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Use of Low Cost Prostheses to Improve Upper Extremity Function in Children with Cerebral Palsy

PURPOSE OF STUDY AND BACKGROUND

Purpose of the Study: To assess the effectiveness of upper extremity prosthesis in improving the upper extremity function of children with cerebral palsy who have limited use of their hands

Background

Cerebral palsy is the most common childhood disability, affecting approximately two to three out of every one thousand live births in the United States, and the most common form is spastic (77%) *(CDC)*. Up to 83% of children with cerebral palsy have upper extremity involvement, which limits their ability to live and work independently.[1]

In the past, there have been very few well-designed studies proving efficacy of various treatment modalities of the upper extremity in patients with cerebral palsy. Traditional methods such as surgery have only weakly positive data.[2] In two recent comprehensive reviews, the most supportive data was found for therapeutic techniques, in particular, constraint-induced movement therapy (CIMT) and bimanual training.[2,3] A review of over 100 patients studied since 1997 showed that forced use of the weaker hand and intensive bimanual training in patients with unilateral spastic cerebral palsy can improve measures of dexterity and use.[4] Additional focuses include other intensive and structured therapies, Botox injections, and family-centered or home programs. However, most treatments are effective only in patients with relatively advanced ability.

The Manual Ability Classification System (MACS) is a simple way to describe how children with cerebral palsy use their hands during routine activities at school and home.[5] Level I indicates a child who has full use, while level V would be one without any use. The intervening levels describe increasingly severe limitations; level II pertains to a child who can handle most objects, level III to someone who handles items with difficulty, and level IV to a patient who can only use their hands in adapted situations. Many of the intensive and structured therapeutic regimens were developed for children at higher functioning MACS levels.[6] For children with lower levels of activity, MACS IV and V, there are much fewer available treatments.

Upper extremity function in cerebral palsy patients can have a profound effect on their quality of life and ability for self-care.[7,8] Children with MACS IV or V comprise 15-30% of the pediatric cerebral palsy population and are more globally involved.[1] Although they are a minority of total patients, they consume a large portion of resources for care, and should have options for improvement of the upper extremity.

In recent years, three-dimensional printing has expanded to medical uses, and prostheses of the hand are being produced and proven to be functional.[9] The advantages of three-dimensional prostheses are lower cost, customizability and rapid turnover. The major disadvantages are durability and initial set-up fees. Given that children can quickly outgrow an expensive prosthesis, the advantages of three-dimensional printed prostheses may outweigh the disadvantages. The feasibility of three-dimensional printing means that children are eligible to receive sophisticated devices earlier and more frequently than they would otherwise, given economic constraints.

Orthotics and prostheses both refer to external devices, though prostheses are more specifically meant to replace a missing part. One manner of considering low-functioning patients with cerebral palsy is that they are lacking useable parts, such as mobile fingers or opposable thumbs. The most common upper extremity contracture pattern in cerebral palsy patients is thumb in palm with clasped hand, followed by shoulder adduction and internal rotation, and wrist flexion with pronation.[1] In spite of having contractures, even children with severe limitations maintain a small amount of active motion of either the wrist or elbow. This active motion in proximal joints can be used to motor distal motion by means of a prosthesis which is

driven by tenodesis. Templates for functional, three-dimensionally printed prostheses which give patients the ability to grasp and release by means of wrist or elbow motion are already available and have been utilized for pediatric patients with congenital finger amputations or malformations. Cerebral palsy patients with contracted, poorly mobile fingers and some small degree of control over wrist or elbow motion might also be eligible for utilizing such a device.

A systematic review and meta-analysis was recently performed on the use of orthotics, or splints, in children with cerebral palsy. Unlike constraint or bimanual therapies, orthotics can be applicable to lower-functioning patients. When looking only at functional, as opposed to non-functional, hand splints, preliminary data showed a small, immediate benefit.[10] Some investigators likened functional hand splints to being utilized like spectacles for vision, with the improved use present only during wear, while others speculated that the gains made during usage would carry over into times without wear. Currently, insufficient data exists to determine which theory is most accurate.

