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Occupational Therapy Resource Guide for the Utilization of Three-Dimensional Printing

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OCCUPATIONAL THERAPY RESOURCE GUIDE FOR THE UTILIZATION OF
THREE-DIMENSIONAL PRINTING

by

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A Scholarly Project Submitted to the Occupational Therapy Department

of the

University of North Dakota

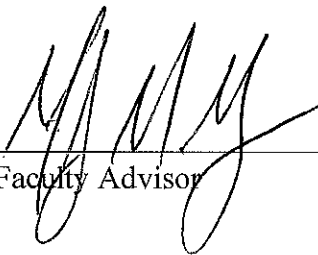
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Master's of Occupational Therapy

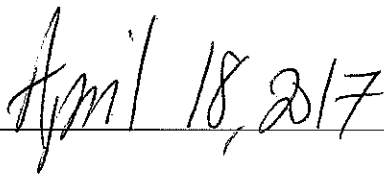
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ABSTRACT

Many practitioners in the field of occupational therapy are unaware of the benefits and importance of implementing a three-dimensional (3D) printer in practice indicating that there is a need for occupational therapy involving the fitting, environmental modifications, and training on how to properly use a 3D printed prosthetic within the upper extremity. 3D printing is when a digital design is converted into a designed material that has a functional purpose and different materials can be used including metal, plastics, and composite materials (Thomas & Claypole, 2016). 3D printing has many unique and effective uses like creating adaptive devices, feeding devices, prosthesis, and splinting. While 3D printing is currently being implemented across certain pediatric populations creating prosthesis, a lack of evidence was noted regarding the use of a 3D printer throughout occupational therapy. (Burn, M. B., Anderson, T., & Gogola, G. R., 2016). This is unfortunate as 3D printing is an innovative field of study that can aid many populations in becoming more independent and functional in daily tasks while increasing quality of life.

A comprehensive literature review on the populations that utilize printing was conducted. The lack of occupational therapy involvement in the transition process of creating and training for the use of a 3D prosthetic, yields the demand for occupational therapy services. The information obtained aided in the development of a resource guide containing the importance of occupational therapy services involved with the transition process of a 3D printing. The literature review led the authors to focus on the main areas

of rehabilitation phases, splinting and prosthetics, adaptive equipment, 3D printers, printing filaments, and various safety considerations.

The integration of occupational therapy in 3D printing will greatly ease the clients' transitions during rehabilitation phases while increasing their level of function and quality of life. 3D printing is a cost effective, user-friendly, creative, and innovative approach to add to practice. 3D printing is an up-and-coming area of occupational therapy and has the potential to change lives.

CHAPTER I

INTRODUCTION

There is an estimated 541,000 individuals in the United States that suffer from an upper limb deficiency in a given calendar year, many of which reported that they did not receive an adequate number of therapy visits. Of these reports, the overall cost was the number one limiting factor. (Zungia et al., 2016 & Domerick et al., 2008). With the use of 3D printing, the cost of a prosthetic can be dropped from upwards of \$50,000, to \$50. 3D printing is defined as an additive process that creates a three dimensional product from consecutive layering of various materials (Hughes & Wilson, 2016 & Domerick et al., 2008).

The issue of significance is directly related to the use of 3D printing, and the integration of occupational therapy services. The use of 3D printing in the scope of occupational therapy provides endless possibilities. Specifically within the areas of prosthetics, splinting, and adaptive equipment, 3D printing provides a readily available, and affordable option to those in need. With the cost of prosthetics, splints, and pieces of adaptive equipment, often difficult for those in need to purchase, and maintain the

quality upon reception of the piece. 3D printing offers a cost effective, uniquely designed approach that will allow occupational therapists to broaden their scope of practice, as those in need will be able to afford the equipment, splints, and prosthetics they need to increase their quality of life and performance range. The population of interest in regards to 3D printing and occupational therapy is predominantly children. This is a result of the filament strength, as the durability is limited and children do not often perform occupations requiring heavy loads. Another predominant reason as to why children are the main population of interest is due to their ever changing physical and psychosocial selves'. With current prosthetic costs ranging from \$25,000-\$50,000, children are often unable to fit their prosthetics over time and cannot afford to purchase a new one prior to insurance covering the medical expenses (Burn, Anderson, & Gogola 2016).

The use of 3D printing offers children a \$50 prosthetic that yields both increased quality of life physically and mentally. The uniquely designed prosthetics provide the children with “super hero” limb, which lessens the stigma of limb differentials at a growing period for children (Zungia et al.,2016). The prosthetic offers children to broaden their peer supports, while improving in physical performance of meaningful occupations as well. Children are not the only population appropriate for the use of 3D printing,

as it may be used across the life span for a wide variety of opportunities to increase quality of life through broadening performance range.

The type of interventions being proposed to increase performance range includes an upper extremity rehabilitation protocol, while integrating the 3D printed prosthetic training process within. If the protocol is followed accurately, the “golden window” of the rehabilitation phases should be met, yielding a 100% return to work, and 93% success rate overall within the first 3 months of rehab (Smurr et al., 2008). The timeliness and versatility of 3D printing will allow for greater access to prosthetics when needed. The promotion of 3D printed adaptive equipment and splinting is also incorporated throughout intervention strategies. These interventions include opportunities within splinting and adaptive equipment realm, and what possibilities are capable within these areas of practice. These capabilities are essentially endless, as unique splinting and pieces of adaptive equipment are ever changing.

Various factors that will influence the application of 3D printing into occupational therapy practice are as follows:

- Advanced technology training with the use of up and coming technologies and medical equipment.

- Timelines with the development of 3D printed material
- Durability of 3D printed filament throughout the life span
- Funding for the expenses of a highly credible 3D printer
- The pros and cons of 3D printing compared to traditional prosthetic development
- The availability and accessibility of 3D printers and filaments to those in need
- Affordability of 3D printed products compared to current price ranges

To guide the process, the theory used throughout the project is the Ecology of Human Performance model (EHP). This model was chosen because it encompasses many aspects involved with upper limb differentials, such as the person, the context, the tasks, and the overall human performance. The EHP model can be used across disciplines, with a focus on the environment and overall performance range of the task at hand. The EHP model will address all aspects of the task allowing for the most comprehensive, client focused approach to address the patient's meaningful task. The use of the EHP model will yield an increased performance range within the patient by setting up the appropriate environment. If used correctly, the EHP model will guide 3D printing and its practice across the health care spectrum (Turpin & Iwama, 2011).

In chapter II, a comprehensive literature review examines the needs for those who have suffered from an upper limb differential, and where the use of 3D printing has great potential. Chapter III includes a description of how the overall product, the Occupational Therapy Resource Guide for the Utilization of Three-Dimensional Printing, was developed which includes phases from pre-reception of a prosthetic, to various pieces of technology used to increase ones performance range throughout the process. Chapter IV supplementary introduces and contains the product. A summary of the project is included in chapter V, which includes limitations, recommendations, and justifications that were discovered throughout the process of project development.

CHAPTER II

REVIEW OF LITERATURE

Three-dimensional printing

Three-dimensional printing is an ever-fast growing and developing portion of a variety of professional practices like occupational therapy, physical therapy, prosthesis, rehabilitation, and medicine, among many others. The use of three-dimensional printing is becoming more widely known across professions as technology continues to improve. A large variability of possibilities and opportunities are available with new developing technologies of three-dimensional printing. Three-dimensional printing can create items like architectural models, industry-wide prototypes, human tissues, hearing aids, braces for teeth, assistive devices, therapeutic toys and tools, anatomical models, orthotic components, adaptive equipment, and prosthetics among other functional products (Hughes & Wilson, 2016; Janson, 2015).

Process of three-dimensional printing

Carl Deckard, Joe Beaman, and Paul Forderhase worked together in 1981 to develop the process of Selective Laser Sintering (Hughes & Wilson, 2016). Selective Laser Sintering consists of using a computer design to

develop a three-dimensional product using laser beams to fuse the powdered particles together, which is often a powdered polymer build material typically known as nylon. Later in 1984, Charles Hull created the first three-dimensional printer (Janson, 2015). Overtime, new technologies developed and the three-dimensional printing industry began to emerge. Additive manufacturing is often used as a term holding the same meaning as three-dimensional printing (Huges & Wilson, 2016). Three-dimensional printing, in today's literature, can be known as rapid prototyping and solid freeform fabrication (Huges & Wilson, 2016).

Laser sintering is a process that utilizes a laser to create the desired three-dimensional model and a Fused Deposition Model (FDM) works by layering small layers of a plastic material one on top of the other to create the finished three-dimensional product (Paterson et al., 2015).

Stereolithography utilizes a liquid polymer to create a three-dimensional model with the use of a laser beam (Paterson et al., 2015). Polyjet material jetting via Objet Connex works similarly to a inkjet printer, but instead of putting ink on a piece of paper, it uses liquid photopolymer to form a three-dimensional product by building layers upon layers (Paterson et al., 2015).

Dr. Andrian Bowyer developed the replicating rapid prototype in 2005, which is a program that allows people to create a FDM three-

dimensional printer (Hughes & Wilson, 2016). FDM is used in the process of the prototyping and production of the three-dimensional product. Due to the fact that the Stratasys Company coined the FDM in the early 1980s, Dr. Bowyer used the term fused filament fabrication (Hughes & Wilson, 2016).

According to Burn et al. (2016), the process used to create and print a prosthetic limb is referred to as material extrusion, or FDM. FDM is readily available to the general public, and at a more affordable rate than current technologies of myoelectric or body-powered prosthesis. The FDM can be broken down into 5 major components, which are as follows:

1. Hot end: This is referred to as the heating element that melts the desired material, most likely thermoplastic filament, which is the first step in the extrusion process to beginning printing a three-dimensional product.
2. Cold end: This device is responsible for feeding the filament into the hot end to create an extrusion force.
3. X, Y, & Z Axes: each of these axes works together to allow for a three-dimensional motion throughout the printing process.
4. Print bed: The surface within the machine where the three-dimensional printed product is produced.

5. Motherboard: This device is essentially what controls the x, y, and z axes, along with what temperatures the hot end and printing bed are set to.

According to Silva et al. (2016), the process of three-dimensional printing encompasses the consecutive addition of two-dimensional layers to create the three-dimensional construct. The creation of the final product of the three-dimensional construct uses thin layers that harden or cure when exposed to ultraviolet light (Silva et al., 2016). The three-dimensional object under production is designed by using a three-dimensional computer-aided design, which is then saved to a file call a stereolithography file (Hughes & Wilson, 2016).

Janson (2015) continues to explain that three-dimensional printers have specific settings to help determine how much plastic will be needed to create the final product, temperature setting, and what type of plastic should be used. The three-dimensional computer-aided design programs may include Autodesk Maja 2011 (Autodesk, San Rafael, CA, USA), Geomagic Studio 2012 (3D Systems, Rock Hill, SC, USA); McNeel Rhinoceros Version 4.0 (Robert McNeel & Associates, Seattle, WA, USA); PTC Pro/Engineer Wildfire 5.0 (PTC, Needham, MA, USA); and FreeForm Modeling Plus (3D Systems, Rock Hill, SC, USA). These software design

programs may be used to create customized wrist splints, among other adaptive equipment.

Paterson, Donnison, Bibb, and Campbell (2014) explain that the use of the layering mechanism, to create the three-dimensional product, allows users to be endlessly creative by building almost any geometrical project with design freedom without major increase in cost to build. The process of three-dimensional printing is similar to the way a regular household inkjet printer works (Paterson et al., 2014). Instead of using ink cartridges to print a single layer of ink to a piece of paper, the three-dimensional printer uses a special material called resin to help create the layers to build the three-dimensional construct (Paterson et. al, 2014). The resin is the material that is cured to harden with the exposure of the ultraviolet light (Silva et al., 2016; Paterson et al., 2014).

Zungia et al. (2016) discussed the materials and machines used to develop a three-dimensional shoulder prosthetic for children to allow for increased quality of life and functional use for unilateral and bilateral daily activities. The three-dimensional printer used to develop the device was the autodesk inventor. The three-dimensional printer utilized the materials of polylactide plastic, acrylonitrile butadiene styrene, and taulman nylon. Other materials utilized in the finalization of the prosthetic included: spectra

prosthetic cable, cable housing, circular magnets, screws of various sizes, thrust bearings, springs, elastic cords, velcro, and foam. Per patient report, despite the advancements in technology and myoelectric prosthetics, a lightweight, body powered prosthetic is preferred in children for functional use and flexibility (Zungia et al., 2016).

Overall cost of three-dimensional printers.

According to the Wohlers Report in 2016, the three-dimensional printing industry developed by 25.9% as a corporate annual growth rate to \$5.1 billion. Specifically occupational therapy can benefit from the use of three-dimensional printing by utilizing printers to quickly develop low cost assistive devices, assistive equipment, splints, and anatomical models for use in both educational and professional practice purposes. According to Hughes and Wilson (2016), three-dimensional printers can range from to \$300 to over \$5000. Janson (2015) explains that a quality three-dimensional printer can be purchased for approximately \$600 and up. When considering purchasing a three-dimensional printer it is important to consider the type of customer service made available with purchase of the printer, types of accessories that come with or are available, type of filament, and the construction of the printer (Hughes & Wilson, 2016).

Customer service is an important piece to consider during the purchase of a three-dimensional printer because support may be required from the company in the future regarding warranty or user situations that require additional support from the purchasing company. Some accessories that may or may not be included with the purchase of the three-dimensional printer include USB cables, wrenches to service the printing head, on board LCD screen, memory cards, power supply, or a plastic printer filament (Hughes & Wilson, 2016). Paterson et al. (2014) indicated while using three-dimensional printing, it is important to take into consideration the cost, the limited selection of processes and materials, accessibility and affordability of equipment, and how quickly different materials are changing. When selecting a three-dimensional printer, it is always important to complete research on the printer of purchase to ensure that a good-quality printer is being purchased and will serve its appropriate purpose.

Zungia et al. (2015) describes the development of the Cyborg-beast, a three-dimensional printed prosthetic designed for children with hand deformities leading to decreased functional use, as a rather simple process. The plastic pieces of hand are developed through the use of a three-dimensional printer, and a cord is placed on the dorsal aspect of the digits allowing for passive finger extension. Finger flexion is produced by non-

elastic cords along the palmar surface of the digits, and is activated through the use of 20-30 degrees of wrist flexion. With the use of everyday materials, the cost of the Cyborg beast is surprisingly affordable, around \$50 in the United States of America (Zungia et al., 2015).

Implications

Smurr, Gulick, Yancosek, & Ganz (2008) developed a protocol for success, encompassing five phases of rehabilitation. Phase one addressed wound healing and acute management, phase two incorporates the introduction of prosthetic training, phase three encompasses the prosthetic training, phase four places an emphasis on advanced functional training, and phase five involved planning for discharge. The acute management in phase one emphasizes the healing process and prepping the residual limb for prosthetic fitting.

