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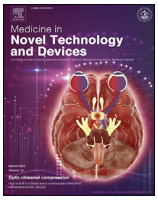

Short Communication

Towards a new frontier in wrist rehabilitation: The traction-free posture orthosis

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ABSTRACT

This study presents the novel Traction-Free Posture Orthosis, designed to address wrist stiffness without the use of traditional traction methods. The orthosis employs a velcro system to stabilize the position of the wrist in flexion or extension, thereby avoiding the compression and rotational disadvantages associated with non-perpendicular traction forces. Triangular-shaped cuts in the brace allow for plastic material flexibility, ensuring movement and comfort. Significant is the absence of a traction strap, which traditionally reduces the support surface and could create pressure points leading to patient discomfort or treatment rejection. The design facilitates a wide contact surface with the hand, optimal load distribution, and the capacity to adjust dual traction straps independently, adapting to the natural wrist movement. This single-piece base orthosis offers a stable, cost-effective, and patient-friendly alternative to conventional splints. However, patients with stiffness in both flexion and extension may require two separate orthoses, potentially increasing costs and patient inconvenience. Overall, the Traction-Free Posture Orthosis represents an innovative step in wrist rehabilitation, providing a quick-to-construct, easy-to-wear solution with the promise of enhanced patient compliance and comfort.

1. Introduction

Wrist fractures, the most common of which are represented by fractures of the distal radius epiphysis and scaphoid fractures, if not mobilized early, can lead to wrist stiffness, resulting in hand dysfunction [1–4]. The immobilization period for these types of fractures is very variable and depends on: the type of fracture, localization, stability, and the type of surgical intervention. The formation of post-traumatic and/or post-surgical edema and scar tissue entails the physiological modification of the connective tissue around the joint [5], consequently, if the wrist is not mobilized early, it will easily lead to the inevitable formation of structured stiffness [6–9]. Many associated factors such as: the general health conditions of the patient, the fracture mechanism, the involvement or not of the joint surface, associated injuries of other tissues, and the motivation of the patient can be factors that will affect the final result [10]. Most patients manage to recover a functional range of motion within 3–6 months after trauma [11,12], while a minority fail to achieve this goal despite treatments, which are often represented by mobilization exercises, stretching, strengthening, and physiotherapy [13–17]. In these cases, the use of mobilization orthoses can be useful for joint recovery. As widely described in the literature, these braces must be worn for several hours a day, depending on the type of stiffness and orthosis, which can be of a static progressive or dynamic type [18,19]. However, the disadvantages of using these braces are related to factors such as the same prolonged use time, which must be greater if the stiffness is more structured, reaching up to 6–12 h a day [20,21]. Other critical issues in the use of braces are related to the pain they can generate [21–23] and the risks of damage to the articular cartilage due to prolonged compression caused by traction [24]. Such compression increases if the traction angle is not perpendicular to the segment to be pulled but $<90^\circ$ (Fig. 1 a), in which case the F1 vector increases the compression at the expense of the F2 vector with a reduction in the rotation effect. Physiologically, an increase in wrist flexion or extension results in an increased compression of the carpal bones [25–27], this associated with the increased compression caused by traction could lead to an intolerance of the brace by the patient, with consequent treatment failure. On the other

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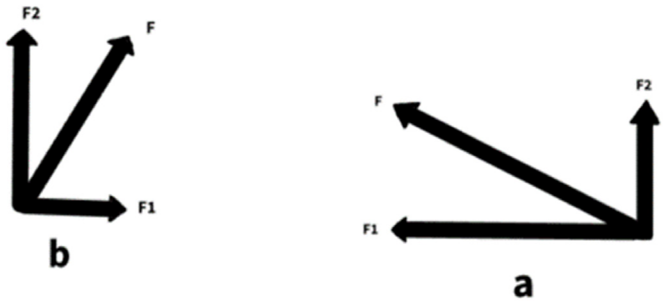

Fig. 1. Vector analysis of wrist orthosis traction angles.

hand, when the approach angle is > 90°, a reduction in the effect of the F2 vector occurs while F1 will create a traction in distraction of the radiocarpal joint (Fig. 1). When the wrist has few degrees of movement, to achieve the perpendicularity of the traction, it is essential to create a rather high outrigger so that it acts as a reflection pulley to the traction wire. (Fig. 2). A very high outrigger, although technically correct, is very bulky and visible, not useable while wearing a long-sleeved garment, and is not discreet if worn outside. Furthermore, a high outrigger, if not provided with a sufficiently wide support base, can undergo flexion stresses, with loss of traction efficacy and possible long-term breakage (Fig. 2).

In Fig. 1, a force vector F represents the traction force needed to mobilize the wrist. When this force F is applied perpendicularly to the segment being mobilized, it maintains a single direction, either flexion or extension, without decomposing into additional vectors. Conversely, if the traction force F is not perpendicular (i.e., not at 90°), vector decomposition occurs on Cartesian axes.

If we consider the vector F aligned with the Y-axis (F=Y), forming a right angle with the X-axis, it exerts a perpendicular force on the segment. However, if the vector F shifts from the Y-axis towards the X-axis (e.g., from 90° to 120°), three vectors form: the main vector F, vector F1 creating joint distraction, and vector F2 creating a degree of rotation. The sum of F1 and F2 equals F (F1 + F2=F). The same principle applies if the vector F shifts towards 0°, with the difference that vector F2 will create joint compression instead of distraction.