Study Design: Prospective one group pretest-posttest design
Primary outcome measures: passive and active range of motion, MACS, Assisting Hand Assessment, Melbourne Assessment of Unilateral Upper Limb Function, Pediatric Motor Activity Log
Secondary outcome measure: Pediatric Quality of Life Inventory

CHARACTERISTICS OF THE RESEARCH POPULATION
Number of Subjects: Participants will be 12 children.
Gender of Subjects: Males and females will be enrolled
Age of Subjects: 4-17 years
Racial and Ethnic Origins: Participants of all racial and ethnic origins will be included.
Inclusion Criteria:

- Diagnosis: cerebral palsy
- 4-17 years old
- MACS levels III - V
- Active movement of wrist or elbow

Exclusion Criteria:

- MACS levels I, II
- Botox or orthopedic surgery in past 6 months
- Severe contractures
- Lack of voluntary arm motion

Vulnerable Subjects: Children are the target population. Appendix: Children will be uploaded. Some children may have cognitive limitations, so Appendix: Cognitively Impaired Subjects will be uploaded. A review of the patient's medical record as well as a discussion with parent/legal guardian will be used to assess the patient's ability to provide assent and sign the form. If unable to sign and patient is able to indicate and understanding of the study, verbal assent will be obtained. Additionally, children without the capacity to provide assent will be included because they may benefit from this study in that their upper extremity function might improve.

METHODS AND PROCEDURES
Methods and Procedures
Participants will be 12 children, aged 4-17 years, with cerebral palsy and MACS level III - V

All patients, with CP and upper extremity involvement, who are being seen during a regularly scheduled clinic/office/occupational therapy visit by the PI, co-investigator or occupational therapist, and are potentially eligible for enrollment in the study will be provided information about the study. The PI, co-investigator, occupational therapist or research coordinator will explain the project to the child and the child's parents. The parents will be asked if they are interested in having their child voluntarily participate in the study. The Consent form (please see Process of Consent section below for further details) will be presented to the parent/legal guardian and the age appropriate Assent form will be presented to the child. If parent/legal guardian and child agree to participate, then they will be asked to sign the Consent and Assent forms.

Additionally, the PI, co-investigator and occupational therapists will review their own individual databases for potential subjects and contact their own patients by phone to describe the research project. The Telephone Recruitment Script and Waiver of Authorization have been uploaded. If patient and parent are interested, then patient will be referred to the occupational therapist. For these subjects, the occupational therapist or research coordinator will be obtaining consent/assent (please see Process of Consent section below for further details) when the patient comes for Visit 1.

All visits for this study are for research purposes. The patient will be scheduled for Visit 1, Screening Visit. At Visit 1, a pediatric occupational therapist will perform a comprehensive initial evaluation to determine functional level, range of passive and active upper extremity motion, presence of contractures, and level of spasticity/abnormal tone. The evaluation will include the following widely used measures of upper extremity function in patients with cerebral palsy: MACS, the Assisting Hand Assessment (AHA), Melbourne Assessment of Unilateral Upper Limb Function, and Pediatric Motor Activity Log (PMAL). From this information the occupational therapist will determine patient's eligibility for enrollment, i.e., if the patient meets inclusion and exclusion criteria. Additionally, for the patients that are enrolled in the study, this will serve as their initial evaluation.

Those patients determined to be eligible and signed consent/assent/authorization forms will be fitted with a three-dimensionally printed arm prosthesis, which uses wrist or elbow tenodesis for grasp and release. Three-dimensional printers can manufacture prostheses, which use proximal motion to activate opening and closing of the fingers.

Patients with MACS III have limited active finger and wrist motion. Many patients with MACS level IV have a small amount of active wrist motion and minimal finger motion. These two groups of patients can have prostheses with extension caps on the fingers and thumb driven by wrist motion. The palmar fingertips would then be utilized for sensory input and additional fine control. In contrast, those patients (some MACS IV and some MACS V) with unusable, contracted fingers and no wrist motion may need more involved prostheses. Similar to prostheses for children with congenital finger amputations, a prosthetic hand component would be fitted over the existing hand, and extension and flexion of the prosthetic fingers (not just caps) would be driven by elbow motion.

