MEWHOs that are personalized to the user's specific rehabilitation goals and activities can accelerate the learning and adaptation process. Users are more likely to achieve functional gains and independence quicker with a customized orthosis.

8. Efficient Use of Resources: Customization reduces wastage of materials and resources by producing orthoses that precisely fit the patient's needs. This can lead to cost savings in the long run by minimizing the need for repeated adjustments or replacements.

9. Versatility and Multi-Functionality: Customized MEWHOs can be designed to support multiple functions, such as switching between different grasp patterns or accommodating specific tasks in the user's daily life. This versatility enhances the orthosis's usability in diverse scenarios.

10. Empowerment and Independence: Customized MEWHOs empower users to regain control over their upper limb functions, fostering a sense of independence and improving their overall quality of life.

In conclusion, customization in myoelectric elbow-wrist-hand orthoses offers a host of advantages that go beyond traditional, off-the-shelf orthotic solutions. By tailoring the orthosis to meet individual needs, patients erxperience improved functionality, comfort, and confidence in their daily activities, ultimately leading to better outcomes and greater patient satisfaction.

Software used for 3D modeling –

For 3D modeling of the orthosis we used SOLIDWORKS Software.

SOLIDWORKS is a widely used computer-aided design (CAD) and computer-aided engineering (CAE) software suite developed by Dassault Systèmes. It is renowned for its powerful 3D modeling, simulation, and design capabilities, making it a staple tool for engineers, designers, and manufacturers across various industries. SOLIDWORKS offers a comprehensive set of features and tools for product development, prototyping, and simulation. Here are some key aspects of SOLIDWORKS:

Features and Capabilities:
1. 3D Modeling: SOLIDWORKS provides robust tools for creating detailed 3D models of parts and assemblies. Users can generate complex geometries, surfaces, and parametric models.

2. Assembly Design: Users can create and manipulate assemblies by combining individual parts, ensuring that components fit together correctly and analyzing how they interact.

3. Sheet Metal Design: The software includes features tailored for designing sheet metal parts, such as bends, flanges, and hems.

4. Surface Modeling: SOLIDWORKS supports both solid and surface modeling, allowing users to create intricate curved surfaces and Class-A surfaces for aesthetic design.

5. Simulation and Analysis: SOLIDWORKS Simulation enables engineers to analyze designs for strength, durability, and performance under various conditions.

6. Motion Analysis: Users can simulate the motion of assemblies to assess mechanisms, detect interferences, and optimize motion paths.

7. Rendering and Visualization: SOLIDWORKS Visualize helps create photorealistic renderings and animations, aiding in product presentations and marketing materials.

8. Electrical and PCB Design: SOLIDWORKS Electrical allows for the creation of electrical schematics and integration with mechanical designs. SOLIDWORKS PCB facilitates printed circuit board design.

9. CAM Integration: SOLIDWORKS CAM enables users to generate toolpaths for machining directly within the software.

10. Data Management: SOLIDWORKS PDM (Product Data Management) helps manage and organize design data, ensuring version control and collaboration.

11. Additive Manufacturing: SOLIDWORKS supports 3D printing and additive manufacturing workflows, facilitating the design of parts optimized for additive processes.

Benefits:

1. Ease of Use: SOLIDWORKS offers an intuitive user interface and workflow, making it accessible to both beginners and experienced professionals.

2. Parametric Modeling: Parametric features allow users to create designs that can be easily modified and updated, saving time and effort during design iterations.

3. Interdisciplinary Collaboration: SOLIDWORKS promotes collaboration between mechanical, electrical, and other engineering disciplines through integrated tools and features.

4. Integrated Simulation: Built-in simulation capabilities enable engineers to test and optimize designs before physical prototyping, reducing costs and time to market.

5. Comprehensive Training and Support: SOLIDWORKS provides extensive resources, including training materials, tutorials, and a vibrant user community.

6. Industry Applications: SOLIDWORKS is used across industries such as aerospace, automotive, consumer products, electronics, medical devices, and more.

7. Customization and Add-Ins: Users can enhance SOLIDWORKS functionality through third-party add-ins and customization.

8. Continuous Innovation: SOLIDWORKS regularly introduces new features and updates, ensuring users have access to the latest tools and technologies.

SOLIDWORKS has established itself as a versatile and powerful software suite for product design, engineering analysis, and manufacturing preparation. Its broad range of features and user-friendly interface make it an invaluable tool for professionals seeking to bring innovative designs to life.

