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Short Communication

Dynamic Elbow Brace for Post Operative Rehabilitations

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ABSTRACT

Background and aim: The author created a dynamic elbow brace for a 48-year-old lady who had suffered a brachial plexus injury following surgery. The device was developed with therapeutic rehabilitation in consideration while being cost-effective. This design was distinct because it made use of low-cost items that were easily sourced and maintained.
Technique: Device with mechanical parts such as DC motor, DPDT switch, pulleys, belts and MS bar were conceptualized and manufactured. The design work in the pulley system.
Discussion: This device allowed the individual to do therapeutic exercise which help in the motion rehabilitation after brachial plexus injury. To meet economical limits, low-cost and conveniently accessible materials were used.

Keywords: *dynamic elbow brace, brachial plexus injury, cost effective, therapeutic rehabilitation, post operative brace.*

INTRODUCTION

Brachial plexus (BP) injuries are uncommon, yet they are difficult to treat. Following such injuries, both before and after surgery, as well as in situations that are managed conservatively [1]. The major goals of BPI rehabilitation are muscular atrophy prevention, subsequent deformity prevention and restraint, pain suppression, sensorial deception recovery, developmental disregard restraint, and postoperative care [2]. Despite their desire to reclaim functional activity in the damaged extremity, many patients fail to attend follow-up sessions with the therapist due to social and financial issues [3].

Therapeutic exercise is critical for BPI patients, regardless of the diversity of nerve abnormalities, postoperative care. Despite the fact that active assistive rehabilitation has been shown to aid in the restoration of musculoskeletal functionality, many patients fail to adhere to their rehabilitation program due to social obligations, forgetfulness, lack of motivation, boredom, and/or a lack of immediate feedback [4].

The great majority of planned robotics devices are technologically advanced and intended for use in clinical settings. However, there is still a major need to enhance the efficiency and lower the cost of home-based treatment and ADL support devices [5]. The device's weight Although the shoulder strap and detachable actuation mechanism compensated for the prototype's overweight, heavier components should be weight optimised further [6].

This technical note details the conceptualization and design concepts behind the fabrication of dynamic elbow brace for an individual with brachial plexus injury with special consideration for patient with musculocutaneous nerve injury.

The uniqueness of this solution was that it used low cost items, such as aluminium rectangular bar, DPDT switch, DC motor with planetary gear box, etc., which is not a typical orthotic componentry. The items used were not highly specialized or difficult to source. The aim was to create easily reproducible device at low cost, effective portable device which can be used easily.

TECHNIQUE

Client description

A dynamic elbow brace is fabricated for Female 48 year old with brachial plexus injury because of RTA affected in left side. Nerve graft surgery is done. The inner thigh is dissected to reveal a fully functional gracilis muscle with its own nerve and blood supply. The gracilis muscle is then transplanted and attached to the upper limb's prepared recipient site, and the gracilis muscle's nerve is connected to a functioning nerve in the arm. The aim is to reconstruct a single function, elbow flexion. After surgery the, the patient wears a static splint for about 6 weeks to immobilise the elbow and protect the transferred gracilis muscle. The client was clinically assessed. After the 6 week the patient were asked to use the dynamic elbow brace for motion rehabilitation.

Design concept

The mechanical parts and the brace's control system should be evenly distributed throughout the upper limb. The aim is to develop an elbow mechatronics-enabled elbow brace that weighs less than 1 kg, including the actuators and control system, based on talks with an expert. The device's main energy source is thought to be portable batteries. Because they may be carried with a built-in waist belt, their weight can be deducted from the device's overall weight.

To provide support to the impaired arm during training sessions and ordinary activities, the device provide 10 Nm. The DC motor is a mechanical powerhouse that transforms direct current into mechanical motion. It is based on Lorentz's Law, which asserts that "a current carrying conductor placed in a magnetic and electric field experiences a force."

Cable/pulley transmissions are ideal for torque control applications because they feature zero backlash motion, high stiffness, and extremely low friction levels. Backlash has a significant influence on closed loop bandwidth, whereas stiction can restrict a system's force resolution by causing limit cycling. High stiffness, of course, aids in the expansion of the system's bandwidth.

