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Original article

Changes in the pressure distribution by wrist angle and hand position in a wrist splint

Changements de la distribution de la pression selon les angles du poignet et la posture des mains dans une orthèse de poignet

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ABSTRACT

The study was conducted to provide basic data to develop a system that distributes pressure over a broader area by measuring and analyzing pressures in various wrist angles and hand positions while wearing a wrist splint. With 0, 15, 30, and 45 degrees of wrist extension, full-finger extension and finger flexion, pressure distribution changes were measured three times. Average peak pressure was analyzed and mean value picture (MVP) in zones 3–5 was calculated. A one-way Anova was conducted to identify changes in pressure distribution by wrist angle and hand position. Mean peak pressure values (kPa) in zones 3–5 changed depending on the wrist angle. Peak pressures (kPa) changed significantly in 15, 30, and 45 degrees wrist extension, depending on the hand position. Since pressure distributions differ depending the wrist angle and hand position (finger flexion), it is necessary to consider how pressure varies in each wrist position and to provide information on postures that should be avoided during tasks and occupational activities based on various wrist angles or hand positions.

Mots clés :
Syndrome du canal carpien
Orthèse de poignet
Mesure de pression
Posture du poignet
Position de la main
Distribution de pression

RÉSUMÉ

Cette étude a été menée pour fournir des données de base visant à créer un système qui permet de répartir la pression sur une zone plus large en mesurant et en analysant les pressions selon les différents angles du poignet et postures des mains dans une orthèse de poignet. Dans les cas d'extension de poignet de 0, 15, 30 et 45 degrés, en extension complète des doigts et en flexion complète des doigts respectivement, les changements de distribution de pression ont été mesurés à plusieurs reprises trois fois, puis une analyse sur la moyenne de pression maximale a été effectuée et une image de valeur moyenne (MVP) dans les zones de 3 à 5 a été calculée. Afin d'identifier les changements dans les distributions de pression selon les angles du poignet et les postures de la main, l'analyse de variance à un facteur (*one-way* Anova, en anglais) a été effectuée. Les valeurs moyennes des pressions maximales (kPa) dans les zones 3 à 5 changeaient en fonction des angles du poignet. Aux angles d'extension du poignet de 15, 30 et 45 degrés respectivement, en fonction de la posture de la main, les pressions maximales (kPa) ont considérablement changé. Comme les distributions de pression diffèrent selon les divers angles du poignet et les postures de la main (flexion des doigts), il est nécessaire de tenir en compte de la variation de la pression selon chaque posture du poignet et de fournir des informations sur les postures qui doivent être évitées pendant que l'on mène des tâches et activités professionnelles selon différents angles de poignet ou différentes positions de la main.

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1. Introduction

Today, people tend to use computers and smartphones for long durations and occupations involving video display terminals are increasing annually [1]. Work-related musculoskeletal disorders (WMSDs) are increasing along with these occupations. WMSDs are functional disabilities brought on by accumulated damage in very fine muscles and tissues due to repeated movements, and appear mainly in the wrist, arms, shoulder, neck, and back [2]. In particular, excessive use of computers, mouse devices, and smartphones can strain the finger and wrist joints, leading to upper limb musculoskeletal disorders [3]. These disorders are collectively referred to as ''overuse syndrome''. Overuse syndrome of the wrist is characterized by pain in the hands or arms because of long-term or excessive use of the hands, and it can lead to functional problems of the hands when the pain persists [4].

Typical treatments for overuse syndrome include rest, injection of pain-relieving drugs in the affected area, and wearing a splint to support the painful area [5,6]. For overuse syndrome on the wrist, wrist cock-up splints, also known as wrist flexion splints, are used. This wrist splint fixes the wrist and is made of plastic. In order to allow some hand function, it maintains wrist flexion between 0 and 45 degrees and is manufactured to allow relatively free motion of the metacarpophalangeal joints [7].

The specific goals of splint use include reducing pain and inflammation of the wrist, providing wrist stability, preventing transformation of the wrist, and minimizing tension on the median nerve [8,9]. In addition, the wrist splint holds the wrist in an extended position for stability to make functional tasks such as finger gripping or grasping possible [9]. The main diagnoses requiring wrist splints are tendonitis, fracture of the radius or ulna, wrist sprain, radial neuropathy, and wrist joint nerve entrapment [9]. In a recent study comparing the therapeutic effects of surgery, corticosteroid injection, and wrist cock-up splints, the most effective treatment for carpal tunnel syndrome was a surgical procedure; the wrist splint had the second-best results [10,11].