3D PRINTING TECHNIQUES AND MATERIALS USED IN ORTHOTICS

Understanding 3D printing

3D printing also known as additive manufacturing, involves grasping the fundamental principles, processes, and applications of this innovative technology. 3D printing is a revolutionary manufacturing method that builds three-dimensional objects layer by layer, directly from digital design files. It has gained significant attention across various industries due to its versatility, customization capabilities, and cost-effectiveness. Here's an overview of 3D printing:

Principles of 3D Printing:
- Layer-by-Layer Fabrication: The basic principle of 3D printing involves building objects layer by layer. Each layer is created by depositing or solidifying material, typically in a controlled manner, until the entire object is formed.

- Additive Manufacturing: Unlike traditional subtractive manufacturing processes, which involve cutting away material from a block, 3D printing is an additive process. It adds material only where it is needed, reducing waste and enabling complex geometries.

Processes in 3D Printing:
Several 3D printing processes exist, each with unique advantages and material compatibility. Some common 3D printing processes include:

- **Fused Deposition Modeling (FDM):** FDM is a popular 3D printing method that uses thermoplastic filaments. The filament is heated and extruded through a nozzle, forming layers as it cools and solidifies.

- **Stereolithography (SLA):** SLA uses liquid photopolymer resins that solidify when exposed to a light source, typically ultraviolet (UV) light. A build platform lowers into the resin, and a UV laser selectively solidifies the resin layer by layer.

- **Selective Laser Sintering (SLS):** SLS involves using a high-power laser to selectively fuse powdered materials, such as plastics or metals, layer by layer to create the object.

- **Digital Light Processing (DLP):** DLP is similar to SLA but uses a digital light projector to cure the entire layer of resin simultaneously.

Applications of 3D Printing:
3D printing has diverse applications across various industries, including:

- Rapid Prototyping: 3D printing allows for quick and cost-effective production of prototypes, enabling designers to validate their concepts and make improvements before mass production.

- Customized Products: The ability to create personalized and customized objects makes 3D printing ideal for creating tailored medical devices, dental aligners, and orthotic devices.

- Aerospace and Automotive: In aerospace and automotive industries, 3D printing is used to create lightweight and complex components, reducing overall weight and improving performance.

- Architecture and Construction: 3D printing is explored in the construction sector to create complex architectural structures and building components.

- Education and Research: 3D printing is increasingly utilized in educational settings to enhance learning experiences and in research for creating prototypes or scientific models.

3D printing, or additive manufacturing, is a transformative technology with a wide range of applications. It revolutionizes traditional manufacturing by offering increased customization, cost-effectiveness, and reduced waste. The technology continues to evolve, opening up new possibilities in various industries and making once complex manufacturing tasks more accessible and efficient.

3D printing orthoses involves the use of various materials that are compatible with the different printing processes and suitable for the specific functional and comfort requirements of the orthotic devices. The choice of material can significantly impact the final quality, durability, and performance of the orthosis. Here are some common materials used in 3D printing orthoses:

1. Thermoplastic Polymers:
   -Polylactic Acid (PLA):PLA is a biodegradable thermoplastic derived from renewable resources like cornstarch or sugarcane. It's easy to print, comes in a variety of colors, and is often used for prototypes, orthotic prototypes, and models.

   - Acrylonitrile Butadiene Styrene (ABS): ABS is a tough and durable thermoplastic that is well-suited for functional orthotic applications. It has good impact resistance and is available in a range of colors.

   - Polyethylene (PE): PE is a lightweight, flexible, and low-friction material. It's used for applications where reduced friction or cushioning is desired, such as in padding or cushioning components.

2. Flexible and Elastic Materials:
   - Thermoplastic Polyurethane (TPU): TPU is a flexible and elastic material with good wear resistance. It is commonly used for producing orthotic components that require a degree of flexibility or impact absorption.

- Nylon (Polyamide): Nylon is known for its strength, flexibility, and durability. It is used in applications where a balance between rigidity and flexibility is required.

3. Resin Materials:
   - Photopolymer Resins: These liquid polymers solidify when exposed to specific wavelengths of light (usually UV light) during the printing process. They offer high detail and smooth surface finishes. Resins can be specialized for different applications, such as clear resins for transparent components or tough resins for functional parts.

4. Metallic Materials:
   - Stainless Steel: For applications that require strength and durability, such as custom braces or supports, stainless steel can be 3D printed using technologies like Selective Laser Melting (SLM).

   - Titanium: Titanium is lightweight, biocompatible, and corrosion-resistant. It is used in medical and orthotic applications where strength-to-weight ratio and biocompatibility are crucial.

