Published in final edited form as:

Technol Innov. 2016 September ; 18(2-3): 207–210. doi:10.21300/18.2-3.2016.207.

PLAY HANDS PROTECTIVE GLOVES: *TECHNICAL NOTE ON DESIGN AND CONCEPT*

Michele Houston-Hicks[1], **Derek J. Lura**[2], and **M. Jason Highsmith**[3,4,5]

[1]Physical Therapy Center, University of South Florida Morsani College of Medicine, Tampa, FL, USA

[2]Department of Bioengineering and Software Engineering, Florida Gulf Coast University, Ft. Myers, FL, USA

[3]School of Physical Therapy & Rehabilitation Sciences, University of South Florida, Tampa, FL, USA

[4]Extremity Trauma & Amputation Center of Excellence (EACE), U.S. Department of Veterans Affairs, Tampa, FL, USA

[5]319th Minimal Care Detachment, U.S. Army Reserves, Pinellas Park, FL, USA

Abstract

Cerebral Palsy (CP) is the leading cause of childhood motor disability, with a global incidence of 1.6 to 2.5/1,000 live births. Approximately 23% of children with CP are dependent upon assistive technologies. Some children with developmental disabilities have self-injurious behaviors such as finger biting but also have therapeutic needs. The purpose of this technical note is to describe design considerations for a protective glove and finger covering that maintains finger dexterity for children who exhibit finger and hand chewing (dermatophagia) and require therapeutic range of motion and may benefit from sensory stimulation resulting from constant contact between glove and skin. Protecting Little and Adolescent Youth (PLAY) Hands are protective gloves for children with developmental disorders such as CP who injure themselves by biting their hands due to pain or sensory issues. PLAY Hands will be cosmetically appealing gloves that provide therapeutic warmth, tactile sensory feedback, range of motion for donning/ doffing, and protection to maximize function and quality of life for families of children with developmental disorders. The technology is either a per-finger protective orthosis or an entire glove solution designed from durable 3D-printed biodegradable/bioabsorbable materials such as thermoplastics. PLAY Hands represent a series of protective hand wear interventions in the areas of self-mutilating behavior, kinematics, and sensation. They will be made available in a range of protective iterations from single- or multi-digit finger orthoses to a basic glove design to a more structurally robust and protective iteration. To improve the quality of life for patients and caregivers, they are conceptualized to be cosmetically appealing, protective, and therapeutic.

Address correspondence to M. Jason Highsmith, Extremity Trauma & Amputation Center of Excellence (EACE), 8900 Grand Oak Circle (151R), Tampa, FL 33637-1022, USA. Tel: +1 (813) 558-3936; Fax: +1 (813) 558-3990; michael.highsmith@va.gov.

Authors declare no conflicts of interest.

Keywords

Cerebral Palsy; Developmental delay; Finger biting; Physical therapy; Rehabilitation; Self-mutilation

INTRODUCTION

Annually in the U.S., approximately 10,000 infants are born with cerebral palsy (CP) (1). The worldwide incidence of CP is 1.6 to 2.5/1,000 live births, placing CP as the leading cause of childhood motor disability (1,2). Approximately 23% of children with CP are dependent upon assistive technologies (3). Use of these assistive technologies includes functional uses such as walking aids and orthoses but may also include protective roles. Protective roles may be aimed at limiting injury during function but may also be necessary in the case of self-injury caused by behaviors such as finger biting. Currently, technologies to facilitate the dual role of therapeutics and protection of the hand and finger in populations such as these are limited. The purpose of this technical note is to describe potential needs and design considerations for a protective glove and/or finger covering that maintains dexterity of the finger for children with diagnoses such as cerebral palsy, Lesch-Nyhan syndrome, and dermatophagia who exhibit finger/hand chewing, require therapeutic range of motion, and may benefit from sensory stimulation from constant contact.

CONCEPT

Protecting Little and Adolescent Hands (PLAY) Hands Gloves are protective gloves for children with developmental disorders such as CP who injure themselves by biting their hands due to pain or sensory issues. At times, these self-mutilating behaviors result in wounds, pain, loss of function, and increased dependence or self-care. PLAY Hands are conceived to be cosmetically appealing gloves that provide therapeutic warmth, tactile sensory feedback, range of motion for donning/doffing, and protection to maximize function and quality of life for families of children with developmental disorders.