Fabrication technique

In MS rod, barrier is inserted in each end. And the small pulley is inserted in the MS rod at each end and screwed the small pulley.

The small MS bar is inserted in the large pulley and connected to the end rods of each pulley and connected by a long screw. Mechanical stoppers, limit the elbow motion in the sagittal plane, i.e., flexion-extension. Each mechanical stopper provides a 10° step increment. The mechanical stoppers have two functions to protect the affected forearm during the reinnervation process, i.e., to immobilize it. A small arc is drawn at the radius of 35mm which is considered from -10° to 140° with clearance at each end of the arc. The MS is welded adjacent to the arc, they were drilled in every 10° from 0° to 130° at the MS sheet, the arc is wielded with top of the end rods which is attached to a big pulley. The small pulley work as drive and the large pulley act as a driver which moves the forearm when it is connected to belt. The frame of the orthosis consists of the arm and forearm parts, both made from aluminium profiles. The adjustability is done with the help of a polypropylene sheet. The arm part is placed in the base plate the arm part is welded at an angle of ≈ 45° and the end was screwed with a screw and nuts. The forearm part is welded at the centre of a large screw that connects the two large pulleys.

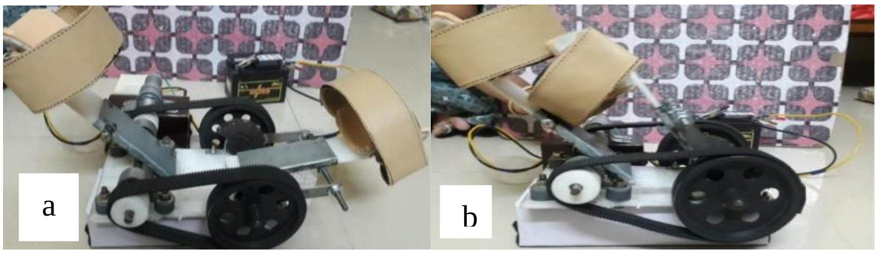

Figure 1 schematic diagram of dynamic elbow brace a. sagittal view of elbow brace with extension b) sagittal view of elbow brace with flexion

Table 1 components of the device and its description

S.NO	IMAGES	DESCRIPTION
1		12v dc 10rpm 140kgcm ig32 heavy duty planetary geared motor. Load current: up to 7.5 A(Max)
2		large Pulley for tracked belt. Fits on any of our geared DC motors with 6mm shaft. 100mm diameter and 20mm width
3		small Pulley for tracked belt. Fits on any of our geared DC motors with 6mm shaft. 30 mm diameter and 20mm width.
4		Flexible coupling, Material: Aluminium, Max. Speed: 20000 RPM, Rated Torque: 1.5 N-m, Bore Diameter d1: 6mm, Bore Diameter d2: 8mm.
5		A Double Pole Double Throw (DPDT) Flush mounting DPDT rocker switch Double pole double throw for flexion and extension
6		Rectangular aluminium pipes for arm mounting with adjustment

Calculation

The rotation motion is the ideal and the simplest means of transmission of mechanical power with negligible losses. Rotational motion can be transmitted from one mechanical element to the other with the help of certain systems known as transmission systems or drives.

This belt has a rectangular cross-section. These belts are capable of transmitting power over long distances between pulley centers. The efficiency of this drive is around 98% [7].

In 12 v DC motor output torque at 10 RPM =0.75 kg

This speed is further reduced to 3.33 RPM

Pulley ratio $= \frac{driven\ RPM}{motor\ Rpm} = \frac{3}{10} = 0.3$ (thus the driven RPM is assumed)

Hypothetically speaking, if we had a 30mm pulley on the motor, we would require a 100mm pulley on the pump. That mathematical equation is as follows: 30mm divided by 0.3 = 100

In diameter of big pulley D =100 mm

Small pulley d=30 mm

The efficiency of pulley drive = 98%

The output torque available at bigger pulley shaft is

= 0.75 × 3.33 × 0.98

= 2.45 kg.m

This torque is used to lift the arm with the lever length of cd =125 mm = 1.25 m (assumed)

Belt length

$$= \pi \times (D \times d) \times 0.5 + (2 \times cd) + \left(\frac{(d-D)^2}{(4 \times cd)}\right)$$

Belt length $= 463.9mm$

Load Carried by Brace:

The weight of the arm × length of the lever = 2.45

The arm that can be in the safety factor = 2.45 /2 × 0.07 = 17.5 kg

So the brace can lift up to 17.5 kg of arm weight using 12v DC motor output torque at 10 RPM.