5. Composite Materials:
   - Carbon Fiber Reinforced Polymers: These materials combine the strength of carbon fiber with the versatility of polymers. They are used in applications where a balance between strength and weight is important.

6. Biocompatible and Medical-Grade Materials:
   - Medical-Grade Resins: These resins are formulated to meet biocompatibility and regulatory standards, making them suitable for applications involving direct skin contact, such as prosthetics and orthotics.

It's important to note that material availability may vary depending on the specific 3D printing technology being used. Additionally, considerations such as material compatibility with the user's skin, comfort, flexibility, strength, and regulatory requirements play a crucial role in selecting the most appropriate material for a particular orthotic application.

SELECTING THE APPROPRIATE 3D PRINTING TECHNOLOGY FOR MEWHOs

Selecting the appropriate 3D printing technology for Myoelectric Elbow-Wrist-Hand Orthoses (MEWHOs) involves a careful evaluation of various factors to ensure the optimal fit, functionality, and comfort of the orthotic device. Here's a step-by-step guide to help you make the right choice:

1. Understand the Requirements:
   - Begin by clearly defining the specific functional and anatomical requirements of the MEWHO. Consider factors such as the range of motion needed, the complexity of joint articulation, and the integration of myoelectric sensors and actuators.

2. Material Compatibility:
   - Different 3D printing technologies work with specific types of materials. Determine which materials are compatible with the printing technology and are suitable for the MEWHO's intended use. Consider factors like biocompatibility, flexibility, and durability.

3. Resolution and Detail:
   - Evaluate the level of detail and resolution required for the MEWHO. If intricate features or fine textures are essential, technologies like stereolithography (SLA) or digital light processing (DLP) might be more suitable due to their high precision.

4. Build Size and Scalability:
   - Consider the size of the MEWHO and whether the 3D printing technology can accommodate the required dimensions. Additionally, assess the scalability of the technology if you plan to produce multiple orthoses.

5. Surface Finish and Texture:
   - Analyze the desired surface finish of the MEWHO. Some technologies produce smoother surfaces e.g. SLA Printing Technology, while others

may result in a textured finish e.g. FDM Printing Technology. Ensure that the chosen technology aligns with the desired tactile qualities.

6. Mechanical Properties:
   - Evaluate the mechanical properties of the printed materials, such as strength, stiffness, and impact resistance. Choose a technology that can achieve the required mechanical characteristics for the MEWHO's components.

7. Speed and Throughput:
   - Consider the speed of the 3D printing process and the estimated time it takes to produce a single MEWHO. For high-volume production or time-sensitive cases, technologies with faster printing speeds may be more suitable.

8. Support Structures and Post-Processing:
   - Some 3D printing technologies require support structures that need to be removed after printing. Consider the complexity of post-processing and the impact it may have on the final orthosis.

9. Cost and Budget:
   - Evaluate the overall cost of the 3D printing technology, including equipment, materials, and maintenance. Ensure that the chosen technology aligns with your budget constraints.

10. Experience and Expertise:
   - Assess the availability of skilled personnel who are experienced in operating and maintaining the chosen 3D printing technology. Adequate expertise is essential for achieving consistent and high-quality results.

11. Regulatory Considerations:
   - If the MEWHO is intended for medical use, consider any regulatory requirements or certifications that the 3D printing technology and materials need to meet.

12. Trial and Iteration:
   - Whenever possible, conduct trial runs and produce prototypes using different 3D printing technologies. This hands-on approach can provide

valuable insights into the feasibility and suitability of each technology for MEWHO production.

Ultimately, the selection of the appropriate 3D printing technology for MEWHOs should be a well-informed decision based on a comprehensive assessment of these factors. It's important to prioritize the specific needs of the users and the functional requirements of the orthosis to achieve the best possible outcome.

MYOELECTRIC ELBOW-WRIST HAND ORTHOSIS: AN OVERVIEW

The components and design of a Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO) are meticulously crafted to provide individuals with upper limb impairments a comprehensive solution that restores mobility, dexterity, and independence. This section outlines the key components and design considerations of a MEWHO:

1. Elbow Joint:
   - The elbow joint is a pivotal component of the MEWHO, enabling controlled flexion and extension of the forearm. It typically incorporates mechanical or electronic actuators to replicate the natural movement of the elbow joint.
   - The design may include adjustable hinges and locking mechanisms to allow for different degrees of freedom and secure positioning.

2. Wrist Unit:
   - The wrist unit of the MEWHO is responsible for replicating the rotational and abduction/adduction movements of the human wrist.
   - A combination of mechanical linkages, motors, or pneumatic systems allows the wrist to mimic natural wrist motion, providing users with a wide range of functional possibilities.

