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A Systematic Review of Partial Hand Prostheses

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ABSTRACT

A partial hand amputation can significantly change a person's life for the better. Partial amputees must be fitted with a prostheses, which is one way to enhance their function and solve some of the issues they confront. The purpose and aesthetics of partial hand prosthetics range widely to help people perform their tasks. There isn't a perfect replacement item available yet that can replace what was lost. The comprehensive study examined the variations in partial hand prosthetics using experimental approaches that explain the physical characteristics that include weight, grip characteristics, design flexibility, shape, adaptability, and pinching action those are used for engineering requirements and formal system analysis. This review article examines and characterizes various prosthetic solutions that have been researched and offered by academics.

1. Introduction

As 3D printing technology improves, custom prostheses are becoming more viable options for people with complicated prosthetic cases. The term "amputee" refers to people who have lost one or more limb. A prostheses is frequently used to overcome this disability, but it can be expensive and uncomfortable for the user. This ailment can significantly impact the population's ability to execute tasks requiring precise handling. The increased reporting of hand accidents has necessitated hand amputation. It is important to take into account the fact that there are numerous prostheses designed specifically for the hand. However, the mechanical construction of these prostheses currently has problems with strength and motor function. A quantitative review of the 3D-printed upper limb prostheses was proposed. To enable the enhancement of present devices based on the needs of prostheses users, it would examine the advantages and disadvantages of 3D-printed devices. On the other hand, 3D printing offers a promising opportunity for customization, such as customized sockets, color, form, and size, without the need to modify the production equipment[1]. Also, examines cutting-edge options for single finger or partial hand prosthetics that have been researched and are commercially available. Many prototypes were

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described, along with their fundamental advantages and disadvantages. The main objective was to establish a strong foundation for the investigation and creation of the subsequent generation of prostheses that could be created to improve the performance of these prostheses [2]. Sophisticated robotic hands with several fingers those could grip a wide range of objects was presented. The subjectivity and accuracy of the robotic hand, as well as some of its design elements, were discussed. The operation of a newly developed four-fingered tendon-operated robotic hand was explained based on these criteria [3]. Provide a comprehensive knowledge of the methods used in bio-printing and 3D/4D printing. Numerous printing processes have been covered, such as extrusion, laser-assisted printing, selective laser melting, poly jet printing, and inkjet 3D printing. It also highlighted some of the potential advantages and future prospects for machine learning in additive manufacturing. Finally, significant constraints and opportunities were noted [4]. Selective laser sintering (SLS), inkjet printing, and fused deposition modeling (FDM) were performed of biomedical elements which used to employ 3D printing. This review article's goal was to examine various additive manufacturing techniques, difficulties, and potential future advancements for 3D printing biomedical elements[5]. Examined the mechanical features of artificial fingers, which are the most crucial parts of bionic hands. After a discussion of the performance standards, which were divided into grasp and physical qualities, an existing linkage-driven artificial finger experiment was conducted. The function of designed hand would determine how useful it might be to include a certain feature in the mechanism of an artificial finger [6]. The development of bionic hands was briefly summarized in this study. The mechanical scheme, signal processing, and control crucial design facets of the bionic hand were developed along with the concept of the bionic hand[7]. A prototype of an approachable 3D-printed mechanical hand and a three separate information sets were provided. Precision grasps, conical, and spherical were tested as gripping functionalities. A wearable tactile sensor was employed for the experimental test. The data set included a mathematical solution of prosthetic fingers made of Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA) materials under with various conveying loads. The LS-DYNA program performed the numerical evaluations [8]. A how a low-cost 3D prosthetic hand with an electromyographic (EMG) interface impacted patients' daily activities was evaluated. It could user in changing demand, as its higher market desire and lower cost of manufacture would make it more popular [9]. A reinforcement learning to generate the entire control strategy for a robotic prosthetic hand and imitative learning has been proposed as a solution to the problematic state space of the issue's scarce compensation arrangement. The simulation findings demonstrate the viability of the learning strategy for robot prosthetic limbs to grip items, potentially improving the robustness of the grab [10]. A four characteristics of three distinct kinds of rubber: appearance, substance, physical characteristic, and sensorimotor were used for the production of gloves with a human-like look in both adult and youth sizes, also the insertion molding technique was used. Furthermore, it would be to use mass production to lower the cost of the cast molding technique [11]. A mechatronic product architecture sparthan, would be used to demonstrate the combination of accessible robotics and wearable sensors, enabling technology available in the powered prostheses and neurorehabilitation fields. Sparthan processes muscle detector data and converts user intention into hand movements using 3rd party EMG sensors from the Signal. The method's high level of flexibility, scalability, and adaptability for the target customers was among its key innovations [12]. A wearable arm sleeve that could be used for a variety of daily activities and was economical and helpful. It can be adjusted using a motor and switch. in comparison with the existing prostheses on the markets, wearable sleeves might be more affordable and accessible [13].

The purpose of this research is to present a comprehensive review of the available 3D-printed partial hand prostheses (PHP). A review was conducted using the Web of Science and Scopus to enable the enhancement of current devices based on the needs of prosthetic users. The overview displays prostheses with various forms of control for all PHP levels.

2. Systematic Review of Partial Hand

Individuals who have experienced a catastrophic accident that has caused them to lose all or part of a limb can benefit from prosthetics. The human hand is especially important because it allows for sophisticated cognitive interaction and task completion. When a person loses an arm, limb, or hand, restoring these abilities provides them with the flexibility to conduct social tasks and take on professional responsibilities once more. Therefore according to the number of lost fingers, the research is organized and divided into three groups:

2.1. One and two prostheses fingers

A case report on a customized, quick-to-prototype thumb prostheses with partial hand loss was proposed. With the help of the device modifications and physical therapy sessions, the patient was able to complete the box and block tests. As well as performing daily activities like cooking, cleaning, and do other tasks with more capability. This case study illustrates a novel method for creating personalized prostheses that could improve partial-hand amputees' acceptance rates of the prostheses [14]. Besides, a quantitative analysis of the effects of using prostheses with silicone implants that are 3D printed was presented. Utilizing a 3D silicone-infused prostheses was preferable for using no assistance, according to quantitative evidence. The patient completed difficult tasks like removing the plastic wrap and nailing something down[15]. Moreover, a low-cost mechanical arm that above- or below-elbow prosthetic limbs could afford has been proposed. The proposed system could be used to move, grip, and replace objects that were heavy or required two hands to carry by using servo motors, Arduino UNO, and linear actuators[16]. Two fingers amputees were given body-powered, 3D-printed Finger Prostheses (FP) and adequate prosthetic training was proposed. With the 3D-printed FP, they expressed increased happiness and better functionality[17]. Likewise a two distinct powered FP and noted the results of a single subject in terms of functionality and comfort. A rise in performance was noticeable when either prostheses was utilized, with the main distinctions being between the construction, design, and use of the prostheses and the general action mechanisms [18]. Also, a two kinds of body-powered finger prosthetics and evaluated a single subject's functional and satisfaction outcomes were discussed. The objective was to investigate how simple it was to use task-specific design in computer-aided, free software for 3D printing design. According to objective evaluations, the individuals' affected hands had lessened prehension, grasp, and expansion capability[19]. Furthermore, a prosthetic finger was geometrically modeled, utilizing programming methodologies. As part of the development process, an artificial finger with one degree of flexibility was modeled in Opens CAD. Experiments were done on a tendon structure that had both flexible and rigid lines. In order to build the prototype, it is first necessary to look at the medical factors that must be taken into account. Next, discuss how the produced shape was made and how it was used[20]. As well as a component of the Otto Bock hand construction project, a unique under-actuated robotic finger design has been developed and examined. The degrees of freedom and the finger's actuation mechanism underwent the most significant modifications. This was carried out using the genetic algorithm's multi-objective capabilities[21]. Additionally, a conception and assessment of a personalized FP that produces a natural finger movement. Two techniques were used: fingertip trajectory analysis in polar coordinates to simulate natural finger movement and a four-bar mechanism that used the subject's last joint as the mechanism's joint. Before using it on the actual finger amputee, the FP was designed so that a prototype could be made using the finger data of a healthy individual. By conducting extensive trials for grabbing and manipulating using the suggested system, the performance of the system was confirmed [22]. A customized thumb prosthetic was established utilizing free software, 3D scanning, and additive fabrication methods. The design, positioning, stiffness, and fastening of the prostheses allowed the person to manipulate objects with his healthy fingers and prosthetic thumb. The process of making a prosthetic thumb using cutting-edge technologies was suitable from a practical standpoint [23]. Along an alternative design for a 3D-printed finger prosthetic that has been manufactured and tested. A significant issue was maintain joint flexibility while also having strong enough grips. This article offers the solution to this problem and rates the various print options. The results provided adequate, cost-effective solutions without compromising the prostheses' effectiveness, which was extremely helpful in the development of hand prostheses [24]. Consequently, an examination and confirmation of a unique Five-Link Epicyclic (FLE) finger for 3D-printed hand prosthetics was provide. Analysis of the comparison between the motion and joint forces of the FLE that used Coupled Four-Bar Linkage (CFBL) show experimental evidence of the FLE finger's enhanced load-carrying capacity. Therefore, it was anticipated that a hand prostheses with an FLE finger might perform better than one with a CFBL finger, benefiting patients who have lost their hands [25]. An electro-mechanical hand with two fingers and six degrees of freedoms (DoFs) was developed. The bionic hand's ability to execute the three grasping patterns power grab, accuracy pinch, and lateral pinch was confirmed by some gripper experiments. The work established the relationship between the variation in finger dimension and shape and the hand movement skill, and it also gave a strategy for creating a two-finger prosthetic hand with various grasping patterns [26].

The components for constructing a prosthetic that must look like the actual hand are indicated in figure 1, which illustrates the hand anatomy from different angles. Additionally, figure 2 demonstrates the one FP, and figure 3 shows the two finger prostheses, which were developed on various papers.

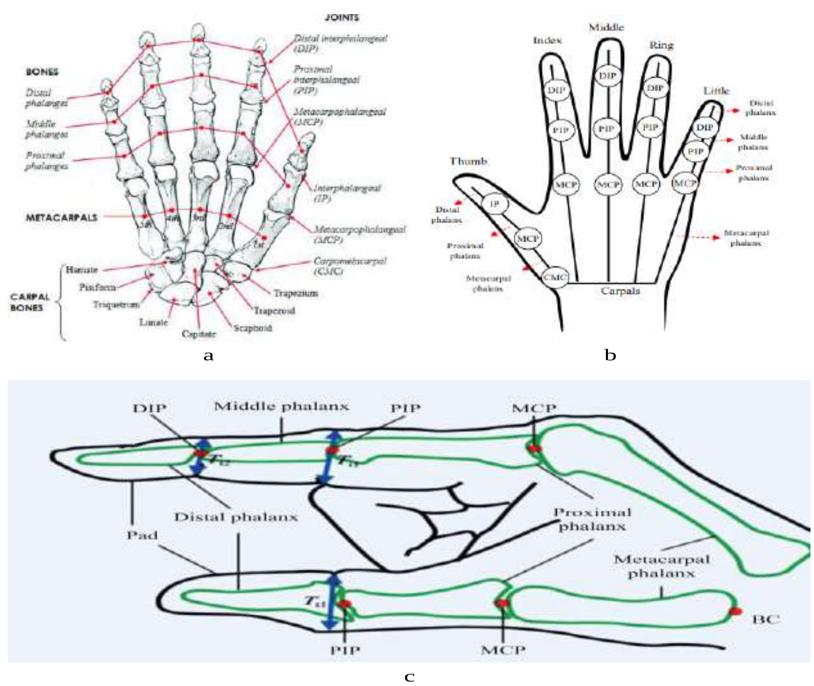


Figure 1. Hand anatomy a) skeletal structure [20], b) joints metacarpals and carpal [22], c) side joints metacarpals and carpal [26].