This schematic represents the mechanical design of an outrigger for a wrist orthosis, showing the pivotal action around the axis to facilitate the desired movement. The arrows indicate the direction of motion enabled by the outrigger, with the red highlighted area signifying the point of force application to optimize the perpendicular traction force for effective joint mobilization.

2. Description of the posture orthosis

The orthosis we propose does not include any type of outrigger, while traction is replaced by a velcro system for the stabilization of the plastic material's flexion that makes up the base of the brace. The orthosis consists of a volar and/or dorsal gutter in plastic material with a thickness of 3.2 mm. To allow the material to flex in wrist flexion or extension movements, triangular-shaped cuts are made in the lateral portion at the level of the wrist, only ulnar for the extension braces, and on both sides for the flexion braces (Fig. 3). The base of the brace is attached to the forearm-hand with a velcro positioned at the wrist. A second velcro is used to stabilize the position of the wrist in maximum flexion or extension. To generate the posture in flexion or extension of the wrist, the patient must push the wrist in the direction of the desired movement; the plastic material, provided with the aforementioned lateral cuts, will bend following the required movement (Fig. 3). Once the right tension to apply is found, the patient can stabilize the position using the long velcro which will be attached to the lateral edges of the brace (Fig. 3). To minimize the twisting of the velcro, which occurs especially in the presence of a wrist that flexes or extends little, the velcro itself must be crossed with its counterpart and then attached to the opposite side (Fig. 3). As clearly seen from image 3, the contact surface of the hand with the brace is quite extensive, resulting in optimal load distribution. Therefore, the absence of a traction strap allows for a better distribution of the applied forces. In fact, the strap could create an edge effect with a reduction of the support surface in case the perpendicularity of the traction is missing. This edge effect, in addition to creating a potential accumulation of edema [28] downstream of the strap, creates a concentration of force in a restricted area. Considering the weight of the hand, to mobilize a wrist, the forces to be applied could be greater than for a finger, where such forces are suggested in the literature to be 200/250 g. An applied force of 500 g on a reduced surface could be a source of discomfort for the patient, leading to pain and the subsequent removal of the brace. In the brace we propose, this problem never occurs as the velcro strap does not come into contact with the patient's skin but is directly attached to the plastic [4,26]. The advantage of the dual traction is also represented by the fact that the two straps can be adjusted differently and independently to follow the natural movement of the wrist, flexing with ulnar deviation and extending with radial deviation. An additional advantage is the single-piece base of the brace: an orthosis consisting of two parts, one on the forearm and one on the hand, can be more unstable, and the two components are subject to approaching each other once traction is applied, always because of the compressive effect of vector F1. In our case, this problem does not arise because, as mentioned before, the single-piece body of the brace does not create this compacting effect of the components but only a rotation effect of the distal part of the brace around a central rotation axis located at the wrist. The orthosis is very quick to construct, theoretically easy for the patient to wear, relatively low-cost, and durable over time as it does not have many appendages that could detach over time or lose effectiveness in case of dynamic traction. However, the disadvantage is that in the case of dual wrist stiffness, both in flexion and extension, the patient needs two orthoses, each dedicated to one movement. This could significantly increase the costs of the brace and the discomfort for the patient of having two aids instead of just one [29].

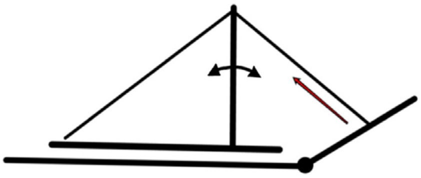

Fig. 2. Mechanical advantage in wrist orthosis design.

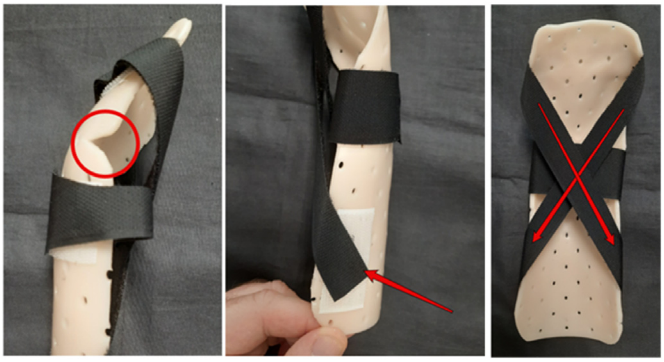

Fig. 3. Orthotic device design schematic.

3. Triangular-shaped cuts (Red circle)

- These cuts allow the plastic material to flex in wrist flexion or extension movements, providing necessary flexibility and comfort.

4. Velcro strap at wrist (Red arrow)

- This strap stabilizes the orthosis by securing it around the wrist, ensuring it stays in place during use.

5. Crossed velcro straps (Red X and arrows)

- These straps allow for adjustable and independent tension, accommodating the natural movement of the wrist. They cross over to provide better stabilization and distribute forces evenly.

In future research, we will focus on the following aspects:

Mechanical Analysis: Conducting a detailed mechanical analysis to quantify the forces and movements facilitated by the orthosis.

Clinical Trials: Implementing clinical trials to gather empirical data on the efficacy, comfort, and patient compliance associated with the use of this orthosis.

We believe these efforts will provide a robust connection between the current research content and the therapeutic effects of the orthosis, thereby enhancing its clinical relevance.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

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Declaration of patient consent

Patient's consent is not required as there are no patients in this study.

CRediT authorship contribution statement

Paolo Boccolari: Conceptualization. **Roberto Tedeschi:** Writing – original draft, Methodology. **Danilo Donati:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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