Cyclic pneumatic soft-tissue compression enhances recovery following fracture of the distal radius: a randomised controlled trial

Murray J Challis[1], Gwendolen J Jull[1], Warwick R Stanton[1] and Mark K Welsh[2]

[1]The University of Queensland [2]Caloundra Private Hospital
Australia

Questions: Does the addition of cyclic pneumatic soft-tissue compression during the 6-week immobilisation period following fracture of the distal radius result in a faster recovery of muscle strength and joint range of motion? Does it result in a larger recovery of muscle strength and joint range of motion immediately after the immobilisation period (at 6 weeks) or four weeks after the immobilisation period (at 10 weeks)? **Design:** Randomised controlled trial with concealed allocation and assessor blinding. **Participants:** 21 patients with fracture of the distal radius. **Intervention**: The experimental group received cyclic pneumatic soft-tissue compression during the 6-week immobilisation period whereas the control group received usual care. Both groups were instructed to actively make a fist 100 times per day during the 6-week immobilisation period and were given an exercise program during the 4-week post-immobilisation period. **Outcome measures**: Function was measured as power grip, pinch grip, key grip, and supination strength using dynamometry from Week 1 to 10 as well as wrist flexion/extension and forearm supination/pronation range of motion using goniometry from Week 6 to 10. The outcome measures are presented as a percentage of the intact side. **Results:** The experimental group improved significantly faster than the control group in muscle strength from Week 1 to 10 ($p \leq 0.001$) but not in joint range of motion from Week 6 to 10 ($p > 0.05$). By Week 6, the experimental group was 12–26% stronger and had 8–14% more range of motion than the control group. By Week 10, the experimental group was 24–29% stronger and had 10–15% more range of motion than the control group. **Conclusion:** The findings indicate that a larger clinical trial is warranted and should incorporate direct measures of fracture healing. **[Challis MJ, Jull GJ, Stanton WR, Welsh MK (2007) Cyclic pneumatic soft-tissue compression enhances recovery following fracture of the distal radius: a randomised controlled trial. *Australian Journal of Physiotherapy* 53: 247–252]**

Key words: Fracture Healing, Cyclic Compression, Fracture Compression, Pneumatic Pump, Randomized Controlled Trial

Introduction

It is well established both clinically and experimentally that fracture healing is largely dependent on the prevailing mechanical environment of the fracture (Sarmiento et al 1977, McKibbin 1978, Goodship and Kenwright 1985, Kenwright et al 1991, Kershaw et al 1993, Park et al 1998). Studies tend to suggest that there is an optimal mechanical environment for the progression of fracture healing, and that too much or too little of the wrong mechanical loading can hinder the process. Compressive forces probably constitute the greatest single positive influence on the mechanical environment of a healing fracture (Goodship and Kenwright 1985). Studies using both animal and human models have shown that intermittent compression or dynamic loading of long bone fractures enhances the rate of healing of these fractures and may promote the earlier return of normal function (Kenwright et al 1991, Goodship 1998, Hente et al 2004).

We have previously shown that the application of pneumatic soft-tissue compression applied to the musculature proximal to a fracture of the distal radius is able to create compressive forces at the fracture site (Challis et al 2005). Further, we found a beneficial effect when applying cyclic pneumatic soft-tissue compression to healing fractures of the distal radius in an *in vivo* ovine model (Challis et al 2006). In that study, the area of periosteal callus on X-ray, peak torsional strength, fracture stiffness, energy absorbed over the first ten degrees of torsion, and histomorphometric analysis were used to assess the progress of fracture healing. At four weeks, fractures treated with the cyclic pneumatic pressure were equivalent to control fractures at six weeks indicating a significant acceleration in fracture healing.

This preliminary study was conducted to investigate the effect of cyclic pneumatic soft-tissue compression, self-administered by use of a simple pneumatic compression apparatus, on the recovery of function following fracture of the distal radius. The research questions were:

1. Does the addition of cyclic pneumatic soft-tissue compression during the 6-week immobilisation period following fracture of the distal radius result in a faster recovery of muscle strength and joint range of motion?
2. Does it result in a larger recovery of muscle strength and joint range of motion immediately after the immobilisation period (at 6 weeks) or four weeks after the immobilisation period (at 10 weeks)?