3. Hand Segment:
   - The hand segment encompasses the fingers, thumb, and palm. It is designed to replicate the intricate movements of a natural hand, enabling activities such as gripping, grasping, and releasing objects.
   - Each finger may consist of multiple phalanges with articulating joints, allowing for flexion, extension, and various grasp patterns.
   - The thumb is designed to oppose the fingers, facilitating precision grip and enhancing overall dexterity.

4. Myoelectric Sensors:
   - Myoelectric sensors are strategically integrated into the MEWHO to detect and interpret the user's muscle signals.
   - Electrodes placed on the user's skin pick up electrical signals generated by muscle contractions. These signals are then processed and used to control the movements of the orthosis.
   - Advanced sensors may incorporate pattern recognition algorithms to provide more intuitive control.

5. Control System:
   - The control system of the MEWHO processes the signals from the myoelectric sensors and translates them into specific movements of the orthotic components.
   - Microcontrollers, processors, and software algorithms ensure seamless coordination between the user's intentions and the orthosis's actions.

6. Power Source:
   - Depending on the design, the MEWHO may be powered by rechargeable batteries or other power sources. Battery life and capacity are critical considerations to ensure uninterrupted functionality.

7. Customization and Personalization:
   - An essential aspect of MEWHO design is customization. 3D scanning and modeling techniques allow for personalized fit and alignment to the user's anatomy.
   - Customization extends to the design of finger patterns, grip types, and control parameters, ensuring a tailored experience for each user.

8. Materials and Ergonomics:
   - The materials used in MEWHO construction should be lightweight, durable, and biocompatible. Comfortable padding and soft liners ensure extended wear without causing discomfort or skin irritation.

The meticulous integration of these components and design considerations results in a MEWHO that emulates natural upper limb movements and offers users a higher degree of autonomy and functional capability.