DESIGN

PLAY Hands are gloves with protective finger pad material reinforcement to prevent young persons with CP, or other diagnoses contributing to self-mutilating behaviors, from biting and traumatizing their fingers. The gloves will be reinforced with protective materials to cover the finger pads where these individuals attempt to bite and traumatize the fingers, leading to pain, wounds, and difficulties with subsequent self-care tasks and play. The reinforcing material will be non-toxic but durable to minimize the risk of ingesting harmful materials. The gloves would ideally appeal to children by being adorned with popular cartoon characters, pending licensing agreements. The gloves will facilitate higher quality of life for patients and caregivers by mitigating complications associated with finger biting. An additional benefit of PLAY Hands is that many people affected by CP and other neurologic disorders may have contractures of the joints of the hands and fingers. The act of donning/doffing PLAY Hands will require a range of motion activity for the hands, offering a

therapeutic effect in addition to protection. Finally, wearing a glove offers a sensory experience from both tactile and thermal perspectives that may be beneficial for some users.

The wearable finger protection design is dependent upon the desired device utilization. A solution is presented that is either an entire glove or independent for each finger, allowing either targeted intervention on digits that are more prone to chewing or protection for the entire hand when used in combination. For this construction, use of high molecular weight poly(lactic acid) PLA or high to ultra-high molecular weight polyethylene (UHMWPE) should be considered in the design of a bite protection device. Both materials are commonly used in food packaging materials, are non-toxic, and can be used in implantable devices with proper processing.

“PLA is a thermoplastic, high-strength, high-modulus polymer that can be made from annually renewable resources to yield articles for use in … biocompatible/bioabsorbable medical device market” according to Garlotta (4). PLA is a thermoplastic material with a melting point of approximately 180 °C, a tensile strength typically in the range of 50 MPa (depending upon processing and origin), and an elastic modulus of 3500 MPa. PLA also has a glass transition temperature of 60 to 65 °C, which allows for easy at-home thermofitting around the patient’s finger to ensure a tight yet comfortable fit. Figure 1 presents a sample prototype showing fitting of a basic protective frame using 3D-printed PLA.

The second thermoplastic under consideration for the proposed design is UHMWPE. Although it typically has a lower tensile strength than PLA (~25 MPa), it is also considerably softer (elastic modulus 500 to 800 MPa) and has a longer elongation range prior to failure (5). These characteristics would make the final product less prone to breakage but more likely to bend and thus less likely to damage teeth. This product would not be formable to the user; therefore, it would require more complex molds to produce the finished product, and careful attention would have to be used when selecting sizes.

Protective plates could also be added to textile gloves for pressure distribution in patients where a rigid frame is not needed (low force chewing). Ultimate selection of materials depends on a variety of desired specifications for the final product, including weight, strength, and stiffness as well as cost and production volume. Initial prototyping in PLA is advisable, as it can be 3D printed readily by fuse deposition modeling or fused filament fabrication. Custom gloves and inserts should be tested along with traditional protective hand wear, such as hockey and motocross gloves, to assure wear and failure commensurate with other established protective wear for hands.

CONCLUSION

PLAY Hands represent a series of protective hand wear interventions that offer solutions in the areas of self-mutilating behavior, kinematics, and sensation. They will be made available in a range of protective iterations, from a basic glove design to a more structurally robust and protective iteration. They are conceptualized to be cosmetically appealing, protective, and therapeutic and to ultimately improve the quality of life for patients and caregivers.

Acknowledgments

Contents of this manuscript represent the opinions of the authors and not necessarily those of the U.S. Department of Defense, U.S. Department of the Army, U.S. Department of Veterans Affairs, or any academic or health care institution. This project was partially supported by the National Institutes of Health Scholars in Patient Oriented Research (SPOR) grant (1K30RR22270).