The fabrication of the prosthesis will involve several steps. First the measurements by the occupational therapist will include: (1) circumferential measurements of all fingers, thumb, web space, wrist and forearm, and (2) length measurements from (a) elbow to wrist, (b) wrist to each metacarpal joint, (c) each metacarpal joint to proximal interphalangeal joint, (d) each proximal interphalangeal joint to distal interphalangeal joint, (e) each distal interphalangeal joint to finger tip, (f) metacarpal to interphalangeal joint of thumb, and (g) interphalangeal joint to tip of thumb. These measurements will be inputted to the software in the computer connected to the 3D printer. This software drives the printer to produce the following prosthetic components for the subjects who will be using their own fingers: (1) 3 dorsal caps per finger, which fit between the joints and the distal joint and tip, (2) 2 dorsal caps for the thumb, which fit between the joints and the joint and tip, (3) dorsal hand hood, which fits between wrist and metacarpals, and (4) dorsal forearm hood. For the subjects for whom a prosthetic hand is being fabricated, the same measurements will be used to make the prosthetic components with the same components being made for the dorsum of the forearm and hand, but complete replicas of the fingers and thumb will be made. For both designs, all of these components are interconnected with nylon cord and tensioning fasteners. The fasteners are used to adjust the tension to provide the movement at the joints of the prosthesis that is generated by either the subject's own active elbow flexion, or wrist flexion or extension. All of the components will be made from a cornstarch-based material called polylactic acid. According to FDA regulations, external prosthetic components are exempt. As SOC, children have previously received similar splints of both designs, but fabricated manually by an occupational therapist.

After the prosthesis has been fabricated, the occupational therapist will place it on the patient's arm and hand. The therapist will assess the fit of all of the components and ask patient if there are any areas of discomfort. Therapist will adjust prosthesis to eliminate any areas of discomfort. Additionally, the therapist

will evaluate the ease of movement between all of the components and adjust the tension of the cords as needed.

Visit Schedule
Visit 1, Screening Visit: Previously described initial evaluation.
Visits 2: The occupational therapist will take circumferential and length measurements and/or 3D scan of the subject's arm and hand. These measurements/scan will be sent via encrypted email to the Maker Space, NYU Tandon School of Engineering, where the prosthesis will be fabricated using a 3D printer. As a secondary outcome measure, all subjects and their parents will be asked to complete the Pediatric Quality of Life Inventory (PedsQL).
Visits 3-4: The prosthesis will have been shipped or delivered to the occupational therapist who will use these two visits to adjust the prosthesis to optimize fit and functioning.
Visits 5-12: Occupational therapy treatment 1x week for 8 weeks. Each occupational therapy treatment will be a one-hour standardized session that will include the following: stretching/strengthening (approximately 20 minutes), bimanual training (approximately 20 minutes), and activities of daily living (approximately 20 minutes).
Visit 13 (one week after 8th occupational therapy treatment): Re-evaluation including measurement of upper extremity range of passive and active motion, level of spasticity/abnormal tone, MACS, AHA, Melbourne Assessment of Unilateral Upper Limb Function, PMAL, and PedsQL. These will be performed both with the prosthesis on and with it off.
Visit 14 (6 months after initiation of occupational therapy treatment): Re-evaluation including same assessments as Visit 13. These will be performed both with the prosthesis on and off.

Additionally, subjects will be asked to keep a log of daily activities including how long prosthesis is worn.

Data Analysis and Data Monitoring
Demographics will be reported. Passive and active range of motion measurements and the MACS, AHA, Melbourne Assessment, PMAL and the PedsQL scores at initial evaluation, end of occupational therapy treatment and 6 months follow-up will be compared. DSMP has been uploaded.