“The components of phase one include comprehensive evaluation, wound healing, edema control, desensitization, and scar management, pain control, gross motor activity, and psychological support.” (Smurr et al., 2008). Phase one involves learning a new level of independence with daily tasks such as self-feeding, hygiene, and toileting. Daily tasks are important milestones, as the actual reception of the prosthetic is time consuming. Regaining a level of independence with self-cares can aid the patient

dramatically both psychologically and physically. It is important to consider the psychological aspect because occasionally patients have a false hope about the prosthetic process.

Upon further progression through phase one, desensitization is introduced to capture the physical aspect. Desensitization starts with the use of various compression techniques, tapping, and massage (Smurr et al., 2008). The procedures of compression, tapping, and massage were performed between 20-30 minutes, three times a day or as the client's skin tolerates. Desensitization is crucial, as when it is time for the client to wear the prosthetic, their limb must tolerate the wear of the prosthetic socket. As it may be difficult for some clients to perform desensitization techniques, it is important for family members to become educated in the desensitization strategies to aid in the process.

Pain control is a major limiting factor that contributes to clients' progression throughout the prosthetic process (Smurr et al., 2008). Medications that are commonly used when addressing pain in amputees include antidepressants, anticonvulsants, and anti-inflammatories. Modalities and therapeutic strategies used to reduce and or manage pain include electrical nerve stimulation, massage, variations of ice and heat, desensitization, functional tasks that require client to move painful

extremity, and constant psychological support through the use of therapeutic use of self. Psychological support is vital for the success of a client throughout the rehabilitation phase. The psychological support begins from the first day and is integral for developing a cohesive rapport between parties. Per patient report, many psychological issues encompass the area of decreased self-esteem, loss of self-confidence, fear of the unknown, fear of rejection, and loss of occupational roles (Smurr et al., 2008).

Upon completion of phase one, the introduction of subacute management, the bulk of phase two, is introduced. Phase two of the prosthetic rehabilitation includes pre-prosthetic, and introduction to prosthetic training. Preprosthetic training begins with wound healing and closure, and ends with the reception of a preparatory prosthesis. This time frame is inconsistent between clients, as the factors that affect the timeliness include sensitivity, range of motion, residual limb, and psychological status. Education of realistic expectation is an area of emphasis, due to clients having varying perceptions from never being functional again, to having a bionic superhuman arm (Smurr et al., 2008). Watching “feel good” videos about those who have undergone the prosthetic process may have a negative impact on psychosocial symptomatology, as well as meeting face to face with someone to hear their story and journey through the prosthetic process.

If available, it is encouraged that the individuals experiencing limb loss should perform occupation-based activities in the same environment to promote the recovery process and achieve psychological healing through one another (Smurr et al., 2008).

Postural exercise and strengthening are integrated at this time to promote body symmetry and balance enhancements. Due to a weight distribution that many are not familiar with, it is essential to educate the clients' awareness of the altered patterns they may develop as to avoid developing cumulative trauma or compensation overuse injuries. An effective way of doing so is to perform both isotonic and isometric strengthening exercises with the use of a mirror to provide direct feedback to the patient on their proper form. Depending on therapy progression and functional capabilities with the prosthetic limb, a change in hand dominance is introduced as seen necessary. Smurr et al. (2008) stated that individuals who are fit with prosthesis within roughly 30 days of their amputation date exhibit a 93% rehabilitation success rate and a 100% chance of returning to work within a 4 month time period. Those who are fit with a prosthetic beyond 30 days exhibit a 42% rehabilitation success rate with a 15% chance of returning to work between six and 24 months. The 30-day time frame from amputation date to prosthetic fitting date is termed as the "golden

window” and success rates with rehab and functional capacity differentiate astonishingly.

Phase three is a crucial segment of the prosthetic process, one of which many clients look forward to from the beginning. This phase incorporates the introduction of the prosthetic training. Throughout this phase, it is important to educate patients on the amount of time they should be wearing their prosthesis at once, which is between 15-30 minutes, two to three times daily. Upon completing a skin evaluation, as well as indicating no evidence of skin breakdown or redness, the patient may increase their wearing time with the prosthetic by 30 minutes. To achieve further independence in daily living activities, the following are of emphasis: education of the operation and performance of the specified prosthesis, initiation of control training, and finally initiation of activities of daily living training. Several computer guided software programs are available that facilitate neuromuscular re-education, such as the MyoBoy software. The MyoBoy software is a computer based exercise program that tracks muscle firing to aid in retraining the muscles to fire independently from one another by participating in various tasks (Smurr et al., 2008).

Advanced prosthetic training, phase four, is where a majority of the functional training begins, where normal body patterns are emphasized to

promote energy conservation, decreased stress on the limb, and efficiency when completing a given task. There are five characteristics of advanced prosthetic training. The first characteristic is that rehabilitation is extremely individualized, and practitioners must know the person's meaningful occupations and approach rehab from a holistic perspective. The second requires the use and operation of an object, tool, cooking utensil, or machine that aids the person in completing their meaningful occupation. The third characteristic is having the client complete a multistep task that requires several bimanual movements to encourage bilateral hand usage and practice efficiency throughout. The fourth is that all advanced training should be with the client's choice of prosthetic type. The fifth characteristic of advanced prosthetic training is there must be a meaningful outcome upon completion of the task. Unfortunately, the walls of a clinic cannot prepare one for community integration upon discharge, which is why prosthetic training must be complete in the natural environment when available.

It is essential that during the prosthetic and advanced prosthetic training phases, meaningful occupations are completed within a functional community setting, to aid in the carry over upon discharge (Smurr et al., 2008). The fifth and final phase of rehabilitation is planning for discharge. If the above protocol is followed effectively, discharging the client to their

appropriate setting should allow for safe, productive, and successful carry over of all learned strategies to increase independence and quality of life (Smurr et al., 2008).

Occupational Therapy and Three-Dimensional Printing

As occupational therapists are upper extremity specialists and approach a patient from a holistic approach, the high rates of rejection indicate a need for occupational therapy to become more involved in the transition process of children receiving upper extremity prosthetics (Burn, Anderson, & Gogola, 2016). Domerick et al. (2008) studied the effects of motor learning in the prosthetic performance process, and concluded that one third of clients who suffered an upper extremity injury, including amputations, reported lack of an adequate number of therapy visits and that the cost was the largest limiting factor in the reception of adequate prosthetic training. By occupational therapy incorporating three-dimensional printing into the practice setting, it may allow for lower cost of prostheses that will increase adequate prosthetic training for patients whose limiting factor is cost.

By involving occupational therapists in the rehabilitation and recovery process of prosthesis, three-dimensional printing can begin to be

incorporated. By using three-dimensional printing therapists can develop customized prostheses that are easily reproduced at a lower cost than current the cost of prosthesis. Three-dimensional printing in occupational therapy can be used in a variety of ways such as assistive devices, educational purposes through the use of three-dimensional models, splinting, and much more. Three-dimensional printing gives occupational therapy endless opportunities for future research and utilization of a three-dimensional printer in the practice setting.

According to Janson (2015) using three-dimensional printing is in the beginning stages of becoming a part of the occupational therapy practice. Using three-dimensional printing can be especially beneficial in the use of occupational therapy interventions and assistive devices. It is an often occurrence where a recipient of a prosthetic is not within functional limits when assessing activities of daily living. Galvez et al. (2015) describes how being the recipient of a transplant or prosthetic can be very emotional and difficulty for a patient and family members. With the process being emotionally, and physically challenging to begin with, experiencing difficulties with functional tasks and improper fitting can only compound these stressors and prolong achieving success. With the use of three-dimensional printed models prior to prosthetic fitting, the accuracy of fitting

a recipient with a functional and proper fitting prosthetic will increase leading to a positive correlation with functional task performance.

Families reported improvements in functional tasks within the children and the bilateral functional tasks yielded improvements such as grabbing a large ball, however, unilateral activities were still difficult due to low grip strength within the prosthetic (Zungia et al., 2016). While utilizing a grasp pattern within the prosthetic, carrying lighter objects such as grocery bags was much more efficient and functional. Limitations of the shoulder prosthetic were low grip and pinch strength and durability. Similarly, Herbert, Simpson, Spence, and Ion (2005) discovered was that with the use of three-dimensional printing, the prosthesis sockets were easily developed and performed adequately in the area of function. However, the sockets did not prove to withstand use overtime, and mechanical characteristics of the sockets require future assessment to increase durability. Maximal grip strength was measured around .85kg and .4kg of pinch strength. Galvez, Gralewski, McAndrew, Rehman, Chang, & Levin (2015) assessed the functional capabilities of three-dimensional printed models of a patient's forearms to ensure a proper fitting hand transplant. A CT scan was performed on the patient's forearms, and a model was created at 80%, 100% and 120% size in relation to the patient's CT scan. The models were then

used to compare sizes to potential donors, to ensure the most appropriate fit for the recipient. This protocol may also be transferred to the process of developing prosthetics for a given patient population to ensure the most accurate and functional fit for the recipient, yielding success in occupational participation.

Occupational therapists can incorporate the use of three-dimensional printed models based on CT scans of the recipient to reduce the emotional toll of the process by ensuring proper fitting of the prosthetic and promote success in shorter periods of time which can lead to steady satisfaction and increased motivation levels of the recipient. Dromerick, Schabowsky, Holley, Monroe, Markotic, & Lum, (2008) stated that the fitting of the prosthetic is a crucial stage in the prosthetic process. Without a perfect fit for the prosthetic, both the therapist and patient will struggle greatly in making functional progression. As a result, rapport developed between both parties will be in jeopardy, increasing the difficulty throughout the prosthetic process. As occupational therapists, the overall prosthetic fitting process requires collaboration with a certified prosthetist. Dromerick et al. (2008), encourages collaboration between occupational therapists and certified prosthetists, as it will enhance the occupational therapists' knowledge base when addressing prosthetics, as well as fostering the relationship between

practices. With collaboration between the two practices of occupational therapy and certified prosthetist, the patients' chances of achieving success will increase, and rejection rates will decrease.

Jo et al. (2016), indicated that students with visual impairments and their teachers saw the importance and the usefulness in using a three-dimensional printing model for educational purposes in the classroom. The students valued the model because it was able to help them improve on their memorization skills and gain a better understanding. Students revealed that the materials used help give a good sense of shapes and helped them to clarify difficult text-based concepts (Jo et al., 2016). The teacher was also able to improve the effectiveness of teaching in the classroom as the three-dimensional printing models allowed for the students to maintain interest and stay better engaged in their own learning (Jo, et al., 2016).

Domerick et al. (2008) conducted a single case study on a 15 year old boy with the participant reporting difficulties with weight, positioning of terminal device, separating glenohumeral flexion from humeral abduction, difficulties with school activities and self feeding with finger foods. The boy would have to rely on his feet to play video games, computer operations, and remote control for his television. The boy participated in 13 sessions of prosthetic training, equaling 19.25 hours within a therapy setting. Various

training and strengthening tasks were completed over this time. Scores were recorded three different times in the Jebsen-Taylor Hand Function Test, Action Research Arm Test, and the Box and block test of manual dexterity. When comparing the first and third scores, the results showed a 300-fold improvement in functional tasks. The above test were chosen to be used in the study because they are amongst the most common measurements used in upper extremity amputee literature, allowing for comparison between clinical experiences (Domerick et al., 2008).

According to Burn, Anderson, & Gogola (2016), the rate of rejection in children with prosthetics is as high as 50%, and reported that rates of rejection increase when focusing on wrist reductions. The top four reasons that a child rejects their prosthetic, some of which can cost upwards of \$50,000, are: limited functionality, high levels of discomfort, heavy weight, and unattractive appearance. With the use of three-dimensional printing, children are allowed to create their own model and design for their prosthetic, at a lighter weight, specialized to their limb reduction, which leads to an overall increase in functional abilities upon receiving proper training.

Therapists using three-dimensional printing in practice

Currently, therapists are using three-dimensional printing in a variety of settings including both practice settings and educational classroom settings. Janson (2015) described that using low cost body powered orthosis prosthesis for occupational therapy student training can allow the students to have the opportunity for hands on learning by custom fitting the prosthesis for students to wear and use for their prosthesis training. The cost of printing the prosthesis used for training is less than \$10. The hands on learning of the prosthesis allows students to learn how to adjust cables and harness tension, don and doff prosthesis, and how individuals wearing the prosthesis use the device to engage in daily occupations (Janson, 2015). However, one limitation of the training device is that it is not made out of material that is thought to be strong enough for heavy daily occupations, students are instructed to use the device for lightweight resistive activities of occupation only (Janson, 2015). Bone models can also be used for education in occupational therapy. Three-dimensional products of bone models of the upper extremity can be created and customized for instructional aids for the students, as well as for clients who better understand with the use of visual aids (Janson, 2015). The three-

dimensional printing of bone models is low cost (approximately \$3) and takes only three hours to complete the final product.

Another way to the use of three-dimensional printing is to create assistive technology devices. By being able to create types of assistive devices for educational purposes, it allows the students to better assess and evaluate the devices to better understand functional outcomes of the assistive devices. Students are also able to make sure the devices are safe to use in all aspects of occupation.

By introducing three-dimensional printing in the classroom it can allow students to become more familiar with how computer-aided design programs work and how to use three-dimensional printers. The use of three-dimensional printers can provide students with the opportunities to collaborate with other disciplines to further learn to create functional assistive devices that have a practical application to the field of occupational therapy (Janson, 2015).

Client populations

According to Zungia et al. (2015), an appropriate and growing client population is children with upper limb differences, as there are an estimated 32,500 children in the United States alone who suffer from major upper limb amputations and an estimated 1 in every 1,000 live births including an upper

limb reduction birth defect. Prosthetics and pediatrics has always been a difficult area of practice when ethics are considered. Children of pediatric age are changing drastically in a short period of time, both physically and mentally. These changes require modifications of the prosthesis to be completed in correspondence to the changes of the children. Unfortunately the average cost for a prosthetic at this age is \$4,000 to \$20,000, which is where the \$50 cyborg beast plays a role in the advancements of three-dimensional printing and prosthetics (Zugia et al., 2015).

An aspect that often goes unrecognized or undermined in the medical community of children with upper limb differences is the psychosocial impact it has on their development within themselves, as well as those relationships around them. The cyborg beast allows for children to modify and adapt their prosthetic in countless ways, making each unique to their personality, and overall more appealing to peers around them. These flexible options with three-dimensional printed prosthetics allow for each prosthetic to be unique to the individual, giving them a sense of independence, and overall diminishing the difficult barriers when developing peer relationships at such a young age.

Zungia et al. (2016) developed a shoulder, elbow, and hand prosthetic based on three-dimensional printing that resemble a superhero's build,

lessening the stigma involved with prosthetics at a young age. Zungia et al. (2016) estimated that in 2005 there were 541,000 individuals in the United States that suffered from an upper limb deficiency, implying there is an estimated 508,500 adolescent or adult individuals who are affected by an upper extremity deficiency. These numbers indicate a large area of practice for occupational therapist to be engaged in, as the upper extremity is a predominant area of focus within the profession.

Splinting.

Splinting is another area of practice that occupational therapists can implement the use of a three-dimensional printer, especially in splinting the upper extremity. Paterson et al. (2015) compared different types of three-dimensional printing for wrist splints. Different three-dimensional printing processes were used to create the customized wrist splints. These three-dimensional printing processes included laser sintering, FDM, stereolithography, and polyjet material jetting via Objet Connex. The processes were then compared to more traditional splinting methods though the use of heating and forming thermoplastic and Velcro fasteners.

