Usability testing of 3D-printed short thumb orthoses for clients with CMC pain

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ABSTRACT

Traditionally, clients with CMC pain wear short thumb orthoses to immobilize the thumb and relieve joint pain. The clinical effectiveness of such orthoses is supported by evidence. The traditional short thumb orthosis is made of low-temperature thermoplastic material. The maker contours thermoplastic material to fit the user’s hand shape at low temperature (about 50-60°C). Although an individualized orthosis is made for each user, the material is hard and the structure is insubstantial. Therefore, some disadvantages have been found with regard to wearing short thumb orthoses. For example, the area contacting the thumb is hard and causes discomfort, the seam on the dorsal side of the thumb orthosis is insubstantial, and movement is limited when the wearer performs daily activities that require fine motor skills.

This research team developed a new 3D-printed short thumb orthosis that is expected to overcome the discomfort and inconvenience of the traditional orthosis. The hand shape is first captured by a 3D scanner, and the maker sketches the 3D-printed short thumb orthosis according to the digitized 3D hand shape. The orthosis is then molded with flexible filaments by a 3D printer. With this method, the orthosis not only can be individualized for each user to immobilize the CMC joint but also provides comfort and soft contact with the thumb.

In this study, the usability, including the effectiveness, efficiency, and satisfaction, of the 3D-printed short thumb orthosis was investigated. Three clients with CMC pain were recruited for the study. They were asked to complete three tests: the Purdue Pegboard Test (for dexterity performance), the Taiwanese version of the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST-T) (for self-perceived satisfaction), and electromyography measurement of four forearm muscles (for objective measurement of forearm muscle loading). All subjects completed the three tests in both traditional and 3D-printed orthoses conditions.

The results indicated that the dexterity performance and the self-perceived satisfaction was better in the 3D-printed condition than in the traditional condition. However, the durability item in the QUEST-T was poor in the 3D-printed condition than in the traditional condition. The forearm muscle loading did not differ in the traditional and 3D-printed orthoses conditions. To improve usability, the researchers will design different styles of 3D-printed orthoses to improve the durability in the future.

Keywords: orthoses, 3D printer, usability testing.

1. Introduction

Individuals with CMC joint pain generally have difficulties in their daily activities that need of manipulating, grasping and twisting (e.g., writing, typing, or twisting a bottle cap). Manipulating, grasping and twisting that can easily cause pain in the hand region (Kjeken et al., 2005). According to one survey, 44.6% of individuals with CMC joint pain have difficulties in twisting a bottle cap (Walker-Bone, Palmer, Reading, Coggon, & Cooper, 2004). The short thumb orthoses usually suggest for individuals with CMC joint pain To protect the CMC joints. Although an individualized orthosis is made for each user, some disadvantages have been found. The area contacting the thumb is hard and causes discomfort, the seam on the dorsal side of the thumb orthosis is insubstantial, and movement is limited when the wearer performs daily activities that require fine motor skills.

This research team developed a new 3D-printed short thumb orthosis that is expected to overcome the discomfort and inconvenience of the traditional orthosis. The hand shape is first captured by a 3D scanner, and the maker sketches the 3D-printed short thumb orthosis according to the digitized 3D hand shape. The orthosis is then molded with flexible filaments by a 3D printer. With this method, the orthosis not only can be individualized for each user to immobilize the CMC joint but also provides comfort and soft contact with the thumb.
2. Method

2.1 Participants
Three clients with CMC pain (Subject A, B, and C) were recruited for the study. All of subjects are right handiness, and have joint pain in right CMC joint.

2.2 Experimental design
Orthoses condition, traditional short thumb orthoses (TRA) and 3D-printed short thumb orthoses (3D), were designed in our experiment (Figure 1).

Figure 1. The client performed PPT while in TRA condition (left), and the client performed texting task for EMG measurement in 3D condition (right).

2.3 Usability testing
The usability, including the effectiveness, efficiency, and satisfaction, of the 3D-printed short thumb orthosis was investigated. They were asked to complete three tests: the Purdue Pegboard Test (PPT), the Taiwanese version of the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST-T), and electromyography (EMG) measurement.

3. Results

Tree cases with regarding the usability testing between TRA and 3D conditions were reported. PPT: The score of PPT in assembly task was better in 3D condition than in TRA condition for three cases (F.2). QUEST-T: Three cases reported that the higher score for dimension, weight, easy and comfortable items of QUEST-T in 3D condition than in TRA condition. Two cases (A and B) reported that the lower score for durability item of QUEST-T in 3D condition than in TRA condition (F.3). EMG Measurement: Only subject B indicated that the lower muscle activity in 3D condition than in TRA condition (F.4).

4. Conclusion
The results indicated that the dexterity performance and the self-perceived satisfaction was better in the 3D-printed condition than in the traditional condition. The forearm muscle loading did not differ in the traditional and 3D-printed orthoses conditions. However, the users indicated the durability issue should be improved in the self-perceived satisfaction for 3D-printed orthoses. To improve usability, the researchers will design different styles of 3D-printed orthoses in the future.