Integrating 3D- Printing Technology in Assistive Adaptive Device Prescription in Rehabilitation Medicine: A Conceptual Framework

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Integrating 3D- Printing Technology in Assistive Adaptive Device Prescription in Rehabilitation Medicine: A Conceptual Framework

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Abstract: *Prescription of assistive adaptive device (AAD) is one of the interventions to assist person with disabilities (PWD) in performing activities of daily living and reduce their dependency level. PWD possess a unique set of disabilities which differ from one to another. Customization of AAD is important to conform toward various disabilities. However, production of AAD in our local clinical setting is limited in customization due to lack of technical expertise and out- dated method of production. The objective of this project is to propose a new conceptual framework of introducing 3D printing technology in AAD prescription. 3D- printing technology allows shorter lead times, mass customization, reduced parts count, more complex shapes, parts on demand and less material waste. This paper will illustrate a conceptual framework to integrate 3D Printing Technology in AAD Prescription process.*

Keywords: Disabilities; Assistive Adaptive Device; 3D Printing Technology; Rehabilitation.

1. INTRODUCTION

The ultimate goal of rehabilitation medicine for person with disabilities is to achieve optimize functional status [1]. Assistive adaptive device (AAD) (Figure 2 and Figure 3) is one of the means to assist person with disabilities (PWD) to assist in performing activities of daily living [2]. Every patient possesses a set of unique disabilities depending on the nature of the diseases and other biopsychosocial factors as described by International Classification of Functional Framework, depicted by Figure 1 [3]. Hence, the adaptive devices must be customized individually to conform towards specific disability in achieving specific functional goal. Globally, more than 1 billion people need 1 or more assistive products. It is interestingly to state many low-income and middle-income countries, people who have access to required AAD is limited to only 5-15% (4). Recent United Nations resolutions has included the accessibility to assistive technology into its action plan in order to realizing towards the targets in Sustainable Development Goals relating to universal health coverage (5). There are six criteria that should be assessed in ensuring a good assistive technology delivery; availability, accessibility, acceptability, adaptability, affordability and quality [6].

In an optimum condition, adaptive device prescription process should be able to conform, amiable to customization, adjustable to more complex parts in order to produce a functioning AAD that address specific different needs [2]. Current local clinical setting, the fabrication of upper limb AAD is very much reliance towards what is available in the market or produced by conventional way by occupational therapist which is limited to only molding or sewing with very few materials options that can be utilized. More complex design of AAD are unable to be produced due to limited technology in modelling, fabrication and production [7].

3D- printing technology allows shorter lead times, mass customization, reduced parts count, more complex shapes, parts on demand and less material waste [8]. The popularity and low cost of 3D printing technology, it has driven a Do-It- Yourself (DIY) movement created by the consumers and hobbyists via online communities [8]. However, there are limited evidence to support DIY AAD production in terms of how the rehabilitation professional should response to this kind of movement [9]. Their AAD production is not supervised or monitored by the rehabilitation professionals, which may not meet acceptable standards. Additionally, the benefits of multidisciplinary team are lost during this DIY process. 3D printing products should be monitored for its adverse effect which is not occurring during DIY process. A proper mechanism on how the 3D printing technology should be conducted in rehabilitation setting is crucial that include the work process and products. In terms of the process, we should examine the CAD/CAM program usability, material variability/availability, costs of 3DP for rehabilitation-related endeavors, identify appropriate professional other than rehabilitation health professional that should be recruited into the multidisciplinary team to assist in the development of new innovative ideas [9]. In terms of product, research should be directed in examining potential improvement in function, aesthetic and quality. Effectiveness of the end product should be examined by administering validated functional outcome measure such Functional Independence Measure (FIM), Modified Barthel Index (MBI) or Goal Attainment Scale [10].

This proposed project is to construct a multidisciplinary framework to conceptualize 3D-printing technology into rehabilitation medicine services, pertaining to the invention of customized AAD.

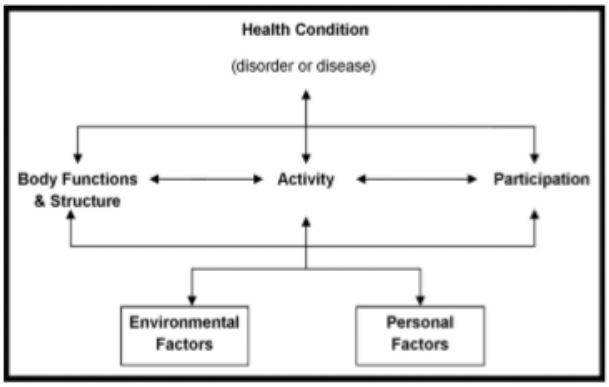

Figure 1: International Classification of Functional Framework describing factors that contribute to the diversity of disabilities.