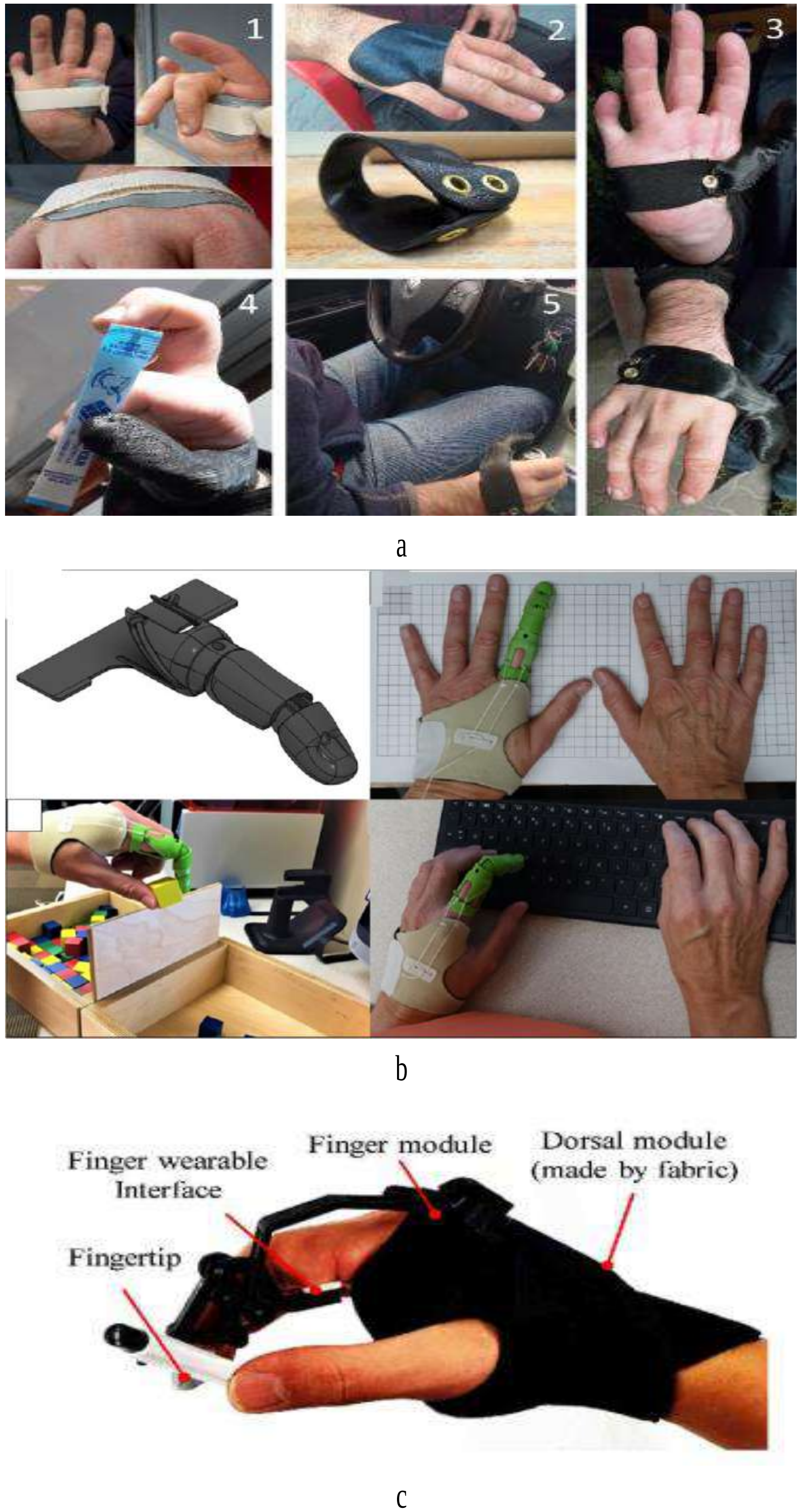


Figure 2. One finger prostheses a) thumb finger [23], b) forefinger [18], c) index finger [22].

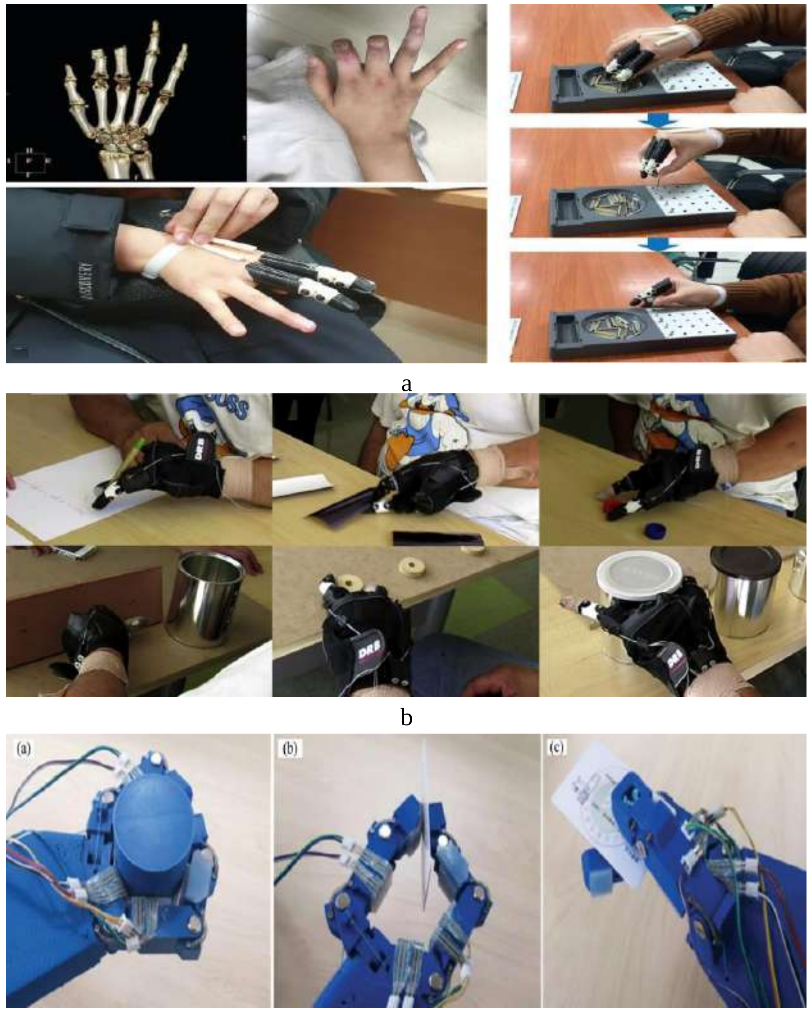
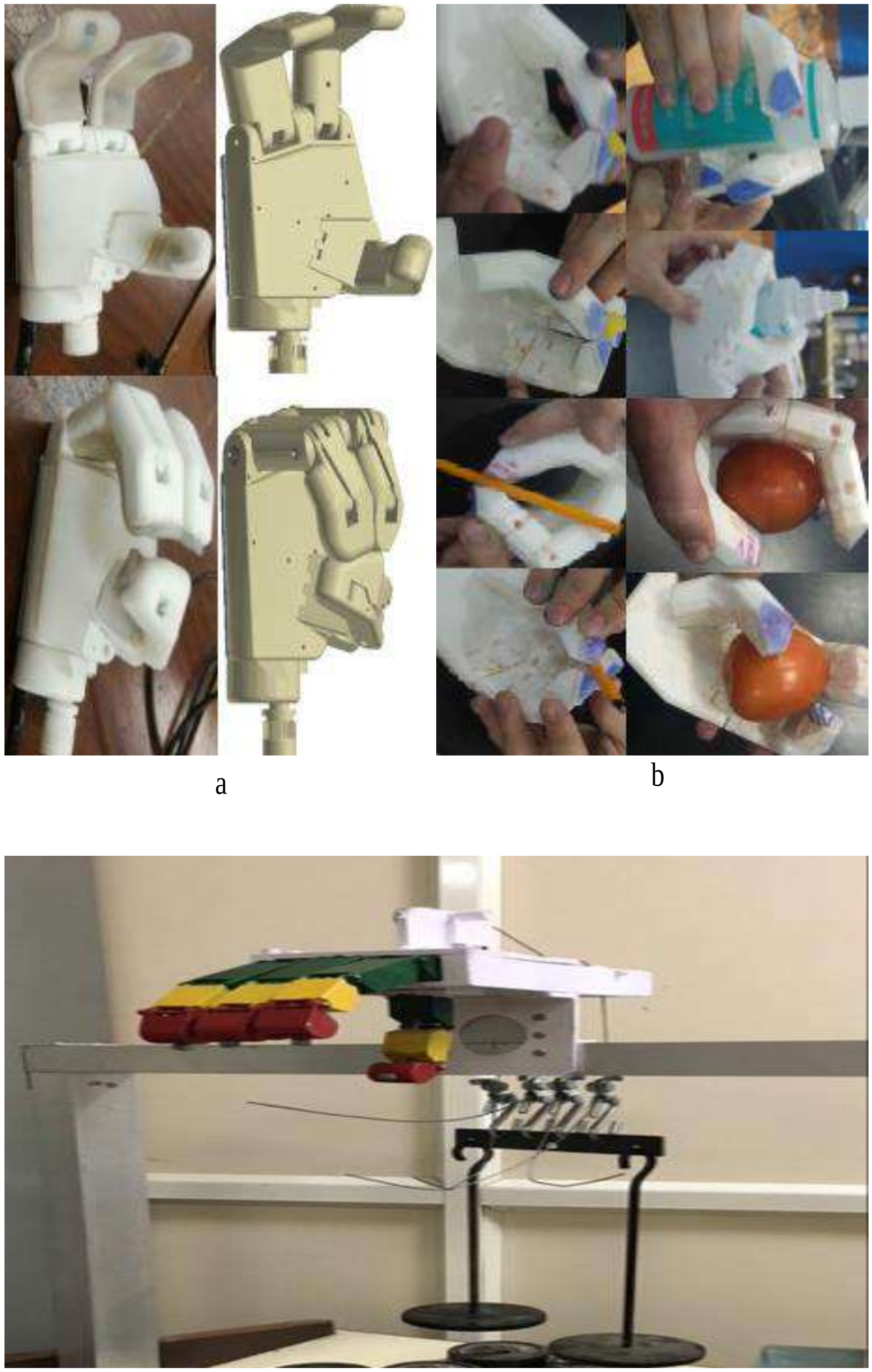