To deliver the standard requirement of custom fit, the patient's skin surface topography was required to gather the patient's anatomical data (Paterson et al., 2015). Before additive manufactured splints were

fabricated, three-dimensional computer-aided design splint models were created. A plaster cast was created to provide a repeatable and static data in case a scan needed to be repeated at a later time to develop a new splint during the research process. Paterson et al. (2015) utilized a large variety of computer-aided design programs to assist in creating a specialized computer-aided design program that was able to effectively record and replicate the splint design used by practitioners to create and improve upon the splint using the three-dimensional printer.

The splint prototypes were built following recommendation parameters from suppliers and utilized materials and machines available. Results for the homogeneous three-dimensional textile splint indicated that laser-sintering splint is successful in capturing the intended outcome of an integrated hinge to enhance and allow for easier donning and doffing (Paterson et al., 2015). This splint was strong and able to maintain form when the splint was being worn. The small links and tight textile design used could cause slight discomfort due to arm hair getting caught between the links, however larger links would reduce this (Paterson et al., 2015). Cleaning may be a problem for this splint but researchers placed this splint in the dishwasher with varying temperatures (45, 50, 65 degrees Celsius) along with a brand dishwasher detergent and had no visible after-effects

(Paterson et al., 2015). In contrast, the FDM splint had poor surface quality with obvious layering and stepping (Paterson et al., 2015). This could have an affect on how comfortable the splint at the edges is for the patient and these areas could collect waste products and by unhygienic for a splinting application.

The stereolithography splint was effective for ease of donning and doffing and overall surface quality was considered to be the highest of the entire additive manufacturing splints (Paterson et al., 2015). This splint had smooth surfaces, which enable easy cleaning and reduce hygiene risks. However manual post-processing with abrasives would be required, which adds labor cost and extra resources, because places where supports were removed can cause discomfort for the patient (Paterson et al., 2015). A limitation of this splint is that it enables a reduction in aesthetic possibilities and limited patient choice of pattern.

The polyjet material jetting via Objet Connex splint initially had a visual and tactile surface quality to be acceptable compared to other three-dimensional splints (Paterson et al., 2015). The fastener design and splint structure was able to withstand and perform how it was designed to function. A significant amount of support material was used to construct the splint but extra material was able to be removed via high-pressure water jet.

Paterson et al. (2015) indicated the most inappropriate three-dimensional splinting method was the FDM splint but even though the material is strong, the surface quality of the splint needed adaptations for it to become wearable. Compared to stereolithography, stereolithography proved to have good surface quality and be reasonably strong. Laser sintering and polyjet material jetting via Objet Connex also showed to have advantages and were made feasible by the additive manufacturing process. The heterogeneous splint was the most versatile and is useful in a variety of different situations. According to Paterson et al. (2015), the choice of splint to use in a clinic setting ultimately is up to the patient and the patient's needs.

Adaptive equipment.

Watanabe, Hatakeyama, and Tomiita (2015) completed three case studies to improve assistive technology service through the use of three-dimensional printing. In case study one, the participant is a student with physical and intellectual disabilities who attends high school. The participant has difficulty holding a spoon but is able to scoop up food and put it in his mouth. An occupational therapist, teacher, and engineer developed a prototype for three-dimensional printing and used trial and error to develop a spoon that best fit the individual. In case study two, the

participant is a person with physical disabilities caused by quadriplegia and uses a personal computer through auto scanning and a custom-made switch to communicate. The switch needs to be replaced due to heavy use.

Through use of three-dimensional printing a new switch is developed that maintains operability, workability, and custom-fit to the participant. In case study three, the participant is an elementary school student with physical, visual, and respiratory disabilities and is bedridden in a supine position. She can communicate through simple commands. Through use of three-dimensional printing the goal is provide her with a switch and circuits that can convert her exhalations into input signals (Watanabe et al., 2015). To make things more convenient for family members, caregivers, and teachers a microphone holder will need to be developed that is customized to the patient using three-dimensional printing (Watanabe et al., 2015).

In case study one, the participant was able to trial multiple different shaped spoons and was able to make copies and new copies to replace old devices that have been damaged through the use of three-dimensional printing. In case study two, the participant was able to have the appropriate devices remodeled and custom fit to increase independence. By using three-dimensional printing, it created the potential to transmit expertise and skills by incorporating knowledge about individual adjustments by computing data

(Watanabe et al., 2015). In case study three, the use and application of three-dimensional printing allowed prior experience to be applied to a new case. Various devices could be redesigned through the use of three-dimensional printing. Watanabe et al. (2015) described clinical significance through the use of three-dimensional technology production operations can be improved and contribute to development products that have multiple users and large amounts of data to be combined into one product. Another benefit with using three-dimensional printing was that the data was saved to the computer-aided design program, which allowed for spare copies to be made and new copies to be made to replace old spoons that may be broken or worn out by overuse (Watanabe et al., 2015).

Testing to track progression of three-dimensional services

The Unilateral Upper Extremity Amputation: Activities of Daily Living Assessment is a likert type scale, that a client or clinician can perform that allows them to assess their functional capabilities in various activities of daily living (ADL). The ratings are from “0-3”, “0” indicating impossible, and “3” indicating minimal delays or awkward movements. The categories of this assessment include personal needs, eating procedures, desk procedures, general procedures, housekeeping procedures, use of tools, and car procedures. This assessment can be used to track functional progression

throughout the prosthetic training process, as scores may be compared and contrasted between various dates (Smurr et al. 2008).

Domerick et al. (2008), utilized the Jebsen-Taylor Hand Function Test, Action Research Arm Test, and the Box and Block test of manual dexterity to track progression throughout a case study report. The above assessments, specifically the Box and blocks test of manual dexterity, are amongst the most popular assessments used in UE amputee rehabilitation, allowing for comparison between disciplines and various research comparisons. The Jebsen-Taylor Hand Function Test is a test that evaluates a range of hand functions that are required within ADLs (Raad, 2012). It consists of seven subtest that are completed by using both the dominant hand and the non-dominant hand (Radd, 2012). The seven subtests include: writing a 24-letter sentence, card turning, picking up small common objects and placing them in a container, stacking checkers, simulating feeding, moving light objects, and moving heavy objects. The test measures the unilateral hand function of the patient indicating that a lower score is equal to greater the function (Raad, 2012). The Box and Blocks test evaluates the unilateral hand function of gross manual dexterity (Ali, 2010). For this test the patient sits in front of a box that is divided into two different parts and is instructed to move as many blocks to the other side of the box one block at a

time, as fast as possible. The patient's hand must cross the partition for the blocks to be counted as points. The higher the score the better the unilateral gross manual dexterity the patient is capable of (Ali, 2010).

Future possibilities

An upcoming area of practice in medicine is the use of telehealth. Zungia et al. (2015) evaluated the effectiveness of distance fitting of the a 3D printed prosthetic, which incorporated the measurements taken based on pictures. These measurements include “hand length (tip of the middle finger to center of the wrist joint, palm width (widest region of the palm above the base of the thumb), forearm length (center of the wrist joint to center of the elbow joint), forearm width at three-fourths (width of the forearm at proximal three-fourths of the length of the forearm proximal to the wrist)...and range of motion of the wrists (extension and flexion...” (Zungia et al., 2015). Measurements were taken by a certified occupational therapist, which was the only portion of the research in which occupational therapists were referenced and involved. Zungia et al. (2016) stated that of the many individuals who are suffering from upper limb deficiency, children are amongst the population that has not been receiving properly fitted and effective prosthetic.

With the advancement in computer-aided design, enhanced software, and the development of three-dimensional printing materials, the opportunities for children to receive an affordable, and effective prosthetic are increasing. With the growing population of children receiving a functional prosthetic, occupational therapy will have yet another scope of practice in which upper extremity specialists, who focus on quality of life through functional activities, will be able to provide appropriate training for children on how to use a prosthetic device to promote independence, and increase level of participation in desired tasks. According to Patterson et al. (2015), further research is needed to assess the usability of different three-dimensional splint designs on a range of activities of daily living.

According to Burn et al. (2016), anyone with access to the Internet can obtain blueprints of three-dimensional hand prosthetics. Not only can they access the blueprints, they can also modify them to properly fit a specific child, and share their contributions online afterward. As many third world countries do not have access to advanced healthcare, the online access allows for millions of others to potentially receive a prosthetic specified to themselves or their loved ones. The websites these blueprints can be discovered at are 3dprint.nih.gov and <http://enablingthefuture.org>. As the future of technology seems endless, it will be crucial that the collaboration

of engineers, clinicians, and most importantly the patients and family members to produce the most efficient, functional, accessible, and affordable medical equipment for those in need.

CHAPTER III

METHODOLOGY

The purpose of the manual is to create a guide for occupational therapists to utilize when implementing the use of 3D printing in occupational therapy practice, and also how to use this manual when treating clients. This manual will incorporate 3D printing in a way occupational therapy practice is unfamiliar with. Within the technology world 3D printing is a fast, changing part, and if occupational therapy practitioners embrace 3D printing it can help to make practice innovative and effective. The manual provides information on important rehabilitation phases to help guide the occupational therapy treatments to ensure rehabilitation is continuing along with the use of 3D printing. The manual also includes information on splinting, prosthetics and adaptive equipment. Multiple case studies are included to help therapists understand real life scenarios of how 3D printing was useful in the different practice areas of occupational therapy. The manual also covers types of 3D printers and filaments used like standard, flexible, and composite. Safety considerations and future possibilities are also included in the manual to aid therapists in the use of 3D printers in the clinic setting. Another valuable piece of this manual is that it

incorporates the use of the Ecology of Human Performance model to assist therapists to be theory based with the use of 3D printing.

A comprehensive literature review on the populations that utilizes 3D printing was conducted. There is a lack of occupational therapy involvement in the transition process of creating and training for the use of 3D in prosthetics, which yields the demand for occupational therapy services. The literature aided in the development of a resource guide containing the importance of occupational therapy services involved with the transition process of a 3D printing.

Through an extensive literature review it is apparent that limited research regarding occupational therapy and 3D printing is available in current research. Prior to creating the product an extensive literature review was conducted. Search results included: OT search keywords: Three-dimensional printing-no results, 3-D printing-no results, Using 3-D printing-no results; CINAHL: Three dimensional printing- 137, Three dimensional printing + occupational therapy 3, Three dimensional printing + hand therapy 1, Three dimensional printing + splint 5, Additive Manufacture- 9, Additive manufacture + 3-D printing- 0; ClinicalKey: Three dimensional printing (specialty in Physical Medicine & Rehabilitation) 84; Canadian Journal of Occupational Therapy:

3-D printing 0, Three dimensional printing 0; PubMed: Three dimensional printing 1512,

(3D printing) AND hand therapy- 6, ((OT) AND 3D printing) OR three dimensional printing- 1549, (Three dimensional printing) AND

Occupational therapy- 1, (Occupational therapy) AND 3D printing- 1,(3D printing) AND therapy- 429

(three dimensional) AND occupational therapy- 99, 3d printing prosthesis- 471.

After a literature search and review was conducted, the problem and purpose of the product was developed. The Ecological Human Performance (EHP) model and rehabilitation frame of reference was then used to create a manual for occupational therapists to utilize 3D printing in their practice.

EHP model was chosen to help occupational therapists increase the client's performance range by setting up the environment for success. The therapist is ultimately utilizing the intervention strategies to increase the amount of tasks the client is able to perform within his or her own environment. By providing the client with three-dimensionally printed adaptive equipment, splint, or prosthesis the therapist can restore old skills, establish new skills, or create situations to promote success in meaningful occupations. Since this model is interdisciplinary the therapist will better be able to explain the

use of three-dimensional printing to colleagues of different disciplines, which aids in advocacy. Through the use of the model, frame of reference, and literature review, the most important, pertinent topics were developed, which make up the manual.

Throughout the completion of the manual, an online search was completed of actual products created through 3D printing. The website thingiverse.com was utilized to get the dimensions and plan about the desired product. The technology director of the simulation center assisted in the process of transferring the data needed to create the product to the 3D printer. Actual products that were created include a right and left prosthetic hand referred to as a cyborg beast, an adapted spoon, and other various small products. Pictures of products created through the use of a 3D printer were scattered throughout the manual, to show occupational therapists that 3D printing is applicable to use in a variety of ways within a clinic setting for populations across the lifespan with varying diagnoses.

CHAPTER IV.

PRODUCT

Occupational Therapy Resource Guide for the Utilization of Three- Dimensional Printing



<http://www.3ders.org/images2015/e-nable-outlines-plan-give-6000-3d-printed-prosthetic-hands-2017-00005.jpg><http://www.3ders.org/images2015/e-nable-outlines-plan-give-6000-3d-printed-prosthetic-hands-2017-00005.jpg>

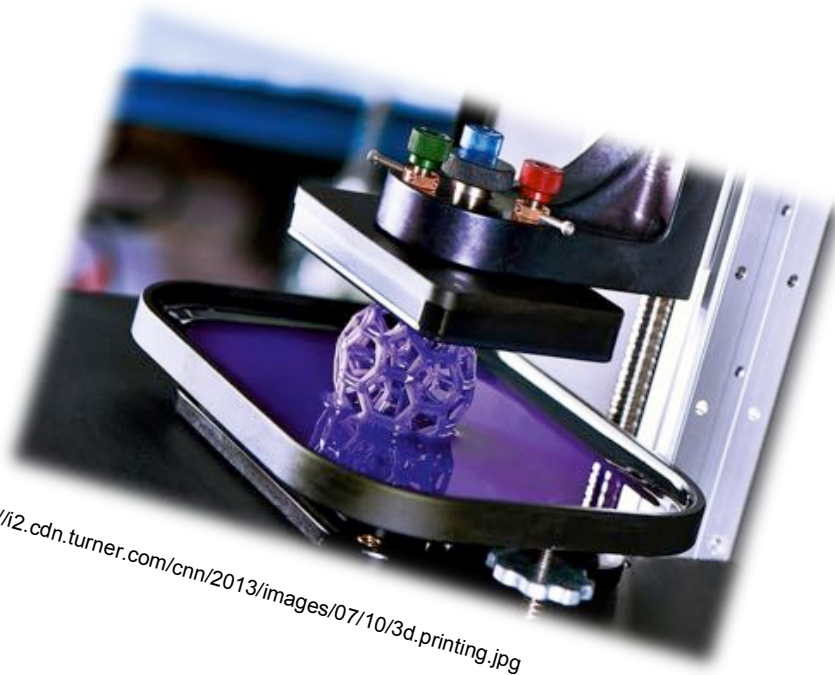
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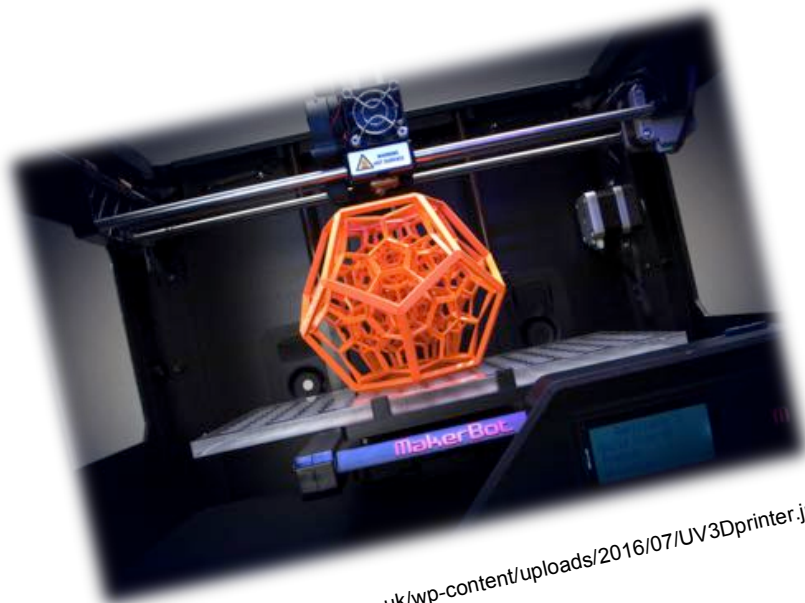
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<http://i2.cdn.turner.com/cnn/2013/images/07/10/3d.printing.jpg>