DESIGN AND ENGENEERING OF THE 3D PRINTED MEWHO

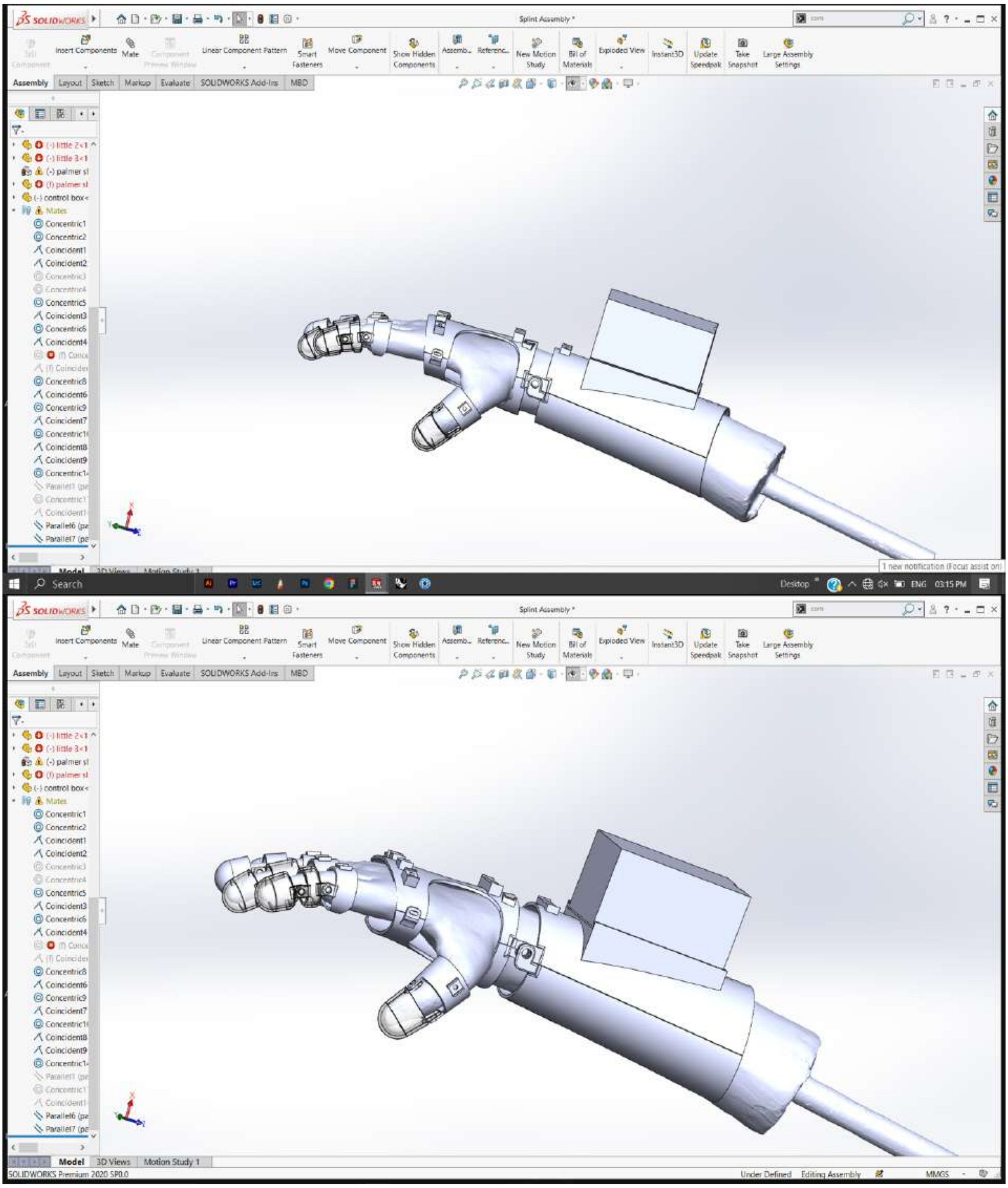

Image source :
SOLIDWORKS Software images during 3d modeling .

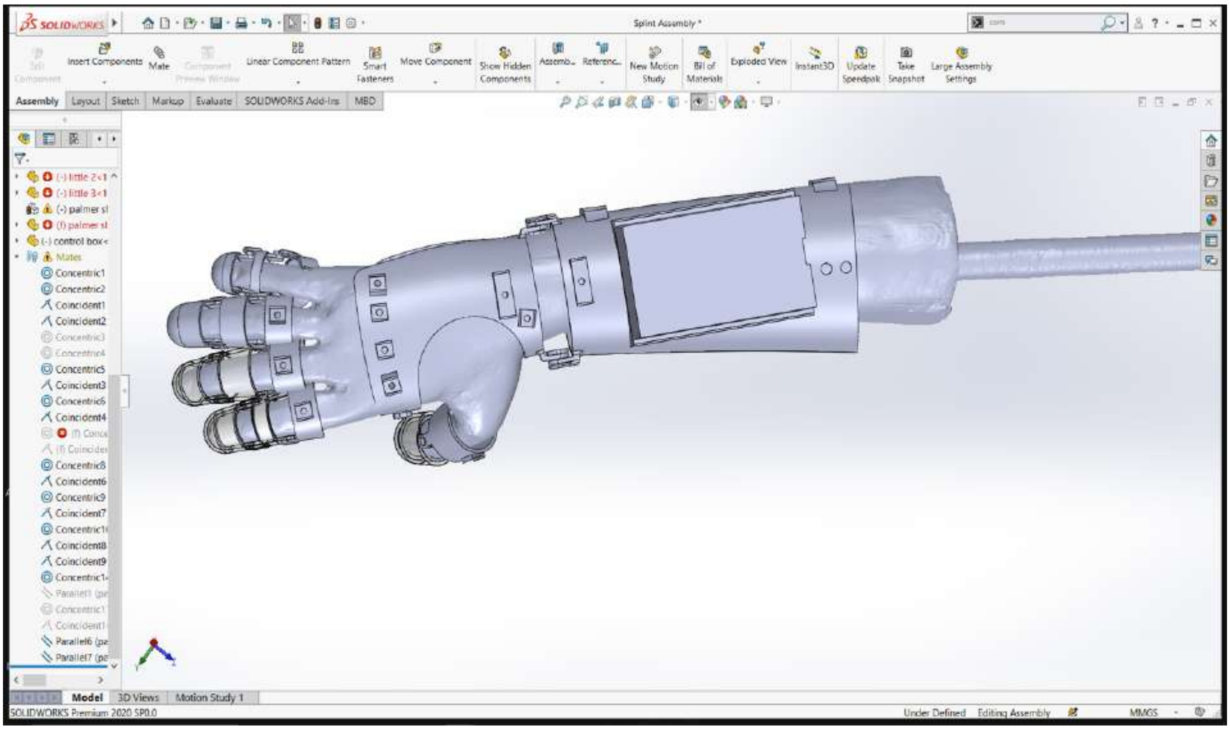

Image source :
SOLIDWORKS Software images during 3d modeling .

