

## Technical note

# Preliminary clinical experience of a contracture correction device

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### Abstract

Joint contractures which do not respond to conventional physiotherapy can be difficult to treat. Serial plastering has been used effectively but is expensive, inconvenient to the patient and does not permit daily hygiene or clinical inspection. A mechanical device has been developed consisting a hinged orthosis which spans the affected joint to which is attached a gas strut to provide a corrective moment about the anatomical joint. Such an arrangement enables prescribed corrective moments to be applied accurately following clinical assessment using routine physiotherapy techniques. The inherently low spring rate of a gas strut ensures that the specified corrective torque is maintained as correction occurs.

Initial treatment experience under the control of the developers had generated wider interest in the system. A geographically distant independent orthotic supply centre was trained in the techniques of application. They treated nine elbow and three knee joints in patients who had not responded to physiotherapy treatment. All of the patients experienced improvement. The average for elbow joints was a reduction in the contracture of 25.6° with a corrective moment of 6.8Nm over a period of 3.9 weeks. For the knee joints the averages were a reduction in contracture of 10.7° with a corrective moment of 12.7Nm over a period of 4 weeks.

The results confirmed the practicality of transferring the system to independent clinical centres and provide evidence to support funding for a formal prospective clinical trial of the

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treatment approach.

### Introduction

The treatment of joint contractures which do not respond to conventional physiotherapy stretching techniques creates problems which are sometimes difficult to overcome. Surgical intervention is not always an acceptable option and the inconvenience of serial plastering can make it impractical for some patients.

Stretching a joint contracture is very demanding of physiotherapy time and for some patients the resources required to achieve a successful outcome are beyond that which it is practical to make available. Orthoses with a turnbuckle have been provided to achieve stretching. Whilst these do apply a corrective moment to the joint it is not normally possible to control that with the sensitivity which a physiotherapist is trained to provide. Such devices are set in a fixed position until a decision is taken to adjust the turnbuckle to increase the stretch still further. Consequently any plastic change in patient tissue achieved by stretching the contracture with the turnbuckle diminishes the effectiveness of the device until adjustment to accommodate the improvement is made. Lively devices employing conventional springs across the orthotic joint have also been provided, but these are usually more bulky than patients would wish. The comparatively high rate of springs which can provide sufficient force in the limited space available also means that their effectiveness diminishes more quickly than is desirable (with changes in spring length) as the joint responds to treatment.

To overcome these problems a design has been developed which employs a gas spring to

provide the corrective moment (Butler *et al.*, 1988; Moore *et al.*, 1990). A gas spring (the device used on the tailgate of many family cars) has the advantage that it is very compact and produces a large force combined with a very low spring rate (i.e. the force deviates only slightly as the device changes in length). These properties make it particularly suited to the requirements of a mechanical device for correction of joint contractures. Recent developments in the supply of gas springs has led to convenient availability in a variety of force ratings, and also with an option for a release valve to permit pressure reductions to accommodate specific force requirements.

Moore *et al.* (1990) described a system in which a physiotherapist (or other appropriate clinician) specifies the corrective moment they wish to apply for stretching the contracture by estimating this with a force transducer and measurement of the moment arm of their input to the patient. The force transducer, fitted with a curved patient interface pad, has a range of 160N with a resolution of 2N and an accuracy of 5%. Moment arms for the physiotherapist force application are measured with a standard orthotists tape, calibrated to ISO9000 requirements. The corrective moment is calculated by multiplying the force by the measured moment arm.

Once the moment has been clinically specified an orthosis, hinged at the joint being treated, is

manufactured which enables the selected corrective torque to be applied to the patient via location points at the thigh, the bottom of the shank and through a strap located just below the patella. Levers of standard design are attached to the metal side member of the orthosis. These provide location points for the gas spring on either side of the orthosis hinge and are arranged to ensure that the 20mm moment arm for the gas spring is only minimally affected by the magnitude of the contracture. An appropriate gas spring is then selected (and if necessary adjusted) to achieve the required moment through the lever arms. The geometrical arrangement which minimises changes of the moment arm with variations in the degree of contracture also ensures that corrections of the joint contracture under the influence of treatment do not significantly affect the corrective moment. A typical set up is shown in Figure 1.