Introduction



<http://www.3dprinterhub.co.uk/wp-content/uploads/2016/07/UV3Dprinter.jpg>

Purpose

The purpose of this manual is to create a guide for occupational therapists to utilize when implementing the use of three-dimensional printing in occupational therapy practice and how to best use three-dimensional printing when assisting clients. This manual will initiate the beginning of innovative thinking in regards to applying new technology of three-dimensional printing to practice and increase the number of tasks and optimal performance during their meaningful occupations. Three-dimensional printing is continuing to grow and becoming a useful tool across a variety of professions. Three-dimensional printing allows for a lower cost price to create adaptive equipment and splinting more efficiently and effectively for clients and families (Hughes & Wilson, 2016). Specifically, instead of prosthetics costing thousands of dollars, three-dimensional printed prosthetics can be developed for much less expensive (approximately \$50 for a hand prosthesis). Having a three-dimensional printer in an occupational therapy practice clinic can allow therapists to increase creativity skills and be more client-centered with the use of best practice for a variety of different populations. Through the use of three-dimensional printing the therapist can change the environment through

adapting and modifying to help the client increase the amount of tasks within his or her performance range.



Description

This product consists of educational information about three-dimensional printing to assist occupational therapists interested in adaptive equipment, splinting, and/or prosthetics, to utilize technology to support clients in modifying, adapting, or creating successful opportunities within his or her own environment through the use of the clients strengths.

Throughout the product, the therapist will gain information about types of three-dimensional printers, material used in three-dimensional printing, safety considerations, and use for adaptive equipment, splinting, and prosthetics. Within this product, case studies are provided to help the occupational therapists gain a better understanding of how the three-dimensional printer can provide clients with an increased performance range to perform tasks within his or her environment.

Model: Ecology of Human

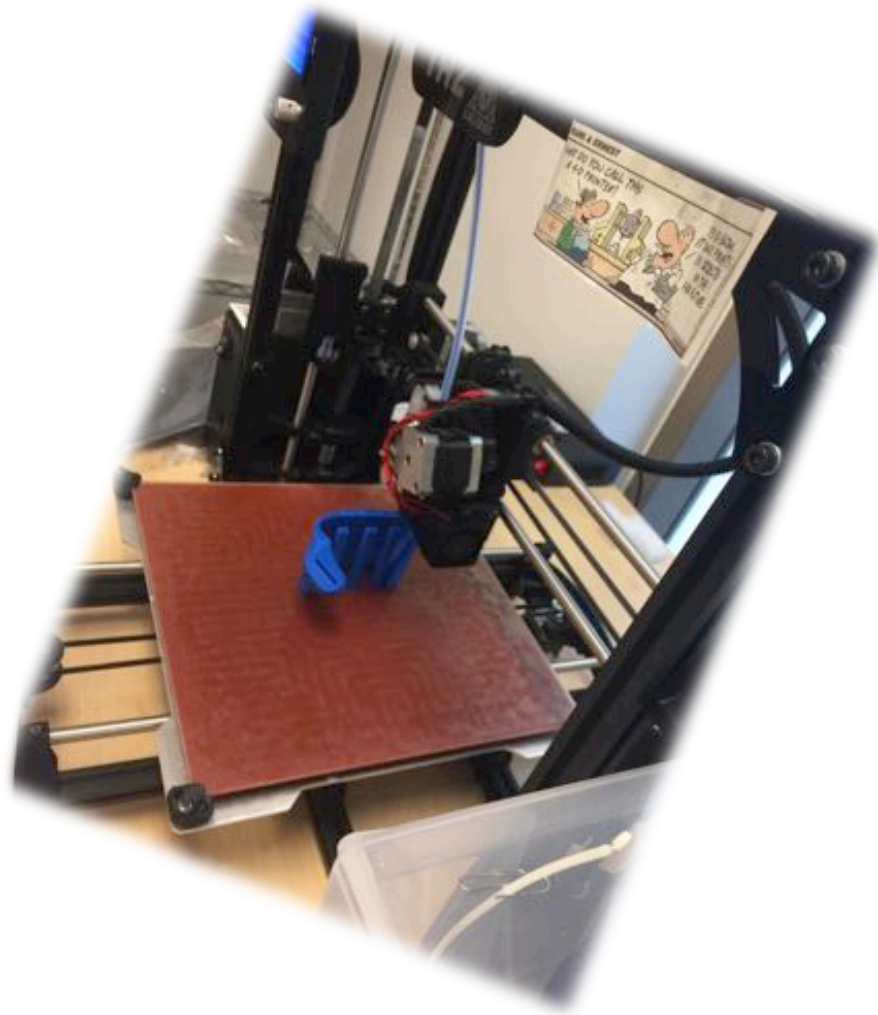
Performance (EHP)

The EHP model focuses on four main components including the person, the context, tasks, and human performance. The EHP is designed for interdisciplinary teams and highlights the environment as being the main context in which the performance range of tasks needs to be understood (Turpin & Iwama, 2011). When considering the environment surrounding the person, it is important to consider that the environment is able to shape the person's task performance and there is more to the environment than the physical context (Turpin & Iwama, 2011). Environment may include physical, temporal, social, and cultural components. The set of tasks that a person engages in within his or her environments is the performance range (Turpin & Iwama, 2011). The supports and barriers of the environment affect the performance range. By therapeutically developing the person's environment it can lead to an increase in the performance range, which enables the person to be more function and complete more tasks (Turpin & Iwama, 2011).

Therapeutic interventions, specific to EHP, include establish/restore, alter/change, adapt, prevent, and create (Turpin & Iwama, 2011). These therapeutic interventions are consistent with the American Occupational Therapy Association Practice Framework. Establish/restore is meant to establish new skills or restore previous skills and abilities that have been lost (Turpin & Iwama, 2011). Alter/change is to select a different environment or change the actual environment in a way to help the person successfully increase performance range of tasks (Turpin & Iwama, 2011). Adapt is to modify the context or task demands to better match the person's task performance abilities (Turpin & Iwama, 2011). Prevent is to aim to inhibit maladaptive task performance within the environment (Turpin & Iwama, 2011). Create is to develop situations that encourage task performance within the environment (Turpin & Iwama, 2011).

Within this product the EHP model is utilized to help therapists increase the clients' performance range by setting up the environment for success. The therapist is ultimately utilizing the intervention strategies to increase the amount of tasks the client is able to perform within his or her own environment. By providing the client with three-dimensionally printed adaptive equipment, splint, or prosthesis the therapist can restore old skills, establish new skills, or create situations to promote success in meaningful

occupations. Since this model is interdisciplinary the therapist will better be able to explain the use of three-dimensional printing to colleagues of different disciplines.



Frame of Reference: Rehabilitation

The rehabilitation frame of reference focuses adaptation, compensation, and environmental modifications to improve the functional occupational independence of clients (Gillen, 2014). The rehabilitation frame of reference uses the clients' strengths to improve and/or increase engagement in meaningful occupations (Gillen, 2014). A top down approach is utilized to better understand functional difficulties to adapt, modify, or compensate to increase independence with desired activities.

The rehabilitation model can be used alone or with another frame of reference or model. Within this product the rehabilitation frame of reference will be used to compliment the EHP model. The rehabilitation frame of reference will be used within this product to guide therapist way of thinking during the five rehabilitation phases created in this product to help clients with physical difficulties perform more tasks within his or her own environment. Through these phases the therapist will be recommended to focus on what the client can do and the strength of the client, instead of the limitations. By focusing on the strengths, the therapist will be able to adapt, modify, or compensation for the environment to promote functional independence and provide the client with the tools needed to be successful.

Rehabilitation Phases

Introduction

Smurr, Gulick, Yancosek, & Ganz (2008) developed a protocol for success encompassing five phases of rehabilitation, that when followed allow for the greatest chance for success with those suffering from a limb differential. Phase one addresses wound healing and acute management, phase two incorporates the introduction of prosthetic training, phase three encompasses the prosthetic training, phase four places an emphasis on advanced functional training, and phase five involves planning for discharge. Psychosocial limitations are addressed throughout the rehabilitation process, and are of a strong emphasis in the early stages.

Phase One

When addressing phase one of the rehabilitation process, the first step in any occupational therapy service is providing a comprehensive evaluation. This includes any physical disability, or psychosocial based evaluation that assesses the person holistically. The following are evaluation tools that occupational therapy practitioners could utilize when evaluating those who have suffered an upper limb difference across the lifespan.

<u>Assessments</u>	<u>Description of Assessment</u>
Activity Index & Meaningfulness of Activity Scale	Examines what activities hold significant meaning within the elderly population.
Adaptive Behavior Assessment System-Second Edition (ABAS Second Edition)	Evaluates the level of adaptive skills amongst children and adults.
Adolescent Role Assessment (ARA)	Evaluates the occupational role of adolescents across domains
Allen Cognitive level (ACL) Screen	Cognitive assessment that yields a suggested treatment approach.
Assessment of Motor and Process Skills (AMPS)	Objective assessment of process and motor skills when performing familiar functional tasks.
Barthel Index	Assesses patients abilities to participate in daily living activities.
Beck Anxiety Inventory (BAI)	Assesses the severity of anxiety in adult populations.
Beck Depression Inventory-II (BDI-II)	Detects severity of depression in various client populations.
Berg Balance Scale	Balance assessment across 14 standing activities

Borg Numerical Pain Scale	Self-assessment of pain
Box & Blocks Test	Assessment fine and gross motor coordination across the lifespan.
Canadian Occupational Performance Measure – 4 th Edition (COPM)	Client centered measurement to evaluate change in a client’s perception of occupational performance.
Child Behavior Checklist (CBCI)	Given to caregiver or parent to record child’s competencies and or problems.
Children’s Assessment of Participation and Enjoyment (CAPE)	Assesses the child’s participation in everyday activities, outside of a mandatory school setting.
Children’s Handwriting Evaluation Scale (CHES)	Reliable measure of rate and quality of handwriting.
Cognitive Performance Test (CPT)	Evaluates existing cognitive processing deficits that affects participation and performance of daily activities.
Competency Rating Scale	A self reported instrument that allows clients to rate their perception of difficulty in relation to tasks and functions.
Functional Independence Measure (FIM)	Measures performance in activities of daily living, such as toileting, communication, self-care tasks, transfers, and social participation.
Functional Reach Test	Assesses balance impairment during reaching task.
Independent Living Scales (ILS)	Evaluates level of competency when addressing instrumental activities of daily living.
Interest Checklist/NPI Interest Checklist	Gathers information in regards to a person’s interests and characteristics.
Kohlman Evaluation of Living Skills (KELS)	Measures level of independence in the area of ADL’s, to determine current status, and where the focus of rehabilitation should be located.

Leisure Interest Profile for Adults	Aids in selecting play/leisure activities to aid in practicing client centeredness
Model of Human Occupation Screening Tool (MoHOST)	Provides an overview of the client's occupational functioning status in the areas of volition, habituation, skills, and environment.
Nine Hole Peg Test	A measurement of finger dexterity across the lifespan.
Occupational Circumstances Assessment-Interview Rating Scale (OCAIRS)	Assess the client's occupational adaptation
Outcome and Assessment Information Set, B-1, M0640-M0800 (OASIS)	Assesses client's ability to perform ADL/IADL's within the home.
Purdue Peg Board	Provides an evaluation of fingertip dexterity and its relation to hand and arm activity.
Role Checklist (RC)	Provides an assessment of what roles a client fulfills in their adult lives.
Volitional Questionnaire (VQ)	A tool used to assess one's volition through observation.

OT Assessment Index. (2012). Retrieved November 04, 2016, from <https://mh4ot.com/resources/ot-assessment-index/>

Upon completing the comprehensive evaluation process and gathering information pertinent to the patient, the introduction of physical modalities and limb management begin. Specific to the use of 3-D printed prosthetics and wound management, edema control is essential to ensure a proper fitting. “The most widely accepted, or “traditional” treatment methods for edema resolution and wound healing include retrograde massage, active exercise and passive motion, elevation, various types of compression, modalities such as high-voltage electrical stimulation, ultrasound, laser,

cryo-therapies, and the use of diuretics” (Rodrick, 2010). As Rodrick stated above, there are various methods to manage one’s edema. The following is a charts created for patient and clinician use, one that can be distributed as a home program for edema management.

Elevation

One’s hand must be above heart level at all possible times throughout the day. Use pillows at night to maintain hand position above the heart.

If possible, hold arm straight above head, and move fingers back and forth for 1 minute. Perform this exercise every 1-2 hours throughout the duration of the day.

Retrograde Massage

Extremity should be elevated above the heart, and the massage should be performed with pushing the excess fluid down towards the trunk as demonstrated by the therapist. (As pictured below)



Following the massage, active range of motion exercises should be complete within the given joints affected.

Services, C. R. (n.d.). Retrograde Massage. 1-1. Retrieved October 15, 16, from [https://www.cokerrehab.com/Documents/public/Retrograde Massage.pdf](https://www.cokerrehab.com/Documents/public/Retrograde%20Massage.pdf).

Edema Glove

Wear edema glove to compress hand and reduce swelling when appropriate. Therapist will instruct guidelines and administration of edema glove.

Coban Wrapping

Coban wrap must be wrapped tightly around edematous area, with leaving slight openings at a given point in the skin to observe skin color.

Contrast Bath

Place hot water in a tub that is large enough to place entire edematous area in (roughly 100-105 degrees F). Place cold water in a separate tub that is large enough to place entire edematous area in (roughly 50-55 degrees F).

Place edematous area in hot water for 4 minutes, followed by placing the edematous area in cold water for 1 minute. Repeat this cycle at a minimum of 4 cycles.

End the contrast bath with retrograde massage.