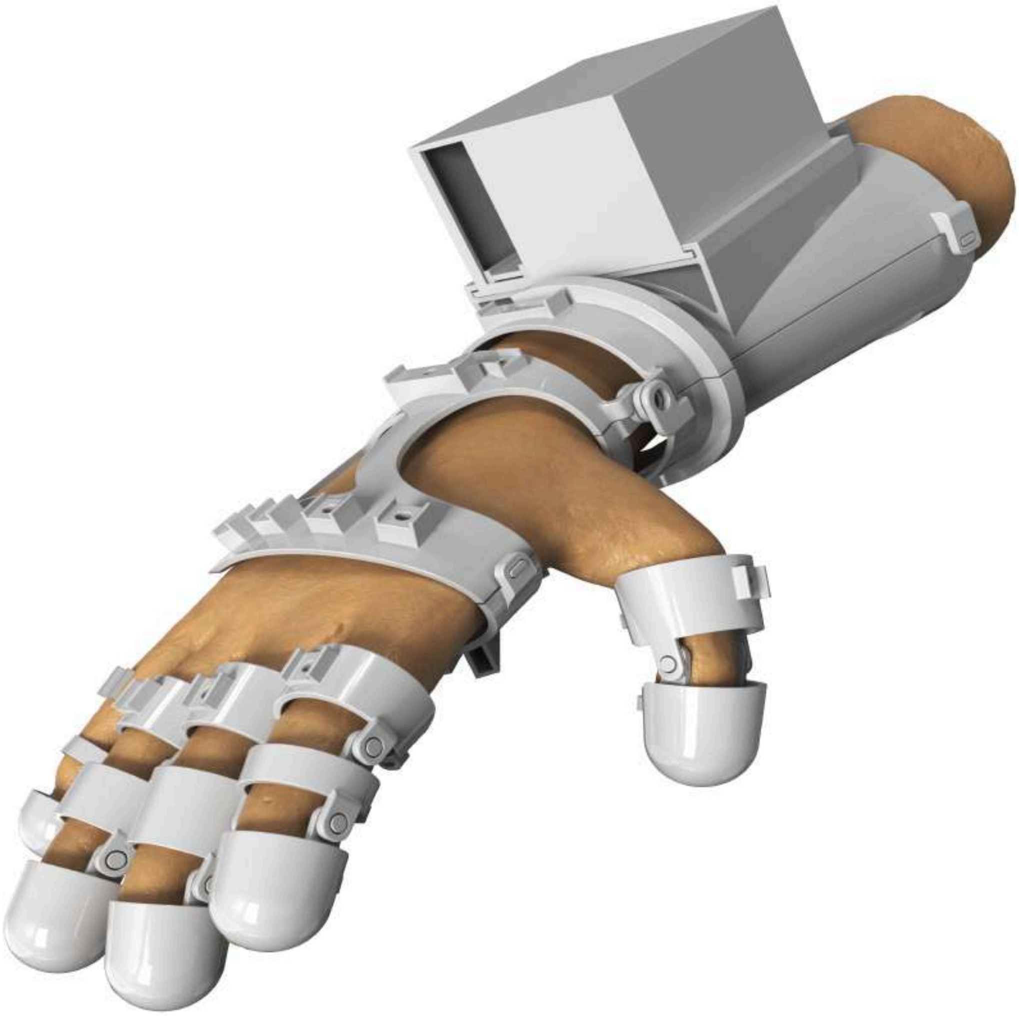

Image source :
Final design image after 3D modeling .

Image source :
Image of final orthosis after soft padding.

CLINICAL APPLICATION OF 3D PRINTED MEWHO

Patient Selection Criteria

Inclusion criteria included: regular/consistent therapy attendance; trace muscle contraction in major upper limb muscle groups; adequate passive ROM to don/doff device; intact cognition; active shoulder flexion 40° and shoulder abduction 20°; ability to don/doff device with/without a reliable caregiver.

Training and Adaptation for Users

Training and adaptation are crucial aspects of introducing users to a Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO). Proper training ensures that users can effectively control and utilize the orthosis to its fullest potential, while adaptation helps them integrate the MEWHO into their daily lives. Here's a comprehensive approach to training and adaptation for MEWHO users:

1. Orientation and Education:

- Begin with an orientation session to introduce users to the MEWHO's components, controls, and functionalities.

- Provide educational materials, user manuals, and resources to help users understand the orthosis's operation and maintenance.

2. Muscle Training and Signal Calibration:

- Guide users through muscle training exercises to enhance the strength and consistency of the myoelectric signals detected by the sensors.

- Assist users in calibrating the sensors to accurately interpret their muscle contractions for optimal control.

3. Gradual Introduction:

- Initiate the training with simple tasks and movements to help users get accustomed to the orthosis's responses and behavior.