When fitted, the contracture correction device (CCD) produces a constant moment against the contracture to achieve correction, in the absence of any voluntary muscle activity across the joint being treated. The clinically specified moment is normally at a level which the patient can voluntarily overcome for reasons of comfort or function. Unlike serial plastering the device can be removed so that it may be used for any prescribed period each day. This facility also permits it to be taken off for reasons of hygiene.

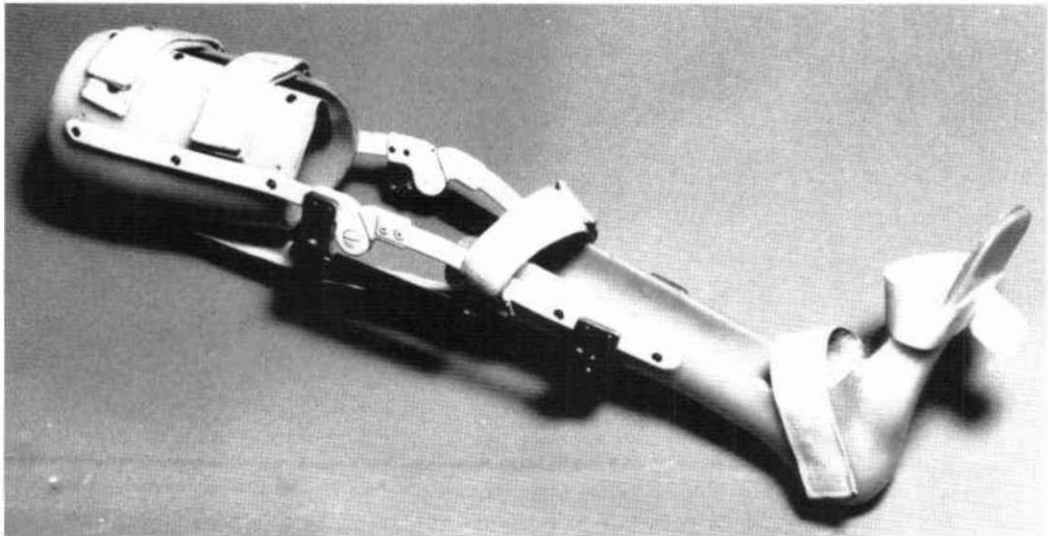


Fig. 1. A contracture correction device for a knee joint.

Where a patient has loss of sensation the CCD allows regular inspection of skin in the area where the corrective moment is applied, so as to ensure the pressure sores or other adverse effects are not developing.

### Initial clinical experience

Original development work was undertaken as specialist rehabilitation engineering for a girl with arthrogryposis. Physiotherapists were concerned that despite providing routine stretching therapy of both knees and hips for as long as practicably possible each day all of the contractures were continuing to increase. Her status as an independent ambulator was considered to be under threat as the increasing contractures were making it progressively more difficult to maintain that function. A device was produced which applied corrective moments simultaneously to knees and hips. This was used regularly each evening under the supervision of the child's parents. The results (Moore *et al.*, 1990) were better than anticipated in that not only were the contractures prevented from increasing still further (the original objective), significant correction in all treated joints was achieved.

Several additional *ad hoc* cases of knee contractures were subsequently treated as part of a routine clinical rehabilitation engineering service. Corrections were achieved in every case, but the improvement varied between patients. The magnitude of the corrective moments in all the cases treated within *ad hoc* rehabilitation engineering services varied from 7-10Nm. Successful local outcomes generated increased clinical interest in the potential of the device for patients with intransigent joint contractures. As a result a patient with an elbow contracture was referred for provision of rehabilitation engineering services. Assessment by the multi-disciplinary team ascertained that bilateral elbow contractures had occurred from unknown aetiology. The left elbow had responded to routine physiotherapy treatment, but the right elbow resisted that clinical approach and the patient was left with a residual flexion contracture of 105°. This severely restricted routine function and the patient was unable to perform many activities of daily living. Some anxiety was experienced in considering the potential of the CCD to achieve

a successful outcome. Previous devices had used moments significantly higher than the 2Nm which was estimated as being clinically acceptable for an elbow joint. The patient was clearly well motivated and keen to proceed with treatment in the hope that she could undertake additional activities to enhance her role as the mother of a young family. As reported by Keeping and Major (1999) a successful outcome was achieved with a reduction of the contracture to 60° over a period of 18 months, after which the patient could undertake many routine activities which were previously impossible (e.g. pick up her young child, iron, tie her own shoe laces).