To minimize carpal tunnel pressure, the splint should be set at 0 degrees (neutral position) [7,12] or 15 degrees extension [13,14] to reduce additional pressure on the median nerve. Alternatively, a wrist splint with 35 to 45 degrees wrist extension is usually prescribed to rest muscle tissues in the lower arms, although there are various splint wrist positions available depending on the injury [15].

Wrist positions in the splint can differ depending on the diagnosis, information provided by orthopaedic specialists, the patient's status, and the treatment goal. An appropriate wrist position plays an important role in maintaining the shape of the hand from a holistic perspective and for moving the hand with regard to connective tissues such as tendons. According to a recent study, the finger position must be checked when applying a wrist splint to carpal tunnel syndrome patients. Since finger flexion affects the carpal tunnel pressure, patients must be instructed not to clench their fists completely but to keep the range of finger flexion within 75% [16].

Previous pressure measurement studies have focused on the pressure distribution in feet, shoes, lower-limb splints, and wheelchair seating or on hand position during cycling or when wearing gloves [17–20]. However, few studies have measured the pressure distribution in splints. If a splint causes too much pressure on soft tissues for a long time, the splint will compress the blood vessels, causing necrosis of the area under the soft tissues [9]. Consequently, a system is required to distribute pressures on soft tissues and bony processes over a broader area of the skin [9].

This study aimed to generate basic data to develop a system that distributes the pressure on soft tissues and bony processes by analyzing and measuring pressures at various wrist angles and hand positions when wearing a wrist splint. In addition, since the amount of finger flexion is known to affect carpal tunnel pressure, this study also provides feedback on finger positions to patients during tasks and occupational activities by showing changes in pressure points depending on the amount of finger flexion.

2. Methods

2.1. Procedures and instrumentation

2.1.1. Design of wrist splint and measuring position

The splint used in this study is a wrist orthosis, made of low-temperature thermoplastic (LTT). It is placed on the front part of the lower arm (2/3 of each participant's arm length) and extends to the distal crease of the palm. It supports the wrist, and allows 0, 15, 30, and 45 degrees of wrist extension to allow some hand function. It also allows free motion of the metacarpophalangeal joints and other finger joints (Fig. 1a). The LLT shape was changed to apply the pressure distribution-measuring instrument (Fig. 1b). For finger positions, the two positions used in the Cobb et al. study – full-finger extension and finger flexion – were used here, and pressure distribution changes were measured three times for each case [4,21]. The flexor tendon zones were classified into 3–5, and the pressure distribution measured [22] (Fig. 2).

The Pliance® X pressure analysis system (Novel GMBH, Munich, Germany) measures the pressure distribution in real-time. Data was collected continuously for 60 seconds using a capacitive sensor (Pliance® hand mat sensor) [23]. The accuracy of the Pliance® pressure analysis system is 5%. Force, pressure, and contact area graphs can be produced. The Pliance® analyzer software is used to view the average pressure and contact areas in both 2D and 3D. It can also be used to graph the changes in pressure

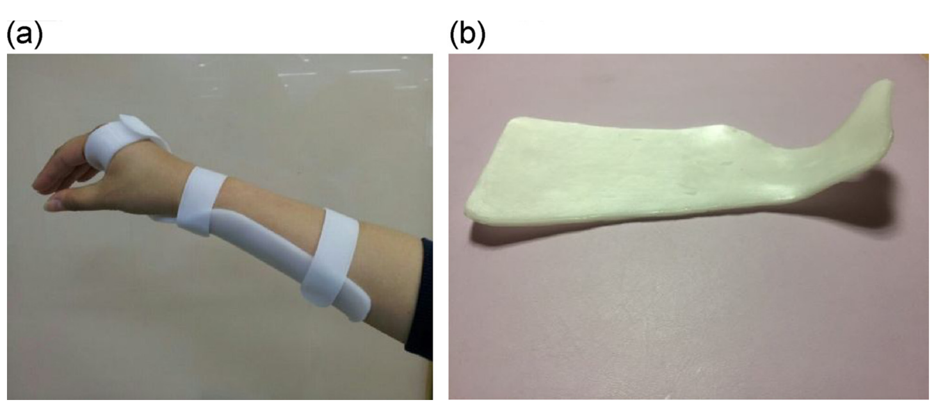

Fig. 1. 30 degrees WO (wrist orthosis) (a) and manufactured with low-temperature thermoplastics (LTT) (b).

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