Techniques to reduce swelling in the hand or arm. (2014). 1-1. Retrieved October 12, 16, from http://www.mccn.edu/library/patienteducation/duplicatenetip_/patienteducatio_/exerciseandreha_/techniquestored/TechniquesToReduceSwellingintheHandorArm.pdf

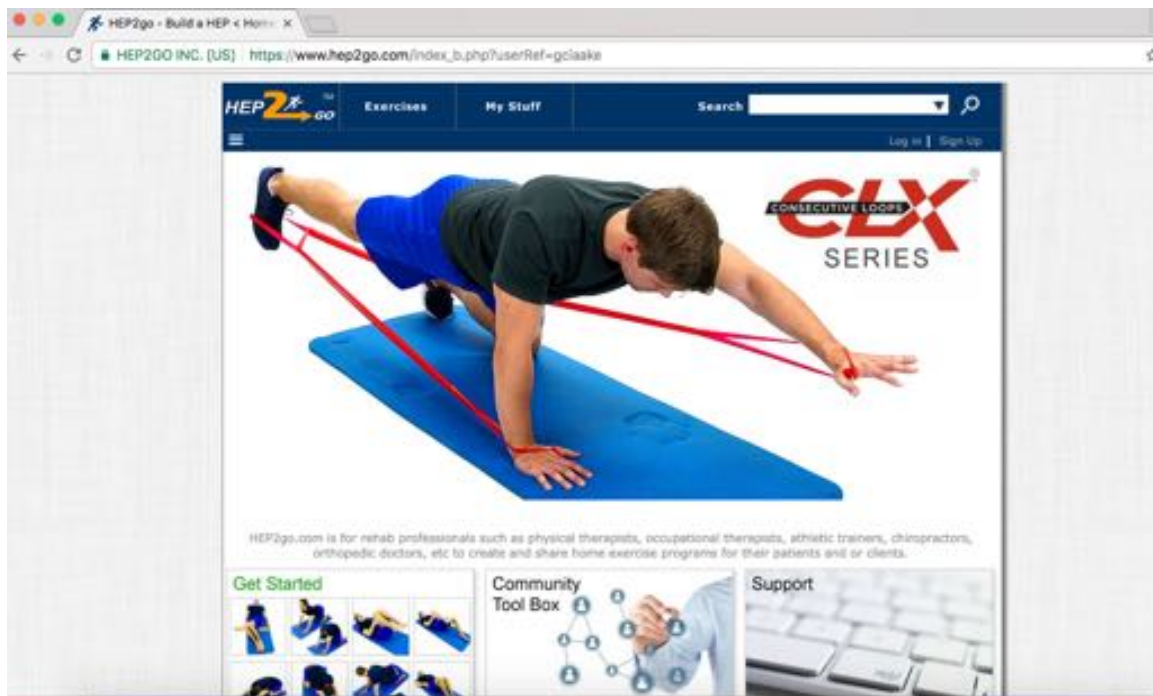
Desensitization, pain control, and gross motor activity are all directly related in the process of ensuring an appropriate prosthetic fit. To begin desensitization on a hypersensitive area in which the 3-D prosthetic will be fitted, one must apply various textures, at various pressures to adapt the limbs sensitivity in preparation for the prosthetic fitting. Silk is often the first material used in the desensitization process, in which it is applied in

various directions with differentiating pressures. As one's hypersensitive area progresses, cotton, velvet, corduroy, and wool are introduced and applied in a similar motion as mentioned above (Smurr, et al., 2008). As desensitization progresses, the level of one's pain will often decrease.

Fortunately enough there are pharmaceutical options that are allotted to patients to aid in pain control, specifically with phantom limb pain. Bach, Noreng, & Tjélliden (1988), reported that those who receive a lumbar epidural blockade (LEB), with bupivacaine and morphine had a reduction in the incidence of phantom limb pain in the first 12 months post limb reduction surgery. This is a great benefit to the patients as it will allow them to make progression in therapy earlier, yielding an earlier fit of the 3-D printed prosthetic. If patients are experiencing high levels of discomfort, the use of pharmaceuticals is a valuable option to aid in pain management.

When tolerable, gross motor activities and exercises will be introduced, in which there are endless opportunities. Gross motor activity will promote proper range of motion, and promote fluid movement to reduce edema and orient the patient to their limb deficiency. Many individuals are unaware of the balance deficits that are encompassed with limb differential, which gross motor activities may be able to address. A great resource to utilize with patients when discussing appropriate gross motor activities and

exercise is the use of www.hep2go.com (As pictured on the following page). This free, online resource allows a therapist to create a simple home program exercise regimen that can be printed and given to patients that allows them to continue their beginning stages of rehabilitation in preparation of receiving the 3-D printed prosthetic.



HEP2go – Build a HEP For Free. (n.d.). Retrieved October 23, 2016, from http://www.hep2go.com/index_b.php?userRef=gclaaake

An aspect that is often overlooked with any physical disability, is the psychosocial impact that is taken on the patient. As a profession, this is an area where occupational therapists set themselves apart from other practicing clinicians. As occupational therapists, we contain the abilities to provide treatment to the patient from a holistic approach, including both

psychosocial deficits and physical dysfunction. Psychosocial deficits play just as important impact on a patient's progression as physical deficits do, if not more. Psychosocial impacts that are common to see within the prosthetic population is depression, decreased self esteem and sense of self, a sense of false hope, feelings of hopelessness, anxiety, maladaptive coping behaviors, and sexual difficulties. With the appropriate, timely reception of the newly developed 3-D printed prosthetic, the psychosocial impacts that are listed above should be diminished. Upon reception of their uniquely designed 3-D printed prosthetic, the patients should gain a greater quality of life. In the beginning stages of the rehabilitation process, it is essential that therapy be focused around the above psychosocial issues, as it is around the physical dysfunction deficits. This is a major area of practice where occupational therapy has an opportunity to display their strengths, which would lead to greater success throughout the rehabilitation process (Desmond & MacLachlan, 2002).

Psychosocial adaptation for those suffering from amputations and limb differentials is an area of the rehabilitation process that is often overlooked. Occupational therapists are uniquely skilled to address both physical disabilities, and psychosocial symptomology in patients in varying diagnoses, which is why they are the perfect fit for an underappreciated area

of practice. Not only are the physical adaptations of utter importance when discussing the early phases of a limb differential, the psychosocial deficits are equally as important. If one has psychosocial limitations present when receiving a 3-D printed prosthetic, the timeliness of progression may decrease leading to further complications. Racy (2002) reported on varying influences that impact ones psychosocial symptomology, and how to manage psychosocial symptoms. Racy (2002) stated that the elderly population often experiences various factors that complicate the adjustment to a limb loss, such as social isolation, financial limitations, decrease in occupational participation, and decreasing health in general. With the above pre-existing limitations, the elderly population is often at risk for developing further psychosocial limitations. The performance range will directly increase as ones social environment increased, yielding a greater quality of life and decreased social isolation. The next area of the individual that was taken into consideration is the personal life style in which the patient lives. Racy (2002) stated that individuals who have lived a previous life that consisted of excessively investing their lives to their physical appearance, and those who have suffered through pre-existing conditions and have lived a timid and self conscious life style are at a higher risk to develop a sense of dysphoria, and suffer from psychosocial limitations. Prior to the progression

in therapy, the client must essentially come to terms, and accept the three phases of body image to allow for progression of psychosocial symptomology. These phases include intact, amputated, and with the prosthesis, and those who cannot adapt and accept the last two will often reject the prosthesis, resulting in difficulty with physical and social adjustments (Kohl, 1984). Shukla (1982) stated that 66% of 72 amputees manifested psychosocial symptoms that included depression, anxiety, insomnia, suicidal ideation, and loss of appetite. Parkes (1984) found that 38 out of 46 amputees suffered psychosocial limitations that included depression, timid behavior self-consciousness, low intelligence, and anger.

It is a regular occurrence that euphoric behavior is reflected due to an increase in motor activity, often times making “jokes” to aid in coping with the residual limb. However, sadness eventually sets in which is why psychosocial symptomology management is crucial in the rehabilitation phase.

When addressing psychosocial limitations in those who have suffered a limb differential, it is essential to include outside support systems, such as family members, and peer supports (Parkes, 1976). If proper support is provided throughout the rehabilitation process, the client’s likelihood of continued depression is lessened, allowing for a steady progression

throughout therapy. In terms of the prosthetic rehabilitation process, the earlier the prosthetic can be applied the better. It has been noted that there are less psychosocial distress in those who receive their prosthetic faster. Racy 2002 reported that those who were interviewed reported that early prosthetic introduction was of utmost importance as it allowed for patients to incorporate emotional efforts as early as possible, as opposed to being focused on the disability and its negativity. Parkes (1973) reported that those who have a prolonged return to work, have a greater likelihood of developing psychosocial distress, which places an emphasis on returning to work within the early stages of the rehabilitation process. If the rehabilitation phases are followed correctly, the timeliness that one receives their prosthetic in should allow for a decrease in psychosocial distress.

Sexuality is an area of ADL's that is often not addressed, however it yields many psychosocial impairments. The three main areas of focus when addressing psychosocial symptomology and limb differentials is the fear of ones body not being accepted by their partner, loss of a functioning portion of their body such as their hands, and the lost of an area of sensation that is meaningful to the (Dise-Lewis, 1989). It is a crucial area of practice that must be addressed when meaningful to the client, as some clients have reported that it took upwards of 15 years before their felt their residual limb

was not an issue during sexual intercourse. Once the psychosocial issues are addressed as mentioned above, ones task performance, and performance range shall increase.

Don't Cry to Give Up
Cry to Keep Goin'
-Eric Thomas

Phase Two

When addressing the pre-prosthetic category of phase two, it very closely resembles the phase one of the rehabilitation process. They are similar in that in phase one, much of the focus is on the wound itself, in terms of range of motion, sensitivity, and edema. These categories often carry over into the beginning segments of phase two. What separates phase one from phase two is the introduction to prosthetic training, continuing psychosocial support, and gross motor exercises of the trunk (Smurr et al., 2008).

An impact that patients often do not consider when a limb is not symmetrical, is the weight distribution differential and how it has the potential to yield decreased coordination in activities of daily living. Due to the decreased coordination, it is important to integrate trunk-strengthening exercises while integrating them with daily functions. As most patients intend to return to a prior living arrangement, it is essential to practice trunk exercises in a natural environment to increase the likelihood of carryover upon discharge. As referenced in phase one, the same website should be utilized when applying strengthening exercises. Upon reaching the above

referenced website, one should follow the below instructions to discover trunk exercises.

**Find the search bar in the upper right hand side of the website ---
> search the word “trunk”---> select appropriate core strengthening--->**

Educate patient on ways to follow exercise program.

The above exercises are used to incorporate core strength in preparation for functional performance in activities of daily living tasks. Once a patient demonstrates adequate core strength, it is time to incorporate functional tasks that one would be performing within the home environment. These tasks can be discovered through interview and observation based assessments, that are motivational and of interest to the patient. Based on clinical impression and interests vary in each patient, the therapist must determine what client centered activities are appropriate for the patient, that would allow for further growth in gross motor coordination in preparation for the reception of the 3-D printed prosthesis. As it is often difficult to instruct and guide a patient in proper techniques while performing gross motor movements, the use of mirror therapy is highly encouraged as the user is able to see and correct their mistakes for themselves. Park et al (2015) found that the use of mirror guided therapy in stroke patients yielded

significant results in the areas of overall function and coordination, as well as performing functional tasks of daily living and self cares.

In phase two there is a period that is referred to as the golden window, which is an optimal time to receive ones 3-D printed prosthetic and begin prosthetic training. This golden window occurs in the first 30 days after amputation, which is when we would like to get the patient fitted for their personalized prosthetic. Smurr et al (2008) states that if a patient receives their prosthetic within the golden window, there is a 93% successful rehabilitation rate, and 100% chance of returning to work within the next 4 months. If the protocol is followed correctly, the patient should not have any complications with receiving the fitting for their prosthesis within the golden window time frame. It is essential that progression of therapy allows for the patient to receive their 3-D printed prosthetic within this time frame to allow for the greatest success in rehabilitation. With the use of the EHP model, the person is a crucial component to achieve an increased performance range. With the above protocol being followed, the person component of EHP should be in an adequate position to aid in the promotion of performance range, yielding an increase in task meaningful task performance.

Phase Three

Phase three is one that each patient is impatiently looking forward to, as it incorporates the introduction of prosthetic training. Prior to beginning the prosthetic training, it is crucial that one must educate the patient on how long they are able to wear their newly received prosthetic. The guidelines call for 15-30 minutes, 2-3 times daily to begin. Upon completion of a skin assessment following the above duration of time, the patient is able to increase the time wearing their prosthetic by 30 minutes (Smurr et al., 2008). Once patient is able to tolerate the wearing of the prosthetic for an appropriate amount of time to participate in therapy, the therapist should begin with education on the operation of the prosthetic, and how to properly manipulate one's body to perform the desired movement of the prosthetic. This education and training will vary from patient to patient, as prosthetics are variant from person to person. Following the education of proper body mechanics, the training of initiation of control should begin. Yoga is a great way to practice in the initiation of control, and below provides a great, user friendly website which provides examples and demonstrations of beginners yoga poses. Following are several beginning yoga poses that increase initiation of control with one's body movements.



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Mountain Pose

- Stand tall with feet together, shoulders relaxed, weight evenly distributed through your soles, arms at sides.
- Take a deep breath and raise your hands overhead, palms facing each other with arms straight. Reach up toward the sky with your fingertips.

[Find out your BMI!](#)

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=1>



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Downward Dog

- Start on all fours with hands directly under shoulders, knees under hips.
- Walk hands a few inches forward and spread fingers wide, pressing palms into mat.
- Curl toes under and slowly press hips toward ceiling, bringing your body into an inverted V, pressing shoulders away from ears. Feet should be hip-width apart, knees slightly bent.
- Hold for 3 full breaths.

PIN IT

CHRIS FANNING

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=2>



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Warrior

- Stand with legs 3 to 4 feet apart, turning right foot out 90 degrees and left foot in slightly.
- Bring your hands to your hips and relax your shoulders, then extend arms out to the sides, palms down.
- Bend right knee 90 degrees, keeping knee over ankle; gaze out over right hand. Stay for 1 minute.
- Switch sides and repeat.

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<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=3>



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Tree Pose

- Stand with arms at sides.
- Shift weight onto left leg and place sole of right foot inside left thigh, keeping hips facing forward.
- Once balanced, bring hands in front of you in prayer position, palms together.
- On an inhalation, extend arms over shoulders, palms separated and facing each other. Stay for 30 seconds.
- Lower and repeat on opposite side.
- **Make it easier:** Bring your right foot to the inside of your left ankle, keeping your toes on the floor for balance. As you get stronger and develop better balance, move your foot to the inside of your left calf.

[Find out your BMI!](#)

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=4>



PHOTO: SHANNON



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Bridge Pose

Stretches chest and thighs, extends spine

- + Lie on floor with knees bent and directly over heels.
- + Place arms at sides, palms down. Exhale, then press feet into floor as you lift hips.
- + Clasp hands under lower back and press arms down, lifting hips until thighs are parallel to floor, bringing chest toward chin. Hold for 1 minute.
- + **Make it easier:** Place a stack of pillows underneath your tailbone.