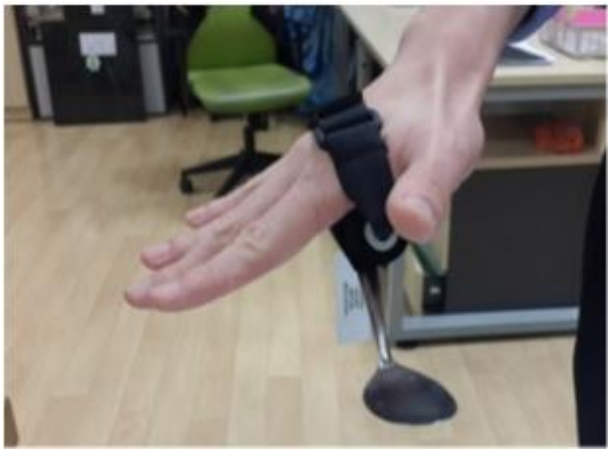

Figure 2: Example of conventional AAD for feeding function for tetraplegic hand

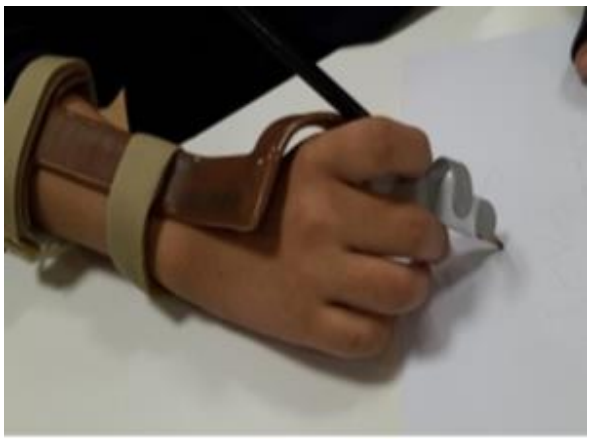

Figure 3: Example of conventional AAD for writing function for tetraplegic hand

The central focus of this paper is to discuss the conceptual framework in analyzing the work process of integrating 3D printing technology into assistive adaptive device prescription in rehabilitation medicine. In this newly developed framework, the bio-mechanic features, designs, material selection and cost of fabrication and production of assistive adaptive devices is explored. Trial project is conducted to test the effectiveness and safety of the produce AAD in improving function in spinal cord injured patients with tetraplegia, stroke patients with hemiparesis of the limbs, rheumatoid arthritis patients with joint problems, patient with progressive motor neuron diseases and other diseases that may presented with variable pattern of disabilities especially affecting the upper limb function.

2. OPERATIONAL FRAMEWORK

The framework is composed of two phases, begins with constructing a trans-disciplinary framework in AAD prescription and measurement of the effectiveness and safety of the invented functional AAD.

Formation of trans-disciplinary team member consist of rehabilitation physician (RP), occupational therapist (OT) and a new addition of technical expertise (engineer) is a new vital step that will be introduced into the existing AAD prescription process. Patients who require AAD are examined by RP and OT to identify the impairment and disabilities that need to be addressed. The patient's clinical condition and disabilities are demonstrated to the technical expertise. Discussion among the team members and patient are held to achieve a collective decision on setting the functional goal specifically pertaining to upper limb function as illustrate in Figure 4. Appropriate specification of design and desired features of AAD that will be produced in order to achieve the functional goal are discussed. This process is crucial, which enable the synchronization of information and understanding of patient's disabilities and theirs needs, hence, ideal solutions can be proposed pertaining to AAD designs.

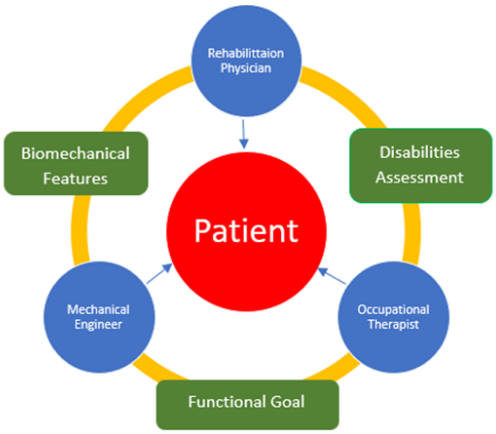

Figure 4: Transdisciplinary Team Proposition

The recruitment of a technical expertise as a new member in the existing multi- disciplinary team allows exploration of a new method utilizing 3D printing technology in customizing AAD. The new method of fabrication and production of customized AAD includes several stages: **Scanning**: Using a handheld scanner to scan the anatomy of the hand to ensure the shape, any deformity and size of the hand are captured. The scan model will be uploaded to the CAD software for further modelling for AAD. **Design:** Using CAD model, modelling involve planning of the AAD blueprint. The process may include modifying, refining or upgrading existing available AAD blueprint or inventing or creating of a new product. AAD for upper limb should possess important features which are required in order to adapt and customize towards patient impairment. **Printing:**

Identification and selection of the appropriate material for the desired strength, durability, strength, usage properties and cost estimation. **Finishing:** This process involves cooling, removing residual debris, polishing, drilling or cutting to prepare the product for further testing on patient. **Product Testing:** The newly produced AAD will be tested on its function onto patients and any adverse event will be monitored which include pressure injury, pain or AAD malfunctions. During this process, any problem or product malfunction will be modified accordingly which may involve re-designing, material re-selection or re-printing. At the end of this process, the finalized product will be analyzed for its characteristics and level of function. **Product Outcome**: CAD designs, bio-mechanical features, material characteristics, cost involve, limitations and advantages of the process framework. **Level of Function Outcome:** Goal Attainment Scale and Modified Barthel Index. **Service Quality**: Orthotics and Prosthetics Users' Survey (OPUS) Questionnaire.

3. CONCLUSION

3D printing technology for advanced medical device applications encompasses a versatile, growing array of technologies for generating AAD products. Identifying correct expertise, formation of a trans- disciplinary team and conceptualizing a new framework to utilize 3D printing technology in rehabilitation services are mandatory to ensure good outcomes. Thus, this will ensure a new upgraded and up-to-date rehabilitation medical service that is cost-effective can be set- up, in order to improve PWD current medical rehabilitation management and may further reduce time and waste materials.

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