- Gradually increase the complexity of tasks to build confidence and skill in operating the MEWHO.

4. Practice Sessions:

   - Conduct regular practice sessions where users can experiment with different grip patterns, movements, and activities.

   - Use simulated scenarios to mimic real-life situations and challenges that users may encounter.

5. Feedback and Adjustments:

   - Provide real-time feedback during training sessions to help users understand the impact of their muscle signals on the orthosis's movements.

   - Collaborate with orthotic specialists to fine-tune the control parameters and adjust the orthosis settings based on user feedback.

6. Functional Activities:

   - Gradually incorporate functional activities relevant to the user's daily routine, such as picking up objects, eating, or typing.

   - Work on improving coordination and fluidity in performing tasks that require multi-joint movements.

7. Problem-Solving and Troubleshooting:

- Train users to identify and troubleshoot common issues that may arise during orthosis operation.

- Teach basic maintenance and minor adjustments to enhance user autonomy.

8. Social and Psychological Support:

- Address psychological aspects of adaptation, such as self-esteem and body image, by providing counseling and peer support.

- Encourage users to share their experiences and challenges with others who have undergone similar training.

9. Real-Life Scenarios:

- Arrange training sessions in real-life environments where users can practice using the MEWHO in different contexts, such as home, workplace, or social gatherings.

10. Follow-Up and Progress Evaluation:

- Conduct regular follow-up sessions to monitor the user's progress and address any difficulties they may encounter.

- Evaluate functional improvements and ensure that the MEWHO continues to meet the user's evolving needs.

11. Continuous Learning and Adaptation:

- Emphasize that learning and adaptation are ongoing processes. Encourage users to explore new activities and challenges to maximize the orthosis's potential.

By providing comprehensive training and support, users can effectively integrate the MEWHO into their lives, achieve functional independence, and experience improved quality of life. The training process should be tailored to individual needs and abilities, fostering a sense of empowerment and confidence in using the orthosis.

Case Study and User Experience with 3D Printed MEWHO

According to above Criteria One Patient was selected.

History of the Patient –

He had a bike accident in the month of April in 2022. Where he got a hit over the Brachial Plexus in the Right arm and also had a Right Transfemoral amputation in Jayram hospital, Nashik, then came to KEM hospital.

He went for Nerve Transfer Surgery of three Intercostal Nerve (2^{nd}, 3^{rd} & 4^{th}) to Musculocutaneous Nerve for Right Pan Brachial Plexus Injury.

Case Study: Rehabilitation and Functional Recovery of Mr. Shubham Aswale, following Brachial Plexus Injury and Transfemoral Amputation

Background:

Mr. Shubham Aswale, a 22-year-old first year BSc student (FYBSc), experienced a life-altering incident in April 2022 when he was involved in a serious bike accident. The accident resulted in a Brachial Plexus Injury to his right arm and a subsequent right transfemoral amputation. After initial treatment at Jayram Hospital in Nashik, he was referred to KEM Hospital for specialized care and rehabilitation.

Injuries and Surgical Intervention:

1. Brachial Plexus Injury: The bike accident caused trauma to Mr. Shubham's right arm, resulting in a Brachial Plexus Injury. This complex injury impacted the nerve network controlling the arm's motor and sensory functions.

2. Transfemoral Amputation: Due to severe damage and complications, a right transfemoral amputation was performed at Jayram Hospital to improve Mr. Shubham's overall health and mobility.

Nerve Transfer Surgery:

Recognizing the severity of the Brachial Plexus Injury, Mr. Shubham underwent a pioneering Nerve Transfer Surgery at KEM Hospital. The procedure involved transferring nerves from the intercostal region (2nd, 3rd, and 4th intercostal nerves) to the Musculocutaneous Nerve of the right arm. This innovative approach aimed to restore motor function and sensation to the affected limb.

Rehabilitation and Functional Recovery:

Mr. Shubham's journey towards functional recovery was a collaborative effort involving medical specialists, physical therapists, and occupational therapists.

1. Post-Surgery Care: Following the nerve transfer surgery Mr. Shubham received comprehensive post-operative care, including pain management and wound healing.

2. Physiotherapy and Occupational Therapy: A tailored rehabilitation plan was designed to address both his Brachial Plexus Injury and transfemoral amputation. Physiotherapy focused on regaining upper limb strength, flexibility, and coordination. Occupational therapy aimed to enhance his ability to perform daily activities using adaptive strategies.