Figure 3. Two finger prostheses a) index and middle fingers [17], b) thumb and index fingers [15], c) robotic fingers [26].

2.2. Three and four prostheses fingers

A 3D-printed prostheses for people who have lost a portion of their hands a patient with a transmetacarpal amputation was the target for the prostheses. The opposite hand operated the final design and made use of thermoplastic polyurethane's enhanced flexibility capabilities. The prostheses was lightweight and could be donned and doffed independently [27]. Meanwhile, a two 3D-printed of a tailored prosthetic hand for a male who had a partially amputated was evaluated. This experiment compared two unique 3D-printed gadgets with an electromyography prostheses to assess muscular endurance, flexibility, and consumer characteristics. The user expressed more satisfaction with the 3D-printed gadgets' weight and thermal properties. However, design initiatives ought to be client-centered and comprise experts in engineering and prosthetics [28]. Also, distal, proximal, and thumb have been improved to strike the right balance between weight reduction and suitable flexibility was confirmed. Five various construction methodologies were proposed, starting with computational models of elastic-plastic materials and experimental results on abandoned components tested under the most severe loading conditions. An iterative architecture optimization method was used to identify the potential material removal locations [29]. Biomechanics and static force analysis was illustrated with diagrams. A biomechanics and static force evaluation of the hands, as well as the design optimization of the prosthetic hand, were presented. The final item was tested and evaluated against other prosthetic hands the Touch Hand 4 performed noticeably better than other prosthetic limbs and was comparable to some artificial limbs in terms of strength and balance [30]. Besides, a four-artificial-finger grab capacity analysis was covered and the numerical equation for cylindrically shaped things was created. These mathematical formulas assist in determining the forces acting on each finger phalange on the surface of the object being grabbed. Several conclusions were reached from the data after comparing the experimentally determined tendon pressures with those calculated using the derived formulas [31]. A mechanical prototype for a myoelectric prosthetic finger that was less expensive and could perform similarly to other prosthetic hands was developed. After examining the design aspects, 3D prints of the generated concepts were tested. Tests were carried out by attempting to grasp objects of various forms and watching how the hand behaved. When tested on various shaped objects, the hold and finger were found to be rigid [32]. Finally, an evaluation of the four-fingered prosthetic hand was done, and the extension and flexion motions of the fingers were controlled by joint structures and a spring return method, respectively. Any mechanical arm with multiple fingers should be able to grasp things steadily and manipulate them precisely [33]. Figure 4 demonstrated the three mechanical FP that grasped various items, and Figure 5 demonstrated the three and four robotic FP.

Figure 4. Three mechanical finger prostheses [27].



a b

c

Figure 5. Three and four robotic finger prostheses a) three fingers [30], b) three fingers grasp different objects [32], four fingers [31].

2.3. Five prostheses fingers

The muscles, joints, tendons, and bones that constitute the complex architecture of the human hand work together to achieve the desired mobility. So, a hand prostheses with a certain level of functionality utilizing 3D printing technology and a non-assembly design method was created. In contrast to other body-powered prostheses, the activation forces and energy needed for a closure cycle are far lower. This prosthetic hand was something people with arm problems in the developing world should seriously consider [34]. A 3-dimensional hand prostheses with bio-inspired fingers that can move was proposed. Present a body-powered, 3D-printed prosthetic hand with all of the all features, including flexible fingers, adaptive gripping, and little post-printing assembly. This prosthetic hand was also affordable and lightweight, which makes it a viable solution, particularly in places without access to modern prosthetic factories [35]. A flexible various soft joint designs are for an inexpensive 3D-printed prosthetic hand was examined. By measuring the angles of the normal stance of the human hands and transferring those angles to the prosthetic hands with flexible joints, it was able to transform this disadvantage into a useful feature [36]. Besides, a low-cost human hand using manufacturing processes was established using an approach that made use of readily available, inexpensive materials. Tensile testing was done to determine the mechanical qualities and confirm the durability of the printing medium. In conclusion, it highlights essential variables that affect the 3D printing, particularly in connection to its mechanical characteristics and printing settings [37]. With the use of the software Abaqus, introduce an analysis of the mechanical design that is low-cost. The hand prostheses has 14 degrees of freedom (DOF), allowing it to grasp objects with grips that are secure, stable, dexterous, and sensitive. Additionally, fused deposition modeling using acrylonitrile butadiene styrene (ABS) was suggested due to its usefulness and low-cost production techniques. Tensile, flexural, and torsional load conditions were used to evaluate the hand prostheses [38]. The conceptual analysis, development, and manufacturing process for a low-cost, flexible prosthetic hand was illustrated. The hand has five continuously moving fingers and a wrist with two degrees of freedom. The development of a low-cost optoelectronic sensor for estimating the finger's curvature was one of the major contributions of this effort [39]. Development and implementation of a low-cost myoelectric hand prototype were demonstrated. One of the major contributions was the suggestion of a unique Computer Aided Design (CAD) suitable for laser etching for prosthetic devices, and the other was the introduction of a new feature, XCORR, to recognize Electromyography (EMG) data. Cross-correlation involving two different channels of EMG data for the same activity is estimated using XCORR [40]. A 15-DOF prosthetic hand's control, assessment, and multi-body modeling were presented. A 3D model of a mechanical hand was made using SolidWorks in accordance with the structural characteristics of an adult person's hand. Hand patterns were displayed in MATLAB using the SimMechanics package. Each joint in a finger was shown by the PID controller output [41]. Also, a code for the electromyography hand was created with two control processes the first for the thumb and the second for the remaining fingers. The finger and thumb responses were then individually recorded after the robotic hand had first been created using a 3D printer. The findings demonstrate that the development of robotic prostheses could be considerably aided by a simple, low-cost prosthetic hand. However, to advice and focus on enhancing the electronic circuit equipment's architecture so that the prosthetic hand could function without a laptop [42]. Two prototypes were made by 3D printers for a solid hand that was examined by a 3D scanning device served as the foundation for all the internal mechanical components. This project's coupling of a literature review and experimental testing enables the mechanical design of a prosthetic hand to be gradually improved [43]. A humanoid hand based on bidirectional elastomeric passive transmission (BEPT) was developed. The energy principle was applied to a semi-static BEPT framework to investigate its mechanical properties, and a dynamical model of finger grabbing was conducted. Customized BEPT was chosen following human finger gripping research for its good mimic of the human hand and excellent grasping efficiency [44]. The creation of prostheses by the creative community and non-profit organizations as a novel case study examining the development of technology and the training options available. These design initiatives would be further examined in the context of the medical regulatory environment, and new related clinical trials that aim to assess the impact of such equipment on the quality of life were highlighted [45]. Developing and manufacturing an intelligent, Hybrid Composite Finger (HCF) would enable the finger to perform activities like holding and tapping. The HCF has a hybrid structure that forms the structure that serves as its metacarpal component and a deformable framework to create bending movement similar to the action of the finger. It was motorized by Shape Memory Alloy