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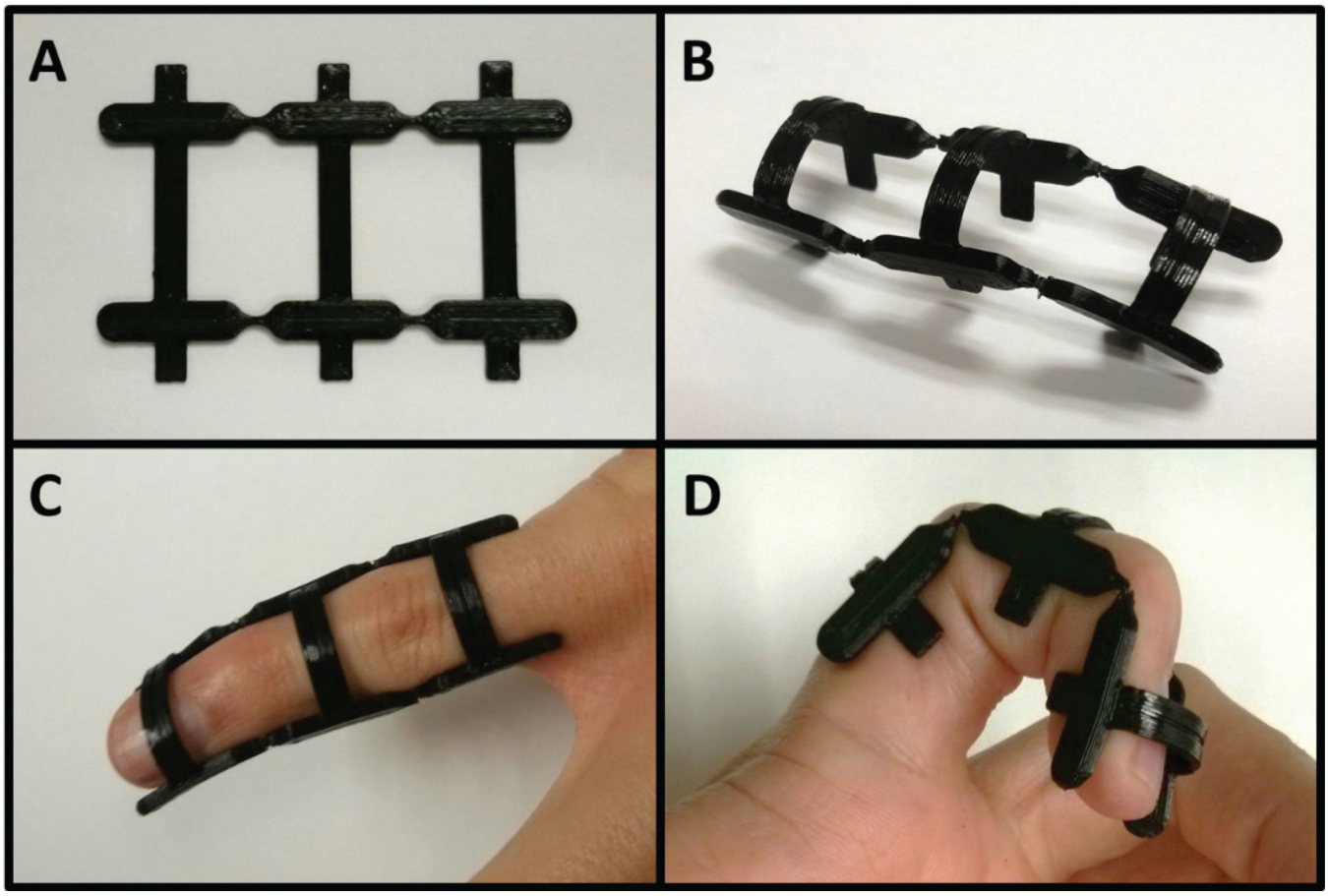

Figure 1.

3D-printed prototype showing a simple thermo-molded protective frame with compliant hinges. A) Original 3D-printed device, B) device after molding to the user's finger, C) device attached to the finger in an extended position, and D) device attached to the finger in a flexed position. These images are a basic orthotic framework for only the single digit and lack the cosmetic/protective outer covering. Further, the concept is envisioned for use either as single- or multi-digit finger covering(s) or as a whole hand glove.