3. Prosthetic Fitting and Training: As part of his rehabilitation, Mr. Shubham was fitted with a transfemoral prosthetic limb. He underwent training to adapt to the prosthetic limb, learn proper gait mechanics, and regain functional mobility.

4. Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO): Recognizing the potential for advanced assistive technology, Mr. Shubham was introduced to a Myoelectric Elbow-Wrist-Hand Orthosis. Through rigorous training and adaptation sessions, he learned to control the MEWHO using his residual muscle signals, enabling him to perform intricate tasks and regain functional independence.

Outcome and Impact:

Mr. Shubham's dedication and the multidisciplinary rehabilitation approach led to remarkable outcomes:

- He is successful in regaining significant motor control and sensory perception in his right arm, allowing him to perform activities of daily living more independently.

- The prosthetic limb significantly improved his mobility and quality of life, enabling him to walk, stand, and engage in recreational activities.

- The MEWHO revolutionized his upper limb function, empowering him to use a computer, write, and grasp objects with precision.

Conclusion:

Mr. Shubham's inspiring journey showcases the power of modern medical interventions, rehabilitation, and assistive technology. Through his determination, skilled medical care, and innovative solutions like nerve transfer surgery and MEWHO, he was able to overcome the challenges posed by a Brachial Plexus Injury and transfemoral amputation, ultimately reclaiming his independence and embarking on a path of functional recovery and renewed possibilities.

ADVANTAGES OF OUR 3D DESIGNED MEWHO

The Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO) offers a range of significant advantages that contribute to its effectiveness and impact on individuals with upper limb impairments. These advantages make MEWHO a transformative solution for enhancing functionality, independence, and quality of life. Here are some key advantages of MEWHO:

1. Natural and Intuitive Control:
   - MEWHO utilizes myoelectric sensors to detect residual muscle signals, enabling users to control the orthosis with intuitive movements similar to those of their natural limb.

2. Precise Movements and Grasping:
   - MEWHO's myoelectric control allows for precise and coordinated movements of the elbow, wrist, and hand, enabling users to achieve various grip patterns and perform intricate tasks.

3. Customization and Personalization:
   - MEWHO can be customized to fit each individual's anatomical measurements, preferences, and functional needs, ensuring a comfortable and tailored experience.

4. Multi-Functional Capabilities:
   - MEWHO's adaptable design enables users to perform a wide range of activities, from basic daily tasks like eating and dressing to more complex actions like typing and handling objects.

5. Restoration of Independence:
   - MEWHO empowers users to regain their independence by enabling them to perform activities that were previously challenging or impossible due to their upper limb impairment.

6. Improved Quality of Life:
   - MEWHO's ability to restore functionality and autonomy contributes to an enhanced overall quality of life for users, promoting greater confidence and psychological well-being.

7. Rehabilitation and Muscle Strengthening:
   - MEWHO can be incorporated into rehabilitation programs, facilitating muscle activation, strengthening, and motor relearning after injuries or surgeries.

8. Support for Prosthetic Limbs:
   - For individuals with lower limb amputations, MEWHO complements prosthetic limbs by restoring upper limb function, creating a more balanced and functional body movement.

9. Enhanced Social Interaction:
   - MEWHO facilitates improved social interaction by enabling users to engage in conversations, gestures, and activities that may have been challenging before.

10. Empowerment and Self-Efficacy:
   - Mastering the control of MEWHO instills a sense of accomplishment and self-efficacy, motivating users to explore new challenges and opportunities.

11. Ease of Learning and Adaptation:
   - MEWHO's intuitive control mechanism allows for relatively quick and straightforward learning and adaptation, enabling users to begin using the orthosis effectively in a shorter period.

12. Technological Advancements:
   - MEWHO benefits from advancements in materials science, 3D printing, and myoelectric technology, ensuring that users have access to state-of-the-art solutions.

13. Functional Rehabilitation in Neurological Conditions:
   - For individuals with neurological conditions like stroke or spinal cord injuries, MEWHO supports functional recovery by providing a platform for relearning movement patterns.

14. Assistive Solution for Various Professions:
- MEWHO can assist professionals in various fields, such as artists, musicians, or office workers, allowing them to pursue their careers more effectively.

15. Long-Term Usability:
- With proper care and maintenance, MEWHO can serve as a reliable long-term assistive device, providing sustained benefits to users over time.

In summary, the Myoelectric Elbow-Wrist-Hand Orthosis (MEWHO) stands as a remarkable innovation that addresses the unique needs and challenges of individuals with upper limb impairments. Its intuitive control, customization options, and transformative impact on users' lives position MEWHO as a pioneering solution for enhancing functionality, independence, and overall well-being.