[Find out your BMI](#)

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=5>



PHOTO BY SUSAN FITZGERALD



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Triangle Pose

- + Extend arms out to sides, then bend over your right leg.
- + Stand with feet about 3 feet apart, toes on your right foot turned out to 90 degrees, left foot to 45 degrees.
- + Allow your right hand to touch the floor or rest on your right leg below or above the knee, and extend the fingertips of your left hand toward the ceiling.
- + Turn your gaze toward the ceiling, and hold for 5 breaths.
- + Stand and repeat on opposite side.

[Find out your BMI](#)

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=6>



PHOTO BY CHRIS FANNING



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Seated Twist

Stretches shoulders, hips, and back; increases circulation; tones abdominals and obliques

- Sit on the floor with your legs extended.
- Cross right foot over outside of left thigh; bend left knee. Keep right knee toward ceiling.
- Place left elbow to the outside of right knee and right hand on the floor.
- Twist right as far as you can, moving from your abdomen; keep both sit bones on the floor. Stay for 1 minute.
- Switch sides and repeat.
- **Make it easier:** Keep bottom leg straight and place both hands on rails; your lower back rounds forward, sit on a folded blanket.

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=7>



PHOTO BY CHRIS FANNING



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Cobra

- Lie facedown on the floor with thumbs directly under shoulders, legs extended with the tops of your feet on the floor.
- Tighten your pelvic floor, and tuck hips downward as you squeeze your glutes.
- Press shoulders down and away from ears.
- Push through your thumbs and index fingers as you raise your chest toward the wall in front of you.
- Relax and repeat.

[Find out your BMI!](#)

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=8>



PHOTO BY CHRIS ANDRZEJ



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Pigeon Pose

Targets the piriformis (a deep gluteal muscle)

- Begin in a full **push up** position, palms aligned under shoulders.
- Place left knee on the floor near shoulder with left heel by right hip.
- Lower down to forearms and bring right leg down with the top of the foot on the floor (not shown).
- Keep chest lifted to the wall in front of you, going down.
- If you're more flexible, bring chest down to floor and extend arms in front of you.
- Pull navel in toward spine and tighten your pelvic-floor muscles; contract right side of *glutes*.
- Curl right toes under while pressing ball of foot into the floor, pushing through your heel.
- Bend knee to floor and release; do 5 reps total, then switch sides and repeat.

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=9>



CHRIS ANDRZEJ



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Crow Pose

- Get into **downward dog** position (palms pressed into mat, feet hip-width apart) and walk feet forward until knees touch your arms.
- Bend your elbows, lift heels off floor, and rest knees against the outside of your upper arms. Keep toes on floor, abs engaged and legs pressed against arms. Hold for 5 to 10 breaths.

Find out your BMI

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=10>



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Child's Pose

- + Sit up comfortably on your heels.
- + Roll your torso forward, bringing your forehead to rest on the bed in front of you.
- + Lower your chest as close to your knees as you comfortably can, extending your arms in front of you.
- + Hold the pose and breathe.

<http://www.fitnessmagazine.com/workout/yoga/poses/beginner-yoga-poses/?page=11>

Not only is yoga shown to increase physical performance in those who participate, but mental performance as well. Yoga also implements relaxation and being able to ground oneself, which results in a multistep, progression towards the end goal of the therapy process. The person, tasks, and environmental aspects of the EHP model are all addressed through the participation of yoga. If performed correctly and sufficiently, the above mentioned exercises greatly increase the patient's performance range, allowing them to participate in more meaningful occupations to aid in therapy timeliness and overall progression.

Once the patient has demonstrated proper initiation of control skills, the integration of activities of daily living (ADL) training begins. This is the main focus of therapy, as it incorporates the integration of daily living

activities that the patient will use upon discharge. The focus of this area in the rehabilitation process is to instruct, collaborate, remediate, and create skills with the patient that he or she will use in everyday life. These skills may include toileting, bathing, cleaning, cooking, dressing, hygiene, leisure participation, etc that involve the use of the patient's newly 3-D printed prosthetic. The therapist and patient should work collaboratively, to re-learn and teach the patient how to perform the tasks listed above, along with others he or she may find meaningful in daily life. This stage of the rehabilitation process was vary from patient to patient, as each person is unique and professes through therapy at various speeds. The therapist should educate the patient on their progression throughout therapy, and always be communicating on discharge plans and dates, as insurance companies may not always cover one's rehabilitation stay until competence is reached.

Phase Four/Five

Phase four involves the advanced prosthetic training phase of rehabilitation, which focuses on normalized body patterns, energy conservation, and decreased stress on the residual limb throughout the duration of the activity (Smurr et al., 2008). Once the patient has demonstrated competence in basic ADL performance, the integration of advanced prosthetic training begins. The major difference in this phase is the introduction of using tools and materials to complete a meaningful task, and being able to complete a multistep, bilateral task with minimal difficulty and errors. At this time, the therapist will be able to develop multistep, bilateral tasks utilizing tools to increase the patient's participation in important tasks of daily living. It is important that the patient learn to use their 3-D printed prosthetic bilaterally, as many daily living tasks are performed as such. Over the course of therapy, discharge planning is being implemented and manipulated as seen fit. Upon completion of phases one through four, the carry through of the discharge planning is the summation of the rehabilitation phases, where the client is able to discharge to an appropriate level of living. As an overall result following discharge, the patient's performance range will increase due to the cohesiveness of the

person, context, tasks, and human performance components of the EHP mode.

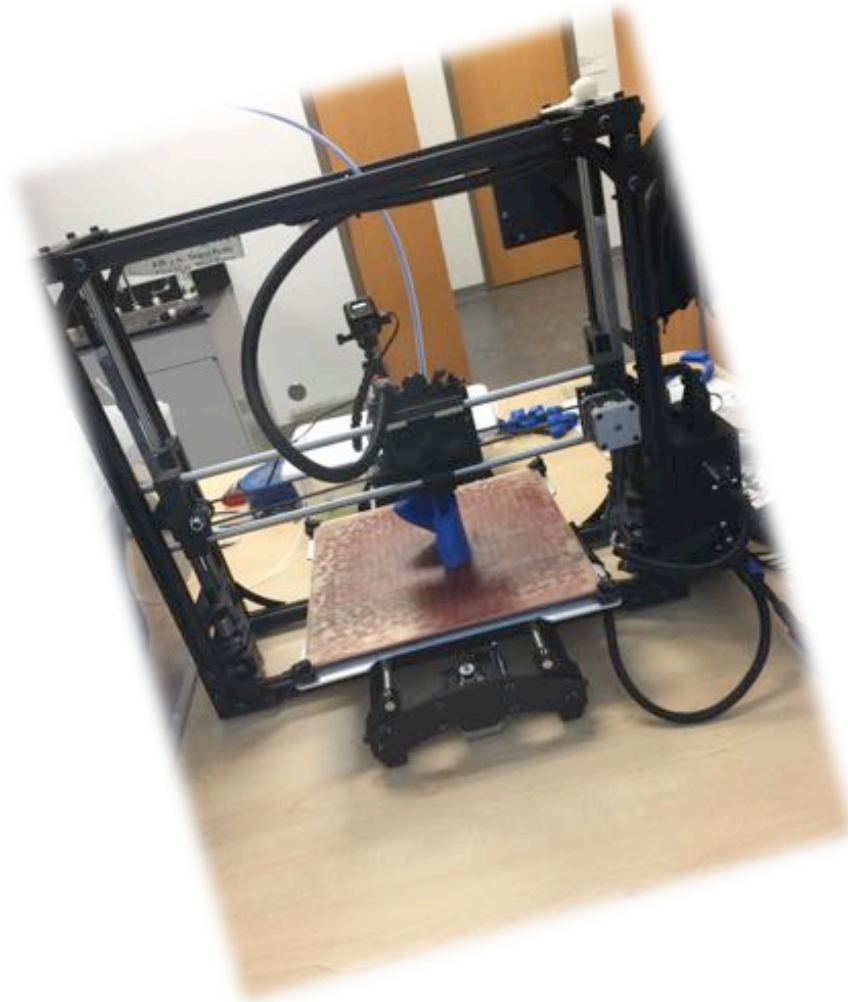


Splinting and Prosthetics

Introduction

Splinting and prosthetics is an area within the 3D printing world that is up and coming and has a tremendous amount of potential to be the future of this area of occupational therapy. Splinting and prosthetics have the capability to change ones ability to perform tasks, and widens their performance range if fitted correctly. The downfall of splinting and prosthetics is that they are in high demand, however costs for the prosthetic itself, and the rehabilitation services is astonishing. According to Blough et al. (2010), a 5-year projection of a unilateral upper limb loss costs average \$31,129 and \$117,440. With the development and introduction of 3D printing with splinting and prosthetics, these costs can be dropped drastically. The average three-dimensionally printed prosthetic ranges around \$50, where as the average costs of a myoelectric prosthetic are upwards of \$50,000 (Burn, Anderson, & Gogola 2016). With the unique, user friendly affordable designs, a patient's performance range will greatly increase as ones personal abilities, social environment, and task performance will increase and collaborate to create an higher functioning patient. Below is a resource guide that provides an overview to splinting and prosthetics from a three-dimensioal printing perspective. General needs, client populations, and activities of daily living are included in each of the

categories, to aid in the promotion and use of three-dimensional printing prosthetics for those in need of a splint or prosthetic to improve performance range.



Splinting

***General Needs**

- Splinting opportunities that allow patient's to uniquely design a functional prosthetic to prevent, modify, promote, or create, proper positioning to allow for optimal performance in meaningful activities.
- Prevent: Use of splinting to prevent further deconditioning and progression of the diagnoses at hand.
- Modify: Use of splinting to modify ones positioning to ergonomically complete meaningful activity safely.
- Promote: Use of splinting to promote a client's performance in meaningful activity through the use of adequate positioning.
- Create: Use of splinting to create an increase in the client's performance range, yielding an increase in tasks available to the client.



<http://www.plasticstoday.com/sites/default/files/images/adesignaward-300.jpg>

***Client Populations**

- Used across the lifespan for those suffering from a physical disability that results in a disposition of a limb.
- Great for children as they grow at an alarming rate
- Examples: Cerebral Palsy, Mental Retardation, CVA, Arthritis, Dupuytren's Contracture, Trigger Finger, Swan Neck Deformity, Multiple Sclerosis, Down Syndrome, Autism Spectrum Disorder, Muscular Dystrophy, TBI, etc.

***Activities of Daily Living**

- Splinting aims in helping performance in all areas of ADL's
- Splinting guides client's to perform meaningful activities in an ergonomic manner, as to not limit the number of tasks they are able to perform.



<http://handworkstherapy.com/wp-content/uploads/2016/07/3D-finger-splint.jpg>

Prosthetic

***General Needs**

- Used to provide an opportunity to be able to participate in meaningful occupations for those who have suffered a limb differential.
- Prosthetics provide the client a chance to increase performance range if appropriate protocols for therapy are followed
- 3D printed prosthetics offer a substantially less expensive opportunity for those in need, as many cost as few as \$50, compared to \$25,000 or more.

***Client Populations**

- Use across the lifespan for those who have suffered an upper extremity limb differential.
- Extremely beneficial for children as they are growing at a higher rate than the average population
- Examples: Birth defects, Orthopedic Injuries, Traumatic Accidents, CVA, etc.



<http://i.dailymail.co.uk/i/pix/2014/12/28/2422CFE100000578-2889393->

***Activities of Daily Living**

- The use of a functional prosthetic can aid clients in having the abilities to complete all ADL's with an increased level of independence.
- Social participation can be increased in children, as they now obtain a bionic, super hero resembling prosthetic.
 - Uniquely designed prosthetics allows children to increase their social supports, decrease environmental barriers, yielding an increased performance range within the patient.



<https://tctechcrunch2011.files.wordpress.com/2016/06/pasted-image->

Introduction to Splinting Case Study

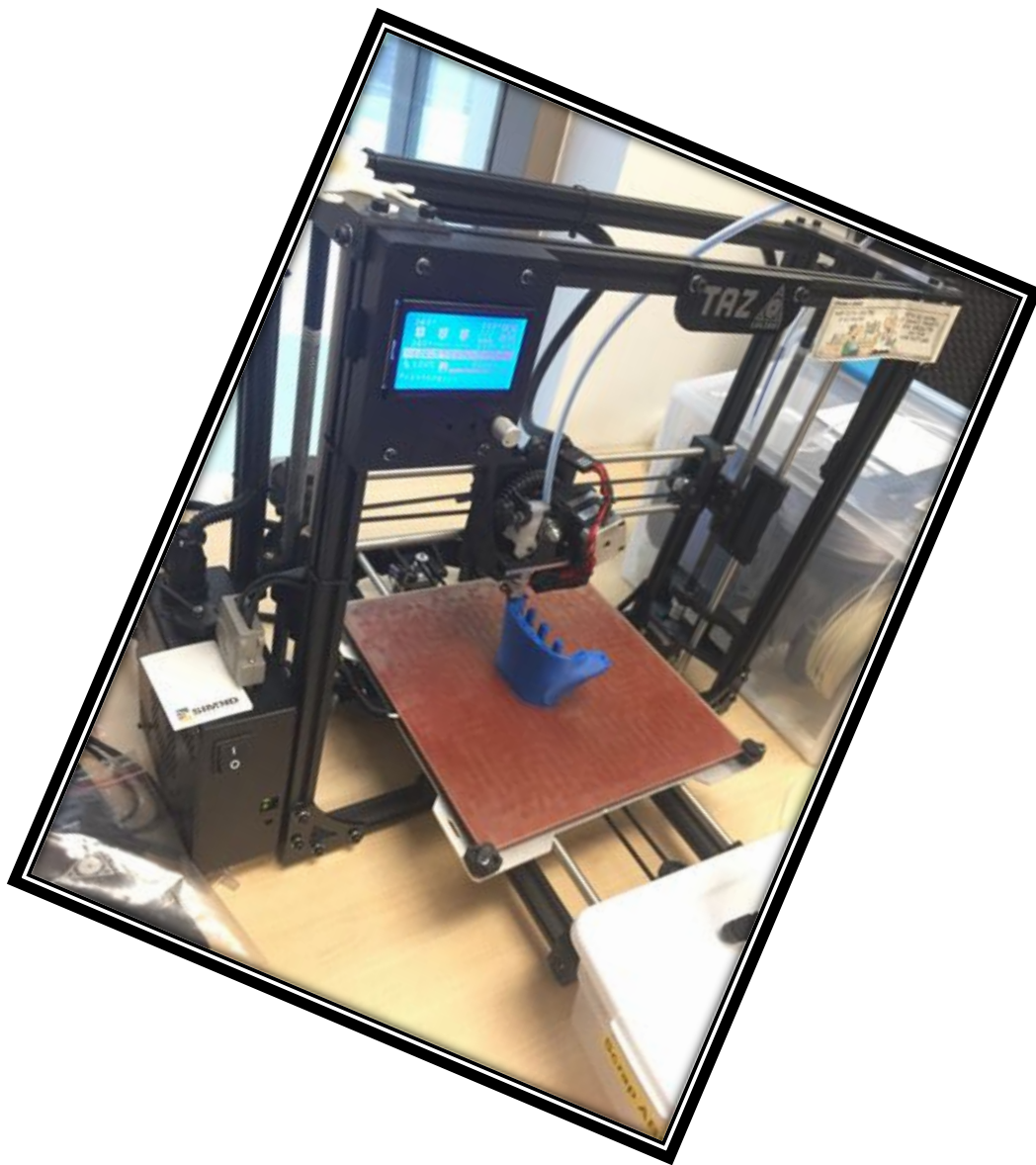
Within the splinting realm of occupational therapy, three-dimensional printing can be used to increase functional tasks within an individual's environment. Different interventions can be used of the rehabilitation frame of reference like adapt and modify. These can be used to adapt splints to better assist an individual within the environment or modify a current splint to increase the ability to perform tasks within the environment. This case study provides an example of how it can help to create a splint for a patient with rheumatoid arthritis. Splinting with three-dimensional printing is not limited to only this population, as it can be used with a variety of populations with various diagnosis. Different materials can be utilized to make the splint more durable or rubber-like to be adapted to the needs of the client.