Method

Design

A prospective, randomised controlled trial was carried out. Participants were volunteers from consecutive patients attending the fracture clinic of a general hospital in a regional area of Queensland, Australia. Patients were managed in a split forearm plaster immediately following fracture and prior to being recruited into the trial. Approximately one week post fracture, patients presented to the fracture clinic of the hospital where potential participants were identified by the fracture clinic nurse and recruited by one of the investigators (MC). The split cast was replaced with a full forearm plaster. All participants had an inflatable cuff positioned around their forearm under their plaster with the valve of the cuff protruding through the cast so that the independent assessor remained blind to group allocation during all measurements. Participants were then randomly allocated to either the experimental group or the control group by the fracture clinic nurse, who drew opaque envelopes containing the concealed group allocation from a box. All participants remained in plaster for a total of six weeks. The intervention was delivered for the last five weeks of the 6-week period of immobilisation. There was also a 4-week, post-immobilisation, follow-up period during which all participants performed a home exercise program. Participants exited the trial ten weeks from the day of their fracture. Measurements of hand and forearm strength were taken weekly both during the immobilisation period (Week 1 to 5) and on removal of the plaster (Week 6 to 10) post fracture. Measurements of range of motion were taken weekly on removal of the plaster (Week 6 to 10) post-fracture. An independent investigator who was blind to group allocation performed all measurements. Ethical approval for the study was given by the hospital ethics committee and participants provided informed consent.

Participants

Patients with fractures of the distal radius were eligible provided they were 18 years of age or older. They were excluded if they had open skin lesions, nerve or tendon damage associated with the fracture, or if the fracture required surgical fixation. They were also excluded if they had known pathology in their intact arm since measurement of strength and range of motion of the intact side were used as a reference against which to gauge recovery in the fractured side.

Intervention

Participants allocated to the experimental group were provided with a compression pump apparatus to use at home (Figure 1) and instructed fully in its use. The apparatus consisted of a compression pump connected to an inflatable cuff (Challis et al 2006) positioned around the proximal forearm flexor and extensor muscle bulk under the plaster. The compression pump was designed to pump air into a reservoir and, at designated periods, release a pressurised volume of air into the inflatable cuff. All components were standard electrical equipment. The apparatus operated on 240 volts and had a high-pressure safety lockout relay. The system was safety tested and complied with Australian electrical standards. One inflation/deflation of the cuff took 10 seconds and 60 compressions were applied per treatment session. The cyclic pneumatic pressure was applied twice per day (morning and evening) taking ten minutes for each session. This regime was based on the work of Rubin and Lanyon (1987) who found beneficial effects of external mechanical loading on intact turkey bones. The absolute compressive force applied to the fracture could not be pre-determined and thus an indirect method was used to devise a treatment dosage. This involved controlling the potential compression force experienced at the fracture site by pre-setting the pressurising period of the compression pumps reservoir to a level that was tolerated without discomfort. Testing the apparatus on two cases prior to the commencement of the study predetermined the pressurising period. A pressurising period of 3.5 seconds was found to result in a cuff inflation that did not produce any pain at the fracture site. It was considered that a pneumatic pressure on the forearm musculature that did not produce any pain at the fracture site would at best create an osteogenic effect, and at worst not interfere with the healing process. All participants in the experimental group received the same dosage of cyclic pneumatic pressure for the period they were in plaster (five weeks following the one week spent in a split cast). Participants were asked to complete a form to monitor their use of the compression pump apparatus.

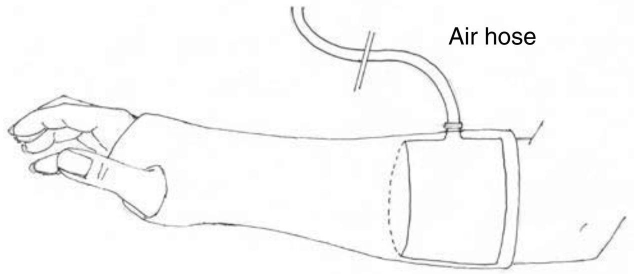

Figure 1. Diagram illustrating the position of the inflatable cuff under the plaster.

The control group received usual care of immobilisation in a plaster cast and did not use the compression pump apparatus while they were in plaster.

Participants in both the experimental and control groups were asked to use the fractured arm while in the plaster to the extent that it felt comfortable and to actively make a fist 100 times each day. It was considered that this would provide a more stringent test of cyclic pneumatic soft-tissue compression than no exercise. After removal of the plaster, all participants were given a program of strengthening and stretching exercises for the hand, wrist, and forearm to be carried out twice a day for four weeks (Wakefield and McQueen 2000).

Outcome measures

In clinical practice, one of the most common forms of measurement of fracture healing is function (Kenwright et al 1991) and measuring function over time can be used as an indicator of progress (Goodship and Kenwright 1985). Function was measured as power grip strength, pinch grip strength, key grip strength, and supination strength as well as wrist flexion/extension and forearm supination/pronation range of motion. Power grip strength was measured using a Jamar dynamometer with participants in a seated position with the elbow fully extended (Mathiowetz et al 1985, Kuzala and Vargo 1991). Pinch grip and key grip strength were measured using a dynamometer in the same position. Supination strength was measured isometrically using a torquometer made and calibrated specifically for use in this trial. The total range of movement from flexion to extension and supination to pronation was measured using a goniometer.