RESULT

A follow up interview was performed one week after therapeutic exercise. This includes a Medical Research Council (MRC) Scale for Muscle Strength, SF- 36 for quality of life, Visual Analogue Scale for pain, The Disabilities of the Arm, Shoulder and Hand questionnaire to rate upper extremity disability, OPUS: Satisfaction with Devices and Services for device satisfaction survey. There is no improvement in muscle grading, pain was decreased, the disability score is below the average and the quality of life is slightly above the average, the satisfaction of brace is the average. The patient felt easy in donning and doffing. There is slight effective change, slight improvement in the motion rehabilitation of elbow, slight restoration of range of motion, improvement in quality of life and moderate satisfaction by using dynamic elbow brace. The patient felt that brace should be cosmetically good and weight should be decreased.

DISCUSSION

Brachial plexus (BP) injuries are rare, they are difficult to overcome. Following such injuries, both before and after surgery, as well as in cases when conservative management is used[1]. A number of published research have looked into the effectiveness of orthoses in improving upper limb function, reducing future contractures, and improving postoperative therapy after BP injuries.

Parry was the first to offer elbow flexion orthosis manufacturing for BP injuries in 1966. The goal of Parry's invention, as well as all later modifications of his design, was to give people a set functional degree of elbow flexion regardless of muscular weakness or a flail arm. Despite the fact that Parry's orthosis allows for improved upper-extremity usage, it is a compensating technique rather than a rehabilitative one[8].

Many robotic devices are being developed to aid in the rehabilitation of patients with disabilities. Various upper-extremity rehabilitation robots, in especially, have lately been created across the world[9].

Throughout the creation of this dynamic elbow brace, several key design features became apparent. The polypropylene calf, Velcro straps, aluminium bar and ethaflex covering were all low cost materials, easy to fabricate with adjust and replace. This addressed the patient’s concern regarding cost of device.

As we planned to design the device weight to be below 1 kg but after adding motor, coupling the weight of the device increased above 1 kg. The device is accepted as therapeutic device which help in the motion rehabilitation but cannot accepted as cosmetic one. This device is in low cost with high effective but it is cosmetically poor so patient felt that it should be both cosmetic and functional.

CONCLUSION

This focused on developing a dynamic elbow brace for training as part of the BPI postoperative rehabilitation process. The mechanical design specifications were double-checked. The suggested device achieves natural elbow motion by simulating a 1-DOF single-axis hinge type elbow model. It offers natural elbow motion while reducing modifications in joint anatomy and restrictions in elbow movements. in the following manner:

1. The complete range of elbow mobility was obtained, ranging from 0 to 130 degrees.
2. The flexion-extension motion of the elbow is limited by mechanical stoppers. A 10° step increase is provided by each mechanical stopper.
3. The elbow brace may be adjusted to fit a wide variety of upper limb sizes as follows:

a. The forearm length may be adjusted between 110 and 220 mm.
b. The length of the upper arm may be changed from 110 to 205 mm.
c. cuffs may be customised to each user's specific forearm and upper arm circumference.

A customizable actuation system was created, which can be adjusted to each stage of the BPI rehabilitation process. By removing the coupling, the drivers can be easily removed from the elbow brace, achieving the following goals:

a. remove the actuation systems and use the device as a mechanical brace during the immobilization phase.
b. To reduce the device's weight in instances when the rehabilitation process only necessitates physical workouts a few times each day.

This brace is functionally good needed to develop in the cosmetically. The device weight should be reduced by changing the actuation system and material used.

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