Splinting: Case Study

Three-dimensional printing is being used to print wrist splints for patients with rheumatoid arthritis. Currently splinting materials used, that are not three-dimensionally printed, tend to be poorly ventilated and difficult to clean (Nelson, 2016). Therapists working with patients with rheumatoid arthritis have heard feedback from their patients saying that they tend to avoid social events due to the appearance of their current splint and the splints are not comfortable (Nelson, 2016). This results in the occupational therapists having difficulty to achieve patient compliance with the splinting program (Nelson, 2016).

Dr. Paterson, who is a three-dimensional splinting specialist, using three-dimensional printing to work with hand therapists to develop clinician friendly software to enable practicing therapists to develop splints for patients with rheumatoid arthritis (Nelson, 2016). By using a three-dimensional printer, Dr. Paterson is able to create a less rigid mesh splints that patients see as attractive and easy to clean (Nelson, 2016). Through using a three-dimensional printer, multiple materials can be incorporated so that the overall splint is durable material but in places that may rub on joints to cause pressure sores, a softer more rubber-like material can be used to

without changing the physical shape of the splint (Nelson, 2016). The three-dimensional splints are created so that the patients with rheumatoid arthritis are easily able to apply the splint without causing an aggravation to tender joints, muscles, or tendons which has improved patient satisfaction (Nelson, 2016).



Introduction to Prosthetic Case Study

The following example of a case study focuses on a middle-age man who was born without a left hand. The three-dimensional printed prosthetic increased the man's performance range by adapting the three-dimensional hand to increase ability to complete needed tasks within his environment. Even though the man in the case study was born without an arm, it is important to remember that this is not the only population that prosthetics can be used with. Three-dimensionally printed prosthetics can be used in a variety of populations with different diagnosis including CVA, traumatic injuries, and orthopedic injuries.

Prosthetics: Case Study

Jose Delgado, Jr. was born without a left hand and has been using prosthetics since a young age. He has previously spent most of his life using a hook prosthesis that uses a rubber-band to pull the hook open (Ulanoff, 2014). In recent years, Mr. Delgado received a myoelectric replacement. The sensors in the myoelectric device detect muscle movement to open and close the prosthetic hand (Ulanoff, 2014). Mr. Delgado indicated that not all of the fingers of the hand are functional, only digits one through three are able to functionally complete a pincher grasp (Ulanoff, 2014). At times when he is driving, he explained that when he hits a bump or makes a wrong movement the hand would close up or open without warning (Ulanoff, 2014). He would then need to concentrate to initiate the correct movement by contracting specific muscles. He indicated that because of these things he see the myoelectric prosthesis as uncooperative and unpredictable at times, thus leading Mr. Delgado to find a new solution for a prosthetic hand (Ulanoff, 2014).

Mr. Delgado decided that a three-dimensionally printed prosthetic would be the best fit for him. The specialist that developed the three-dimensional printed prosthetic had previously been done with pediatric

populations, not adults. The specialist began by taking measurements and customizing the design to fit Mr. Delgado's stump and forearm. The specialist printed the pieces for the hand using the FlashForge Creator printer (costing around \$1200) and ABS material.

Mr. Delgado noticed instantly how light the three-dimensionally printed prosthetic was and how easy it was to use (Ulanoff, 2014). The three-dimensional printed hand prosthetic works through bending of the wrist (Ulanoff, 2014). By bending the wrist forward the prosthetic hand closes and by bending the wrist back to neutral/slightly backward the hand opens up. The hand is durable and able to support 20 to 30 pounds of force (Ulanoff, 2014). Mr. Delgado expressed that the three-dimensional hand makes it easy to grip boxes and functions like a real hand due to fingers being functional and having rubberized tips (Ulanoff, 2014). The cost of the myoelectric hand is approximately \$42,000 and the three-dimensionally printed hand is approximately \$50 (Ulanoff, 2014).

Adaptive Equipment

Introduction

In the realm of three-dimensional printing, the opportunities often seem endless. Within an occupational therapy setting, adaptive equipment seems to be administered more and more often. With an increase in adaptive equipment administration, comes an increased cost to provide equipment. With 3D printing integration in the area of adaptive equipment, the tools become much more individualized, customizable, unique, and most important of all, much more affordable. With the use of an individualized, unique piece of adaptive equipment, the patient will be able to increase personal abilities, allowing for further interaction within ones environment. With the cohesiveness of the person and environmental aspects, the patient will be able to increase performance range with meaningful occupations. Below is a resource guide that encompasses the adaptive equipment involved with feeding, and wheel chair mobility. Within each of these sections, general needs, client populations, and activities of daily living are addressed to help promote and discover what options may be best for a given patient.

Feeding

***General Needs**

- Adaptive methods to complete feeding and meal preparation tasks.
 - Unique to persons internal and external limitations
 - External Limitations: Involving physical disabilities, yielding a piece of adaptive equipment that focuses on ergonomic guidelines.
 - Larger grip
 - Longer utensil
 - 90 degree angles within the utensil
 - Increased flexibility of material



<http://www.quickmedical.com/images/sku/original/35953.jpg>

- Internal Limitations: Involving internal sensitivities or withdrawals, yielding an adaptive equipment that is motivational, and unique to the patient's personal needs.

- Sensory appropriate utensils
- Modified utensils that resemble a meaningful object/ character
- Color sensitivity



***Client Populations**

- Across the life span, ranging in a large variety of diagnoses addressing both psychosocial issues, and physical disabilities.
- Examples: Arthritis, Gout, Cerebral Palsy, Mental Retardation, Cerebral Vascular Accident (CVA), Sensory Sensitivity, Autism Spectrum Disorder, Upper Extremity Orthopedic Conditions, Amputations, Muscular Dystrophy, Anxiety Disorders, Obsessive Compulsive Disorder, Phobic Disorders, Eating Disorders, Traumatic Brain Injury (TBI) etc.

<http://internetvswallet.com/wp-content/uploads/2015/06/pokemon->

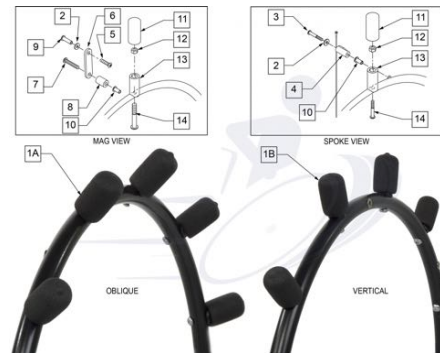
***Activities of Daily Living**

- Feeding and Meal preparation

Wheelchair

*General Needs

- Use of adaptive equipment to promote safe, independent ambulation within ones immediate environment to enhance performance in meaningful activities.



<https://cdn.southwestmedical.com/fs/sunrise-medical-parts-1000/Projection%20Handrim.png?wm=6>

- Create: The proper use of adaptive equipment will create an area of opportunity to increase interactions both socially, and within ones immediate environment.
- Prevent: With the use of appropriate equipment, prevention of deterioration of both the patient and durable medical equipment will be implemented allowing for the greatest use and most appropriate fit between the patient and their medical equipment.
- Modify: Being able to modify ones medical equipment with a less expensive option will allow for a greater level of independence and sense of self due to a more cohesive fit with the medical equipment.

- Using the above-mentioned approaches to create the most appropriate fit with the patient and their equipment will allow for the patient to use the medical equipment functionally throughout its duration.

***Client Populations**

- Physical disabilities yielding limitations or inability to ambulate with ones lower extremity.
- Examples: Amputations, Muscular Dystrophy, Multiple Sclerosis, Cerebral Palsy, CVA, TBI,

***Activities of Daily Living**

- ADL's that require ambulation
- Leisure participation
- Community mobility
- Mobility within ones immediate

environment



<http://www.tuvie.com/wp-content/uploads/innovative-wheel-chair-leading-e.d.g.e-enables-user-roam-around-even-in-a-standing->

Introduction to Adaptive Equipment

Case Study

The following case studies provide examples that wheelchair and feeding are not the only ways three-dimensional printing can be utilized. Ideas and possibilities are endless when three-dimensional printing is involved. The following case studies provide examples of how to use a three-dimensional printer for a high school student, elementary student, and for another individual with quadriplegia. The case studies provide examples of how to use three-dimensional printing for feeding and communication. Using three-dimensional printing is not limited to the populations in the case study, but rather can be used in a variety of ways for a variety of populations. Adaptive equipment can help to create or modify the environment in which the individual needs to create more tasks to increase performance range. Through creating adaptive equipment that allows the individual to become more independent in his or her environment, it can improve quality of life and overall function within his or her environment.

Adaptive Equipment: Case Study

Watanabe, Hatakeyama, and Tomiita (2015) completed three case studies to improve assistive technology service through the use of three-dimensional printing. In case study one, the participant is a student with physical and intellectual disabilities who attends high school. The participant has difficulty holding a spoon but is able to scoop up food and put it in his mouth. An occupational therapist, teacher, and engineer developed a prototype for three-dimensional printing and used trial and error to develop a spoon that best fit the individual. In case study two, the participant is a person with physical disabilities caused by quadriplegia and uses a personal computer through auto scanning and a custom-made switch to communicate. The switch needs to be replaced due to heavy use. Through use of three-dimensional printing a new switch is developed that maintains operability, workability, and custom-fit to the participant. In case study three, the participant is an elementary school student with physical, visual, and respiratory disabilities and is bedridden in a supine position. She can communicate through simple commands. Through use of three-dimensional printing the goal is provide her with a switch and circuits that can convert her exhalations into input signals (Watanabe et al., 2015). To

make things more convenient for family members, caregivers, and teachers a microphone holder will need to be developed that is customized to the patient using three-dimensional printing (Watanabe et al., 2015).

In case study one, the participant was able to trial multiple different shaped spoons and was able to make copies and new copies to replace old devices that have been damaged through the use of three-dimensional printing. In case study two, the participant was able to have the appropriate devices remodeled and custom fit to increase independence. By using three-dimensional printing, it created the potential to transmit expertise and skills by incorporating knowledge about individual adjustments by computing data (Watanabe et al., 2015). In case study three, the use and application of three-dimensional printing allowed prior experience to be applied to a new case. Various devices could be redesigned through the use of three-dimensional printing. Watanabe et al. (2015) described clinical significance through the use of three-dimensional technology production operations can be improved and contribute to development products that have multiple users and large amounts of data to be combined into one product. Another benefit with using three-dimensional printing was that the data was saved to the computer-aided design program, which allowed for spare copies to be

made and new copies to be made to replace old spoons that may be broken or worn out by overuse (Watanabe et al., 2015).

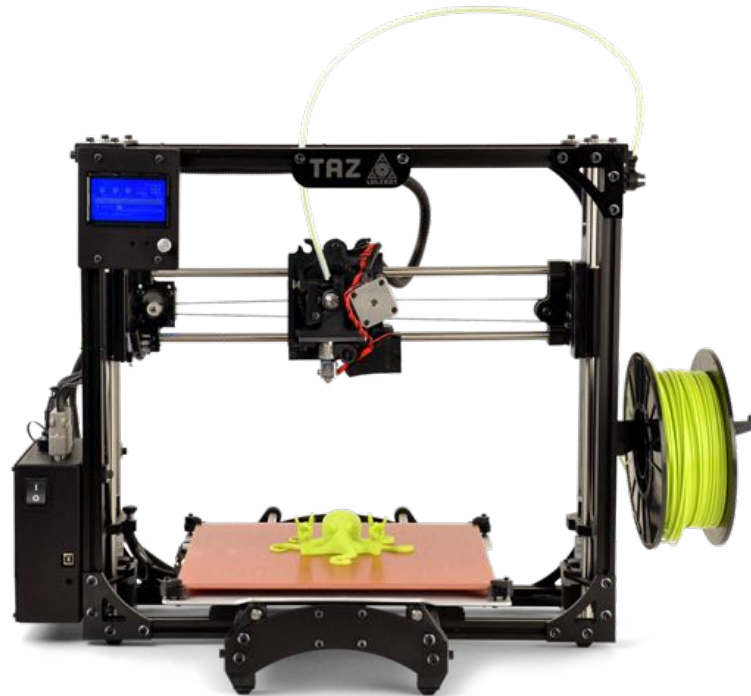


3D Printers

Introduction

There are a wide variety of three-dimensional printers that are capable of producing the before mentioned products to guide occupational therapy services. Each printer is uniquely different, however most share the same concept in terms of how products are complete. The average three-dimensional printer ranges in price from roughly \$300 to \$3,000, as quality directly relates with cost (Ventola, 2014). Following are various popular 3-D printers that are readily available to those who are interested. As 3-D printing is an up and coming piece of technology especially in the healthcare field, it is a wise investment for facilities to begin research on the pros and cons to owning their own 3-D printer and the service possibilities involved. Below is a resource guide that compares and contrasts several popular three-dimensional printers, which includes pricing, pros and cons, and dimensions of each.