Data Storage and Confidentiality
The data will be stored on a computer to which only research personnel have access and will be password protected to prevent unauthorized access. Data will be stored in either the locked office of the PI or the research coordinator.

RISK/BENEFIT ASSESSMENT
Risk
This study is low risk because it involves the fabrication and use of upper extremity splinting, which are commonly an integral part of typical occupational therapy treatment of this population of children. The primary difference will be in the fabrication technique, 3D printing, being utilized. For the evaluations, measurements, scans and treatment by the occupational therapists, the only potential for any discomfort would be mild discomfort during the stretching portion of the treatment session. For the prosthesis, one risk is minor skin irritation or discomfort from it.

Protection Against Risks
The parents and children will be instructed to monitor the upper extremity for redness or discomfort and report any problems to the occupational therapist.
All necessary precautions will be taken to maintain confidentiality of data and prevent unauthorized access to data. The data will be entered into a REDCap database. Only personnel associated with this study will have access to the data. The data will be stored and accessible only on password-protected computers.

Potential Benefits to Subjects
The use of the prosthesis may improve the subject's upper extremity function.

INVESTIGATOR'S QUALIFICATIONS & EXPERIENCE

All research personnel have completed the CITI tutorial training in the protection of human subjects. Copies of the CVs of all personnel are included.

SUBJECT IDENTIFICATION, RECRUITMENT AND CONSENT/ASSENT

Method of Subject Identification and Recruitment

Subjects will be patients, aged 4-17 years, with diagnosis of cerebral palsy and MACS level III - V who have been seen at regular clinic/office/occupational therapy visit by PI, co-investigators or occupational therapist and indicated as a potential subject for study. Each subject will be scheduled for Visit 1, Screening Visit, with a pediatric occupational therapist who will perform a comprehensive evaluation.

Additionally, the PI, co-investigator and occupational therapists will review their own individual databases for potential subjects and contact them by phone to describe the research project. Telephone Recruitment Transcript has been uploaded. If patient and parent are interested, then the patient will be referred to the occupational therapist. For these subjects, the occupational therapist or research coordinator will be obtaining consent/assent (please see Process of Consent section below for further details) when the patient comes for Visit 1, Screening Visit.

For all subjects, from the information acquired through this Visit 1 evaluation, the occupational therapist will determine who is an appropriate candidate for inclusion in the study.

Process of Consent

At a regular clinic/office/occupational therapy visit, potential participants and their parents/legal guardians will be approached by the PI, co-investigator, or occupational therapist who will describe the project to them. For non-English speaking participants, the institution's translation services, a health-care specific telephonic interpreting system, will be used to present the study information verbally and the Short Consent Form in the parent's native language will be used to obtain signed consent.

If the parent/legal guardian and child are interested, the Consent Form and age appropriate Assent Form will be presented by the PI, co-investigator, occupational therapist, or research coordinator. For those patients recruited from the databases of the PI, co-investigator or occupational therapist, the Consent/Assent forms will be presented by the occupational therapist or research coordinator. The parent/legal guardian and patient will be given the opportunity to read the forms and ask and have thoroughly answered any questions that they may have. Only after the parent/legal guardian and child assure the presenter that they fully understand the project and voluntarily agree for the child to participate, will their signatures be obtained. Parents will be given copies of the signed Consent and Assent Forms. Signed Consent and Assent Forms will be stored in subjects' files/binders in a locked office.

Subject Capacity: A review of the patient's medical record as well as a discussion with parent/legal guardian will be used to assess the patient's ability to provide assent and sign the form. If unable to sign and patient is able to indicate an understanding of the study, verbal assent will be obtained. Additionally, children without the capacity to provide assent will be included because they may benefit from this study in that their upper extremity function might improve.

Costs to the Subject

No costs will be incurred by the subject or his/her family.

Payments for Participation

Transportation costs up to $50 will be reimbursed for each completed visit. Participant will be required to provide a receipt of costs incurred in order to receive reimbursement.

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