(SMA) wires. To achieve humanistic gesture movements and human-like clicking motions, tap a keyboard. A soft hand system with a hand was finally established using four different types of HCFs plus a smart control approach [46]. A flexible hydraulic hand actuator prostheses with self-powered and compressed air using the user's forearm's range of motion was presented. The hand prostheses was small, light, and affordable. A requirement for traditional pneumatic systems was a five-finger hand; this method resulted in a stable, flexible grasp on the target object [47]. A prostheses satisfaction, which might be implemented into healthcare practices for the creation of prostheses, was investigated in terms of prostheses effectiveness. Electroencephalogram (EEG) signals were entered into the prostheses' with basic brain-computer interface, which in turn activates actuators through wires to move the 3D-printed fingers and wrist. After conducting both mechanical and electrical simulations to evaluate the reaction to loading situations, a sensitivity analysis was carried out to verify the prostheses' effectiveness [48]. A prototype of a mechanical finger with several joints was developed. The model has been modified using experimental information gathered using digital image correlation and taking friction phenomena in the finger into consideration. To analyze finger configurations with respect to closure performance and write phalange biomechanics relations using the model. Besides, in free mode and with objects present, it was possible to determine the tendon stress and the work analysis that occurred during the activities [49]. An Euler-Lagrangian method in conjunction with an electro-thermo-mechanical prototype-depend on transfer function was evaluated. Three power magnitudes were applied to the Twisted Coiled Polymer (TCP) during the experiments, and the angular displacements of the index finger's muscles tended to correspond with the power levels that were measured. This model would aid in comprehending how the movements of the robotic finger were affected by the TCP muscles and other comparable smart [50]. Additionally, a prosthetic hand depending on the anatomy of the human hand was discussed. The hand phalanges were created using Polylactic acid and 3D printing. The practical outcomes presented the value of soft joins for manipulating objects and adapting to their surfaces. Furthermore, by including situations and classifications in the electromyogram sensor, the force-sensitive detectors enable the prostheses to actuate more naturally [51]. Further, utilization of 3D printing in the eventual fabrication of upper prostheses was used. It focuses on various 3D printing techniques and thermoplastic testing methods. An open-source myoelectric bionic hand from Hackberry was employed as the experimental object. To replicate flexion in a tip-pinch grasp, the fingers were dynamically tested [52]. A technique using shape evaluation and force application to determine how a manipulator was illustrated with an autonomous grasping strategy based on essential form evaluation. By taking into account the manipulator's various surfaces and constructing a grasping performance assessment mechanism based on the force spiral, the ideal grasping attitude was attained [53]. A development of an effective grasp assumptions and the formulation of a new measurement to evaluate stability with human similarity for the most common grasp kinds in normal living activities and the cylindrical grip. In contrast to the other technique, the proposed simulation benchmark produced was more humanistic and accurate grasps of the items' intended use. Although a simulation model has significant drawbacks, the benchmark offered offers intriguing results for choosing the best DAs to achieve steady performance [54]. An attempt was made to create a mechanical limb using schematics that could be easily customized for each patient. The information about a planar four-link method, its design and evaluation processes, and potential upgrades has been described as a result [55]. A MERO hand is revolutionary compliant rolling-contact element (CORE) joint-based automatically robust anthropomorphic prosthetic hand, was developed and evaluated. The hand could resist significant disarticulation and robust impact, according to experiments. The hand could execute a variety of adaptive grasps as well as in-hand manipulations, indicating that the suggested design would be an effective option for a powerful prosthetic hand [56]. A method for specifying upper limb prostheses that were sized and shaped to closely resemble a patient's amputated arm was described. The process to replace the lost arm utilizing computer tomography (CT) pictures of the mirrored form of the unaffected arm was described. The supporting structures, molds, and sockets were all created utilizing computer-aided design techniques. Researchers describe the procedure where silicone material was cast onto 3D-printed molds to mimic the size and form of the lost limb [57].Lastly, a soft bionic hand with a practical requirement-driven architecture was demonstrated. The suggested X-limb was capable of satisfying the robotic, kinodynamic, and operational requirements with system designs that were in line with the specific requirements. The X-capacity limb's ability to complete real-world grasping activities demanded by a typical activities measure for upper-limb prosthetic benchmark assessment was put to the test by completing them [58]. A full hand prostheses with five fingers that grasp various objects has been shown in figure 6.

Figure 6. Full hand prostheses with five fingers that grasp various objects a) pinch, power and tripod gripping [5], b) griping objects with various size [15], c) hand performance in grasping objects [57], d) Comparison of the hand and prosthetic hand [26], e) the act of handling objects [44].

3. Considerations

FP is used for cases that suffer from amputation of the finger under working conditions, whether the amputation is complete or complete partial supplementary finger and limb sizes are also available for any amputated part. FP are an artificial support that helps to fix the finger in the hand in a professional and distinctive manner. Which helps a person to move the hand and fingers like normal. It is manufactured with many different materials, and the person can choose the appropriate type for him in the freedom of installation and in the movement itself. Prosthetic limbs for the fingers provide compensation for the amputated part in an appropriate manner for the size and color of the palm itself, and thus manufactured with very high efficiency. Through these limbs, it can move the fingers very freely, and they are also able to contract and relax naturally. These limbs also compensate the person for the loss of one of the limbs of the amputated fingers, and are also characterized by their light weight. Here it find that the prosthetic part performs the same tasks as the same natural part of the movement of the fingers by bending or straightening, as it can develop pen-holding and writing skills very naturally. However, it must has a physical characteristics such as weight, functionality, durability, appearance, grasp characteristics, number of phalanges, compactness, design flexibility, biocompatible materials manufacturing process, natural motion, shape, adaptively, and pinching motion. Table 1, summarized articles describing the comparisons among the different partial hand in terms of the mean idea, weight, program, number of finger, number of joints, number of degree of freedom, and captured objects.