LutzBot TAZ 5



(https://www.lulzbot.com/sites/default/files/TAZ_5_Transparent_Front_0.png)

Price: \$2200

Pros: High quality three-dimensional printing, open source framework, many features to print using many different printing materials, high quality customer support

Cons: noise during three-dimensional printing process, training may be required to use software, the price

Dimensions: 298 x 275 x 250 mm

MakerGear M2



(<https://images-na.ssl-images-amazon.com/images/I/51yfe1ZnYKL.jpg>)

Price: \$1775

Pros: Frame is very sturdy, high quality customer support, high print quality

Cons: noise during three-dimensional printing process, training may be required to use software, the price

Dimensions: 203 x 254 x 203 mm

Zortax M200



https://www.igo3d.com/media/catalog/product/cache/1/image/1200x1200/9df78eab33525d08d6e5fb8d27136e95/Z/o/Zortax_M200_iGo3D_5.JPG

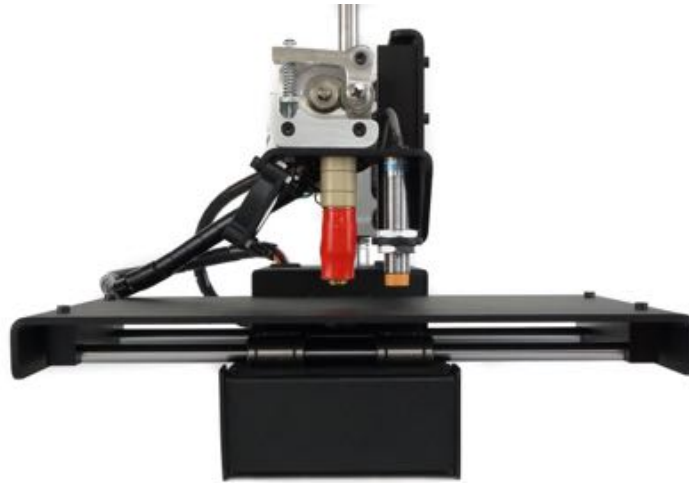
Price: \$1999

Pros: Easy to use, accuracy in printing process, and good print quality, software easy to use, heated build platform, auto calibration

Cons: Connectivity and low material compatibility

Dimensions: 200 x 200 x 185 mm

Printrbot Metal Simple



(<https://3k8g8c3p564l1zjnb621d3aoii6-wpengine.netdna-ssl.com/wp-content/uploads/2014/07/Simple-Metal-3.jpg>)

Price: \$599.99

Pros: affordability, one of the most well-received printers on the market, able to print decent size products, high resolution, overall quality, sturdiness of the machine

Cons: small dimensions of the three-dimensional printing machine

Dimensions: 150 x 150 x 150 mm

Formlabs Form 1+



(<https://static.formlabs.com/static/formlabs-web-frontend/img/products/form1plus/form1plus-hero-models.jpg?f49283egbb57aabg67c4a28>)

Price: \$3299

Pros: Uses the process of stereolithography (SLA) for printing which can be messier than FDM processes, best overall print quality, able to print with fine detail, training required to use the machine and software, appearance

Cons: low material compatibility, expensive to run

Dimensions: 125 x 125 x 165 mm

Markerbot Replicator Mini



(<https://images-na.ssl-images-amazon.com/images/I/41tP-pdTPyL.jpg>)

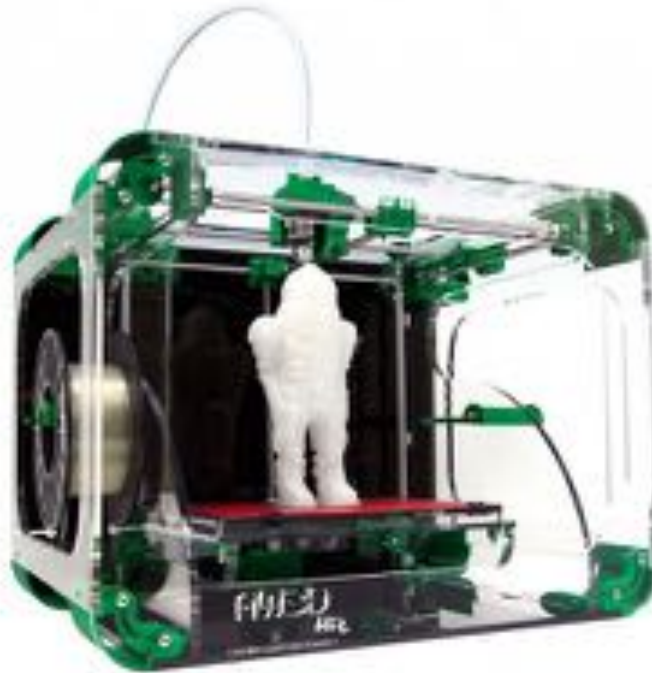
Price: \$1375

Pros: Eco-friendly, on-board camera to monitor printing process, easy software, connectivity

Cons: Only print with PLA material, dimension limitation, noise during printing process, print speed

Dimensions: 100 x 100 x 125 mm

Airwolf HDL



(https://www.rapidscan3d.com/images/hdl_3-1024x967.jpg)

Price: \$2285, option to lease from company starting at \$50/month

Pros: high quality customer service/technical support, large in size, cutting edge quality performance, comes pre-calibrated, high printing speed, easily upgradable, various material compatibility

Cons: price

Dimensions: 12'' x 8'' x 12''

Prusa i3 Hephestos



(<http://filament2print.com/1581/kit-impresora-3d-prusa-i3-hephestos.jpg>)

Price: starting at \$499

Pros: affordable, open printing source, good printing qualityX

Cons: print speed, noise during printing process, simple machine design not including many features

Dimensions: 215 x 210 x 180 mm

Printing Filaments

Introduction

Different printing filaments can be utilized in three-dimensional printers. When using the three-dimensional printers it is important to recognize various types of printing filaments that are compatible with the three-dimensional printer. Typically for printing materials there are three main different types including standard filaments, flexible filaments, and composite filaments. The two most commonly used filaments in three-dimensional printing is the acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA).

Paterson, Donnison, Bibb, and Campbell (2014) explain that the use of the layering mechanism, to create the three-dimensional product, allows users to be endlessly creative by building almost any geometrical project with design freedom without major increase in cost to build. The process of three-dimensional printing is similar to the way a regular household inkjet printer works (Paterson et al., 2014). Instead of using ink cartridges to print a single layer of ink to a piece of paper, the three-dimensional printer uses a special material called resin to help create the layers to build the three-dimensional construct (Paterson et. al, 2014).

Better understanding the different printing filaments can help occupational therapists create and design products that are customized for the client. Three-dimensional printing is a creative and innovate option for occupational therapists to utilize in practice and can provide clients with opportunities that are affordable and usable. By understanding the printing filaments the occupational therapists can pick the best materials that may be either durable, easy to clean, or both, among many other options.



<http://www.3ders.org/images2015/low-cost-innovative-3d-printed-robotic-hand-exoskeleton-to-help-heal-hand-injuries-3.jpg>

Standard Filaments

Standard filaments are some of the most used filament materials in three-dimensional printing. Standard filaments are commonly used as the default material in most three-dimensional printers. Standard filaments can be used to print splints, prosthetics, adaptive equipment, and many more options for use in the therapy clinic environment. The following are some common standard filaments, but many more standard filaments are available.

Polylactic Acid (PLA)



(<https://www.matterhackers.com/3d-printer-filament-compare>)

- One of the most common printing materials used for three-dimensional printing
- Facts:
 - ❖ Odorless
 - ❖ Low-warp
 - ❖ Heated bed is not a requirement
 - ❖ Eco-friendly
 - ❖ The PLA material is often used in food containers, biodegradable medical implants (sutures)

✚ Acrylonitrile Butadiene Styrene (ABS)



(<https://www.matterhackers.com/3d-printer-filament-compare>)

- Most commonly used three-dimensional printing material
- Facts:
 - ❖ Durable and can withstand high temperatures
 - ❖ Stronger material compared to PLA
 - ❖ Heated printing bed is recommended due to ABS being prone to warping when cooled
 - ❖ Commonly used to make Legos

✚ Nylon (Polyamide)



(<https://www.matterhackers.com/3d-printer-filament-compare>)

- Facts:
 - ❖ Strong, durable, versatile three-dimensional printing material
 - ❖ When thin, the material become flexible
 - ❖ With a high inter-layer adhesion becomes strong and durable
 - ❖ Extremely sensitive to moisture

✚ Polyethylene Terephthalate (PET)



(<https://www.matterhackers.com/3d-printer-filament-compare>)

- Facts:
 - ❖ Strength higher than PLA
 - ❖ Food and Drug Administration approved for food containers used for food consumption
 - ❖ No odors or fumes released during printing process
 - ❖ Not biodegradable, but is able to be reused
 - ❖ High clarity and good bridging for three-dimensional printing

Flexible Filaments

Flexible filaments can be used in combination with other printing materials like the standard printing filaments. One example of many, is that this can be useful during splinting when a specific part on the splint is better as a flexible material than as a hard material that may cause pressure sores in areas on the skin that are susceptible. Flexible filaments can be used to create rubber-like structures that need to bend on wheelchair parts, prosthetics, splinting, feeding equipment, communication devices, and more. The following are some common flexible filaments, but many more flexible filaments are available.

TPE



(<https://www.matterhackers.com/3d-printer-filament-compare>)

- Facts:
 - ❖ Compared to soft flexible rubber
 - ❖ Can be used to create things like belts and springs or anything that needs to have a bend/flex to fit the need of the environment

✚ Soft Polylactic Acid (Soft PLA)



(<https://www.matterhackers.com/3d-printer-filament-compare>)

- Facts:
 - ❖ Able to print produces that can flex or bend
 - ❖ Compatible with many three-dimensional desktop printers
 - ❖ Rubber-like

Composite Filaments

Composite filaments are used in situations when it is important to have a hard, rigid built three-dimensional structure. A structural support is built into the composite filaments. This would be useful with, but not limited to adaptive equipment or portions of a splint that needs to be strong in structure. The following are some common composite filaments, but many more composite filaments are available.

✚ Carbon Fiber Reinforced PLA



(<https://www.matterhackers.com/3d-printer-filament-compare>)

- Facts:
 - ❖ High structural strength
 - ❖ Layer adhesion with low warp
 - ❖ Increased rigidity (increased structural support is built-in)
 - ❖ Does not bend

Polycarbonate (PC)



<https://www.matterhackers.com/3d-printer-filament-compare>

- Facts:
 - ❖ Strong and can withstand impact
 - ❖ Used to make bulletproof glass
 - ❖ Temperature resistant
 - ❖ Can be bent without cracking
 - ❖ Able to be pressed or hammered when cold without cracking or breaking.

Safety Considerations

Introduction

Although three-dimensional printing in the realm of occupational therapy is a great up and coming area of practice, there are safety considerations that must be taken into consideration when utilizing the mentioned above printers, and filament materials. Listed below, are several safety considerations that must be taken into affect in order to ensure the safest, and most effective working environment for both practitioners, and patients who are involved in the three-dimensional printing process.



Safety Considerations

- Follow the United States OSHA guidelines for using electrical equipment in the workplace
- Remember to follow the manufacture guidelines when operating a three-dimensional printer
- Notify coworkers while working with three-dimensional printing to ensure safety of yourself and prevent injuries to others from happening
- After beginning a printing job it is important not to open the cover or override the safety interlock switch
- If the safety interlock switch malfunctions, do NOT use printer
- When working with materials, wear proper personal protective equipment which may include: safety goggles or mask, protective apron, long pants, safety gloves, shoes that cover and protect the feet
- If printing material has the potential to splash, it is important to wear safety goggles and other appropriate personal protective equipment
- No not use three-dimensional printer or store materials in places where food and drinks are consumed or prepared

- Three-dimensional hazards to pay close attention to: Hot surfaces, high voltage, ultraviolet radiation, and moving parts during printing process
- Be sure to obtain proper training through the facility that has the three-dimensional printer available

The above information was retrieved from: (Carnegie Mellon University., n.d.).

Future Possibilities

- In home printers: Having an easily accessible, cost effective splinting solution in home for children who frequently grow out of splints, break them, or dirty the splints is a future possibility. Three-dimensional printers can be easily programmed so little is needed to be done by the user than to just hit a button. That way it will save the family a trip to the clinic.
- Educational purposes: By incorporating three-dimensional printing into the classroom, it can provide a whole new educational experience. Students would be able to design and build three-dimensional structures that will help learn hands on.
- Clinic use: Through use of three-dimensional printing in a clinic on a daily basis, it can increase revenue for the clinic by being more efficient and successful with first attempt splinting or prosthesis. It can be a cost effective resolution to adaptive equipment, among other possibilities. With three-dimensional printing the therapist has the opportunity to take technology and occupational therapy to the next level.

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CHAPTER V

SUMMARY

The purpose of this project was to explore the possibilities and various potentials with the use of 3D printing in the practice of occupational therapy. Specifically, with an emphasis on prosthetic advancement, splinting, and adaptive equipment. Overall it was discovered that 3D printing has many great benefits and potential for advancement within the above mentioned areas. The project outlines the model and frames of reference used to guide the design, phases of rehabilitation to ensure a timely fit for those receiving a prosthetic, overviews of splinting, prosthetics, and adaptive equipment, resources to compare and contrast 3D printers and various filaments types, and finally case studies to reinforce the influence 3D printing has on the appropriate population. The limitations of the project include the lack of trial in practice at this time, the product is limited to occupational therapy practitioners, lack of sufficient literature support yielding a insufficient amount of supporting evidence, lack of filament strength and durability, and the requirement of wrist flexion with hand prosthetic. The above mentioned limitations are largely a result of timeliness, in that 3D printing in the scope of occupational therapy is an extremely new area of practice that many have not had the education or opportunity to utilize in practice. Establishing

proposal of the product itself is a major step in validating the usefulness of 3D printing in the scope of occupational therapy. The pediatric population is especially appealing with this product, due to its decreased durability, the occupations children often participate in, and the high tempo physical and emotional changes that children experience throughout their development. To initiate the proposal of our product, we believe it would be most beneficial to present our scholarly project to those who often provide health care services to the pediatric population, while providing hands on demonstrations of the 3D printed prosthetics, splints, and adaptive equipment at hand. These practices may include prosthetists, occupational therapists, physical therapists, teachers, and physicians. If allowed to expand the information gathered across the healthcare field, a cohesive change may be initiated to the approach to care children receive when addressing upper limb differentials. A couple roadblocks to implementation that we predict include the advanced technology training required to use 3D printing equipment, and practitioner's resistance to change. To overcome these barriers, using statistics and researched based facts and articles will be used during the presentation to practitioners. The advanced training in 3D printing will be a more difficult barrier to overcome, and will not be able to be implemented as quickly. In the early stages of implementation, however

contracting a technology specialist on site will aid in the efficiency and early education of the utilization of 3D printers.

The products outcome and usefulness will be measured by pre and post-test evaluations. These evaluations will be given to both providers, and consumers to evaluate the physical, emotional, and social influences both before and after reception of the 3D printed prosthetic. Data will be analyzed as a result of the pre and post-tests to evaluate the efficiency and effectiveness of our product. A 10 day evaluation will also be performed throughout the therapy process, allowing for both practitioners and patients to provide input of their perceptions regarding the newly integrated practice of 3D printing and how it has prohibited, or inhibited their road to recovery.

Overall, we believe our product has a great foundation for the start of integrating 3D printing into the scope of occupational therapy. Our product provides many resources, case studies, and protocols to allow for the greatest success with the implantation of an up and coming area of practice. The overall strengths of our product include the supporting evidence throughout, the cost effectiveness of a 3D printing approach to therapy, and ways to promote an optimal and timely fit for those receiving a prosthetic, ensuring a positive outcome if done correctly. Future improvements to our product include development of pre and post-test questionnaires, and 10-day

evaluation assessments to aid in the progression of therapy with the involvement of 3D printing. The potential for further scholarly collaboration is tremendous. The area of 3D printing in healthcare, specifically with occupational therapy is going to change the future, and the possibilities are endless. As we have just begun to scratch the surface of 3D printing and its potential with occupational therapy services, future research must be complete through trials and research studies, and revisions to protocols will be made as needed. 3D printing and occupational therapy is a very specialized area of practice, which holds an endless potential for those in need. As further research and product development continues, we believe that 3D printing and occupational therapy will change the future.