Table 1. Performance metrics for examinations of reviewers in various terms.

Reff./year	**Main idea**	**Weight**	**Program**	**No. of finger**	**No. of Joints**	**No. of DOF**	**Captured objects**
[1] 2018	Case report	N.A.	Open source grab -cad	Two	N.A.	N.A.	Shovel
[2]2019	Functional evaluation	N.A.	N.A.	Five	N.A.	One	cubes and mug
[4]2020	Mechanical model	Lightweight	N.A.	Three	N.A.	N.A.	Mug, pen, ball, CD, and cylinder.
[5]2021	Mechanical prototype	29 gram	N.A.	Five	N.A.	N.A.	Cylinder, bottle, screwdriver, and ball
[7]2019	Mechanical model	Lightweight	LS-DYNA software	Five	N.A.	One	N.A.
[9]2019	Mechanical model	N.A.	Arduino	Five	Sixteen	N.A.	Ball, key, cube, cylinder, card, and tennis ball.
[10]2018	Case report	N.A.	N.A.	Two	N.A.	N.A.	Spoon, pen, cylinder, and card.
[11]2020	Mechanical model	263.90 gram	3D CAD	Five	N.A.	N.A.	Ball.
[13]2021	Mechanical model	N.A.	Abaqus	Five	N.A.	Fourteen	N.A.

[15]2019	Electro-mechanical model	N.A.	N.A.	Five	N.A.	Two	Ball, Slippery wallet, soda bottle.
[17]2019	Prosthetic robotic	N.A.	Arduino	Two	Two	Three	Cylinder container
[18]2019	Myoelectric prosthetic	N.A.	CAD and Arduino	Five	N.A.	Six	N.A.
[19]2021	Mechanical challenges	1.58 Kgram	N.A.	Four	N.A.	N.A.	Paper cup, sandwich
[22]2019	Kinematics and dynamics analysis(mechanical systems)	N.A.	MATLAB SimMechanics and SolidWorks	Five	N.A.	Fifteen	N.A.
[23]2021	Myoelectric prosthetic	N.A.	Matlab	Five	N.A.	N.A.	N.A.
[24]2022	Case report	N.A.	CAD	Two	N.A.	N.A.	Peg board training
[26]2021	Electro-mechanical model	430 gram	bidirectional elastomeric passive transmission	Five	N.A.	N.A.	raw eggs and paper cup
[27]2019	Case report	N.A.	N.A.	One	Two	Two	Box and Block
[28]2021	Case report	N.A.	N.A.	One	Two	Two	N.A.
[31]2021	mechanical model	N.A.	CAD	One	One	N.A.	N.A.
[34]2022	Electro-mechanical model	N.A.	Genetic algorithm	One	Three	N.A.	N.A.
[35]2022	Electro-mechanical model	light	3D-CAD	Five	One	One	Chocolate cone in a cup and PET bottle
[36]2022	Functional evaluation	Simulation	Arduino	Five	Five and	N.A.	Cubes

					four		
[38]2020	electro-thermo-mechanical model	N.A.	Simulink ® model	Five	Three	N.A.	Ping pong ball, cone, and cylinder.
[39]2020	mechanical model	light	N.A.	One	One	One	Pencil.
[42]2020	mechanical model	light	Mesh mixer 3D modelling software	One	One	One	Tip pinch, lateral pinch, and cylindrical grip.
[43]2020	mechanical model	light	N.A.	One	One	One	N.A.
[44]2020	Electro-mechanical model	480 gram	Arduino	Five	N.A.	Fifteen	tennis ball, pencil, and notebook
[47]2021	mechanical model	N.A.	N.A.	One	Three	Three	N.A.
[48]2022	mechanical model	N.A.	Abaqus CAE	Three	Two	N.A.	N.A.
[49]2022	mechanical model	N.A.	3D-CAD	Three	Two	N.A.	Spray bottle, Apple, Piece of pasta, Piece of paper, Pen, and Book.
[50]2022	mechanical model	N.A.	3D-CAD	Five	Three	Fifteen	Cylindrical and cubic.
[52]2022	Simulation model	N.A.	3D-CAD	Five	Two	N.A.	Pen, coin, drill, can, and cylindrical.
[54]2021	mechanical model	N.A.	Solid work	Four	N.A.	N.A.	Cylinder, glass.
[55]2020	mechanical model	light	3D-CAD	Three	N.A.	N.A.	spray bottle, card, tomato, conchiglie pasta, and pen
[56]2020	Electro-mechanical	N.A.	N.A.	Two	Three	Six	Cuboid, cylinder, triangular prism, triangular

	model						pyramid, cone, sphere and ellipsoid.
[57]2020	Electro-mechanical model	253 g	Flash Forge	Five	N.A.	Three	Bottle, mobile, spoon, egg, tennis ball, and bulb.
[58]2020		Simulation	Matlab	Four	N.A.	N.A.	Cylinder
N.A.= Not Available							

4. Conclusion

This paper offers an explanation of PHP ideas and problems, as well as a suggestion for the architectural design of items that are either not discussed or not included at all and were left for further consideration. The systematic investigation examined the variations in PHP and included experimental attempts in the studies. Weight, grip qualities, design flexibility, manufacturing process for biocompatible materials, shape, adaptability, and pinching action are all physical aspects, which are engineering specifications and formal system analysis. An ideal PHP item that can replace what has been lost is not yet in existence. This review article compares, summarize, and contrasts several academically researched and proposed prosthetic options.

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6. Reference

[1]. J. Ten Kate, G. Smit, and P. Breedveld, "3D-printed upper limb prostheses: a review," *Disability and Rehabilitation: Assistive Technology,* vol. 12, pp. 300-314, 2017.

[2]. E. Difonzo, G. Zappatore, G. Mantriota, and G. Reina, "Advances in finger and partial hand prosthetic mechanisms," *Robotics,* vol. 9, p. 80, 2020.

[3]. E. Neha, M. Suhaib, and S. Mukherjee, "Design Issues in Multi-finger Robotic Hands: An Overview," *Advances in Engineering Design,* pp. 335-343, 2019.

[4]. A. Ghilan, A. P. Chiriac, L. E. Nita, A. G. Rusu, I. Neamtu, and V. M. Chiriac, "Trends in 3D printing processes for biomedical field: opportunities and challenges," *Journal of Polymers and the Environment,* vol. 28, pp. 1345-1367, 2020.

[5]. P. Kumar, D. K. Rajak, M. Abubakar, S. G. M. Ali, and M. Hussain, "3D Printing technology for biomedical practice: A review," *Journal of Materials Engineering and Performance,* vol. 30, pp. 5342-5355, 2021.

[6]. S. R. Kashef, S. Amini, and A. Akbarzadeh, "Robotic hand: A review on linkage-driven finger mechanisms of prosthetic hands and evaluation of the performance criteria," *Mechanism and Machine Theory,* vol. 145, p. 103677, 2020.

[7]. A. Bayrak and E. Bekiroglu, "Bionic hand: A brief review," *Journal of Bionic Memory,* vol. 2, pp. 37-43, 2022.

[8]. F. Alkhatib, J.-J. Cabibihan, and E. Mahdi, "Data for benchmarking low-cost, 3D printed prosthetic hands," *Data in brief,* vol. 25, p. 104163, 2019.

[9]. I. Ku, G. K. Lee, C. Y. Park, J. Lee, and E. Jeong, "Clinical outcomes of a low-cost single-channel myoelectric-interface three-dimensional hand prostheses," *Archives of plastic surgery,* vol. 46, pp. 303-310, 2019.

[10]. M. Sharif, D. Erdogmus, C. Amato, and T. Padir, "Towards End-to-End control of a robot prosthetic hand via reinforcement learning," in *2020 8th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob)*, 2020, pp. 641-647.

[11]. Y. Yabuki, K. Tanahashi, Y. Mouri, Y. Murai, S. Togo, R. Kato, *et al.*, "Development of new cosmetic gloves for myoelectric prosthetic hand using superelastic rubber," *Robotics and Autonomous Systems,* vol. 111, pp. 31-43, 2019.

[12]. T. H. Wong, D. Asnaghi, and S. W. W. Leung, "Mechatronics enabling kit for 3D printed hand

prostheses," in *Proceedings of the Design Society: International Conference on Engineering Design*, 2019, pp. 769-778.

[13]. S. Cribbs, M. Gebremariam, and B. White, "Assisting Partial Hand Amputees with Grasping Soft Objects."

[14]. A. Q. Swartz, K. Turner, L. Miller, and T. Kuiken, "Custom, rapid prototype thumb prostheses for partial-hand amputation: A case report," *Prosthetics and Orthotics International,* vol. 42, pp. 187-190, 2018.

[15]. P. Alvial, G. Bravo, M. P. Bustos, G. Moreno, R. Alfaro, R. Cancino*, et al.*, "Quantitative functional evaluation of a 3D–printed silicone-embedded prostheses for partial hand amputation: A case report," *Journal of Hand Therapy,* vol. 31, pp. 129-136, 2018.

[16]. A. H. Khan, F. N. Khan, L. Israt, and M. S. Islam, "Thumb Controlled Low-Cost Prosthetic Robotic Arm," in *2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*, 2019, pp. 1-6.

[17]. M.-Y. Lee, S. H. Lee, J.-H. Leigh, H. S. Nam, E. Y. Hwang, J. Y. Lee*, et al.*, "Functional improvement by body-powered 3D-printed prostheses in patients with finger amputation: Two case reports," *Medicine,* vol. 101, p. e29182, 2022.

[18]. K. J. Young, J. E. Pierce, and J. M. Zuniga, "Assessment of body-powered 3D printed partial finger prostheses: a case study," *3D Printing in Medicine,* vol. 5, pp. 1-8, 2019.

[19]. D. Panchik, G. C. Feeney, A. A. Springer, C. G. VanBrocklin, and H. E. Winters, "Designing a 3D Printed Prosthetic to Meet Task-Specific Needs: A Case Study," *Internet Journal of Allied Health Sciences and Practice,* vol. 19, p. 1, 2021.

[20]. F.-F. Raduica, I. SIMION, and E. Ionita, "A STUDY ON PARAMETRIC DESIGN OF LINE TENDON BASED PROSTHETIC FINGER USING PROGRAMMING TECHNIQUES," *Journal of Industrial Design and Engineering Graphics,* vol. 16, pp. 4-10, 2021.

[21]. I. A. Baqer, W. A. Soud, and M. R. Ahmed, "Design optimisation for a novel underactuated robotic finger by genetic algorithms," *Australian Journal of Mechanical Engineering,* vol. 20, pp. 397-405, 2022.

[22]. H. Kim, Y. Park, and J. Bae, "Optimized design of a body-powered finger prostheses using fingertip trajectories based on polar coordinate analysis," *Journal of Mechanical Science and Technology,* vol. 34, pp. 387-399, 2020.

[23]. B. Štefanovič, M. Michalíková, L. Bednarčíková, M. Trebuňová, and J. Živčák, "Innovative approaches to designing and manufacturing a prosthetic thumb," *Prosthetics and orthotics international,* p. 0309364620949717, 2020.

[24]. D. Belvončíková, L. Bednarčíková, M. Michalíková, B. Štefanovič, M. Trebuňová, V. Mezencevová*, et al.*, "Development of Mechanism for Finger Prostheses," *Acta Mechanica Slovaca,* vol. 24, pp. 6-11, 2020.

[25]. S. Liu, M. Van, Z. Chen, J. Angeles, and C. Chen, "A novel prosthetic finger design with high load-carrying capacity," *Mechanism and Machine Theory,* vol. 156, p. 104121, 2021.

[26]. Z. Li, Z. Hou, Y. Mao, Y. Shang, and L. Kuta, "The development of a two-finger dexterous bionic hand with three grasping patterns-NWAFU hand," *Journal of Bionic Engineering,* vol. 17, pp. 718-731, 2020.

[27]. R. Alturkistani, S. Devasahayam, R. Thomas, E. L. Colombini, C. A. Cifuentes, S. Homer-Vanniasinkam*, et al.*, "Affordable passive 3D-printed prostheses for persons with partial hand amputation," *Prosthetics and Orthotics International,* vol. 44, pp. 92-98, 2020.

[28]. L. O'Brien, E. Cho, A. Khara, J. Lavranos, L. Lommerse, and C. Chen, "3D-printed custom-designed prostheses for partial hand amputation: Mechanical challenges still exist," *Journal of Hand Therapy,* vol. 34, pp. 539-542, 2021.

[29]. F. Buccino, A. Bunt, A. Lazell, and L. M. Vergani, "Mechanical Design Optimization of Prosthetic Hand's Fingers: Novel Solutions towards Weight Reduction," *Materials,* vol. 15, p. 2456, 2022.

[30]. K. Setty, T. Van Niekerk, R. Stopforth, K. Sewsunker, and A. du Plessis, "Design and Kinematic Analysis of a Multi-Grip Hand–Touch Hand 4," *International Journal of Mechanical Engineering and Robotics Research,* vol. 11, 2022.

[31]. E. Neha, S. Mukherjee, M. Suhaib, and Y. Shrivastava, "An effort for determining the actuating forces in a multi-finger tendon-driven robotic hand for grasping different objects," *Journal of the Brazilian Society of Mechanical Sciences and Engineering,* vol. 43, pp. 1-11, 2021.

[32]. K. Setty, T. van Niekerk, and R. Stopforth, "Design Considerations of the Touch Hand 4," *Procedia CIRP,* vol. 91, pp. 494-502, 2020.

[33]. E. Neha, M. Suhaib, S. Asthana, and S. Mukherjee, "Grasp analysis of a four-fingered robotic hand based on matlab simmechanics," *Journal of Computational & Applied Research in Mechanical Engineering (JCARME),* vol. 9, pp. 169-182, 2020.

[34]. J. S. Cuellar, G. Smit, P. Breedveld, A. A. Zadpoor, and D. Plettenburg, "Functional evaluation of a non-assembly 3D-printed hand prostheses," *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine,* vol. 233, pp. 1122-1131, 2019.

[35]. J. S. Cuellar, D. Plettenburg, A. A. Zadpoor, P. Breedveld, and G. Smit, "Design of a 3D-printed hand prostheses featuring articulated bio-inspired fingers," *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine,* vol. 235, pp. 336-345, 2021.

[36]. F. Alkhatib, E. Mahdi, and J.-J. Cabibihan, "Design and analysis of flexible joints for a robust 3D printed prosthetic hand," in *2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR)*, 2019, pp. 784-789.

[37]. R. C. d. Silveira Romero, A. A. Machado, K. A. Costa, P. H. R. G. Reis, P. Paiva Brito, and C. B. Santos Vimieiro, "Development of a passive prosthetic hand that restores finger movements

made by additive manufacturing," *Applied Sciences,* vol. 10, p. 4148, 2020.

[38]. A. Bastarrechea, Q. Estrada, J. Zubrzycki, V. Torres-Argüelles, E. Reynoso, A. Rodríguez-Mendez*, et al.*, "Mechanical design of a low-cost ABS hand prostheses using the finite element method," in *Journal of Physics: Conference Series*, 2021, p. 012039.

[39]. L. A. Pozzobon, R. da Silva Guerra, and G. R. Librelotto, "A low-cost, compliant, underactuated prosthetic hand with custom flex sensors for finger bending estimation," in *2019 19th International Conference on Advanced Robotics (ICAR)*, 2019, pp. 69-74.

[40]. N. Nahid, A. Rahman, T. K. Das, K. M. Khabir, A. Islam, and M. S. Alam, "Design and implementation of DUFAB Hand, a low-cost myoelectric prosthetic hand," in *2019 Joint 8th International Conference on Informatics, Electronics & Vision (ICIEV) and 2019 3rd International Conference on Imaging, Vision & Pattern Recognition (icIVPR)*, 2019, pp. 206-211.

[41]. T. H. Wong, D. Asnaghi, and S. W. W. Leung, "Mechatronics Enabling Kit for 3D Printed Hand Prostheses," *Proceedings of the Design Society: International Conference on Engineering Design,* vol. 1, pp. 769-778, 2019.

[42]. S. S. Ahmed, A. R. Almusawi, B. Yilmaz, and N. Dogru, "Design and multichannel electromyography system-based neural network control of a low-cost myoelectric prostheses hand," Mechanical Sciences, vol. 12, pp. 69-83, 2021. [43] Y. Huang, "Investigation on life-like 3D printed prosthetic hand," *International Journal of New Developments in Engineering and Society,* vol. 4, 2020.

[43]. T. Chen, X. Zhao, G. Ma, B. Tao, and Z. Yin, "Design of 3D-printed Cable Driven Humanoid Hand Based on Bidirectional Elastomeric Passive Transmission," *Chinese Journal of Mechanical Engineering,* vol. 34, pp. 1-11, 2021.

[44]. A. Manero, P. Smith, J. Sparkman, M. Dombrowski, D. Courbin, A. Kester*, et al.*, "Implementation of 3D printing technology in the field of prosthetics: past, present, and future," *International journal of environmental research and public health,* vol. 16, p. 1641, 2019.

[45]. H. Jin, E. Dong, M. Xu, and J. Yang, "A smart and hybrid composite finger with biomimetic tapping motion for soft prosthetic hand," *Journal of Bionic Engineering,* vol. 17, pp. 484-500, 2020.

[46]. K. Nishikawa, K. Hirata, and M. Takaiwa, "Development of Self-Powered 5-Finger Pneumatically Driven Hand Prostheses Using Supination of Forearm," *Journal of Robotics and Mechatronics,* vol. 34, pp. 454-465, 2022.

[47]. E. O. Ige, A. Adetunla, A. Awesu, and O. K. Ajayi, "Sensitivity Analysis of a Smart 3D-Printed Hand Prosthetic," *Journal of Robotics,* vol. 2022, 2022.

[48]. C. Cosenza, V. Niola, and S. Savino, "A simplified model of a multi-jointed mechanical finger calibrated with experimental data by vision system," *Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics,* vol. 235, pp. 164-175, 2021.

[49]. L. Saharan, L. Wu, and Y. Tadesse, "Modeling and simulation of robotic finger powered by nylon artificial muscles," *Journal of Mechanisms and Robotics,* vol. 12, p. 014501, 2020.

[50]. L. Dunai, M. Novak, and C. García Espert, "Human hand anatomy-based prosthetic hand," *Sensors,* vol. 21, p. 137, 2020.

[51]. J. Koprnicky, J. Šafka, and M. Ackermann, "Using of 3D printing technology in low cost prosthetics," in *Materials Science Forum*, 2018, pp. 199-206.

[52]. Y. Liu, D. Jiang, B. Tao, J. Qi, G. Jiang, J. Yun*, et al.*, "Grasping posture of humanoid manipulator based on target shape analysis and force closure," *Alexandria Engineering Journal,* vol. 61, pp. 3959-3969, 2022.

[53]. I. Llop-Harillo, J. L. Iserte, and A. Pérez-González, "Benchmarking anthropomorphic hands through grasping simulations," *Journal of Computational Design and Engineering,* vol. 9, pp. 330-342, 2022.

[54]. Y. E. Kahraman, M. Madan, B. Sağbaş, and N. M. Durakbasa, "Parametric Design and Modeling of 3D Printed Prosthetic Finger," in *The International Symposium for Production Research*, 2020, pp. 80-90.

[55]. H. Liu, K. Xu, B. Siciliano, and F. Ficuciello, "The mero hand: A mechanically robust anthropomorphic prosthetic hand using novel compliant rolling contact joint," in *2019 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, 2019, pp. 126-132.

[56]. J.-J. Cabibihan, M. K. Abubasha, and N. Thakor, "A method for 3-d printing patient-specific prosthetic arms with high accuracy shape and size," *IEEE Access,* vol. 6, pp. 25029-25039, 2018.

[57]. A. Mohammadi, J. Lavranos, H. Zhou, R. Mutlu, G. Alici, Y. Tan*, et al.*, "A practical 3D-printed soft robotic prosthetic hand with multi-articulating capabilities," *PloS one,* vol. 15, p. e0232766, 2020.

[58]. Jameel, H. F., Mahmood, M. F., Hammed, M. A. N., (2022). A Review of Robotic System to Assist Unhealthy Persons: Architecture, Components, and Challenges. *Global Scientific Journal of Biology*. 7(1): 61-81.