A review of the *ad hoc* clinical experience in supplying the CCD suggested that the technique could usefully be applied in a wider context. A decision was taken, therefore, to produce a prototype system which could be applied in different clinical environments and at distant geographical locations. When this was completed arrangements were made for a preliminary trial with a separate United Kingdom National Health Service (NHS) orthotics contractor to establish whether or not the initial experience could be replicated in an environment independent of the developers.

### The prototype CCD system

Measurement of the appropriate corrective moment is an essential element of the system. A force gauge with the relevant range, which could be directly applied to the patient, and a tape measure for establishing the moment arm through which the clinician applies the input forces to identify the required moment was specified. A range of gas struts with appropriate force rating and length, and incorporating a pressure relief valve were identified. Standard orthotic hinges suitable for knees and elbows and with a suitable section for mounting the brackets for the gas strut to provide the appropriate lever arm were indicated. Training of orthotist staff from the participating company was undertaken so that they could select patients, monitor the required corrective moment in collaboration with a relevant clinician, specify the design of the CCD orthosis for manufacture in the workshop, verify its specification on delivery, fit the system and adjust to accommodate the patient.

## Methods

The purpose of the preliminary trial was to establish whether or not the encouraging results achieved under the direct control of the developers (Moore *et al.*, 1990; Keeping and Major, 1999) could be repeated when the principles were applied independently in a routine clinical setting. When training of three orthotists from the selected contractor (JC Peacock Ltd) was completed they discussed the system's potential with orthopaedic surgeons and physiotherapists amongst their routine clientele. This led to the referral of 12 patients for which existing therapeutic regimes were not achieving reduction in contractures of their anatomical joints. The orthotists assessed patient requirements in collaboration with prescribing clinical teams and specified a CCD for each patient in accordance with the training which had been provided.

Prior to the commencement of treatment the degree of joint contracture was measured using a long arm goniometer. When the system had been produced to the specification provided by the orthotist the patients and/or their carers were instructed in application of the device. The referring clinician specified the regime to be followed by the patient. Arrangements for routine review were established and the degree of contracture was measured at each clinical visit. The trial continued for between 3 and 5 weeks for each patient. At the completion of the established regime the degree of contracture correction was calculated by subtracting the end result from the initial degree of contracture.

## Results

Table 1 shows the joints treated, the corrective moment applied, the time over which the regime was conducted and the degree of correction achieved in each patient.

All the joints treated were either elbows or knees. A measurable degree of contracture correction was achieved in each of the patients. The magnitude of correction ranged from 7° to 43°. Applied moments ranged from 6Nm to 8Nm for elbows and 12Nm to 14Nm for knees. Treatment time was 3 to 5 weeks for elbows and 4 weeks for knees. Average results for all the joints treated were:

### Elbows

Degree of correction = 25.6°  
Applied moment = 6.8Nm  
Period of treatment = 3.9 Weeks

### Knees

Degree of correction = 10.7°  
Applied moment = 12.7Nm  
Period of treatment = 4 Weeks

### Overall

Degree of correction = 21.8°  
Applied moment = 7.4Nm  
Period of treatment = 3.9 Weeks

Since many of the patients had developing contractures it was not possible to determine the length of time these had existed prior to the point when treatment was sought by the referring clinicians. However, it is known that some

Table 1. Results of preliminary trials of the contracture correction device.

| Patient | Sex | Age (yrs) | Pathology | Joint         | Correction (degrees) | Moment (Nm) | Period (weeks) |
|---------|-----|-----------|-----------|---------------|----------------------|-------------|----------------|
| A       | M   | 37        | Trauma    | Elbow         | 27                   | 6           | 4              |
| B       | M   | 10        | CP        | Elbow - left  | 20                   | 7           | 4              |
|         |     |           |           | Elbow - right | 35                   | 7           | 4              |
| C       | F   | 58        | CVA       | Elbow         | 18                   | 8           | 3              |
| D       | M   | 63        | CVA       | Elbow         | 43                   | 7           | 5              |
| E       | F   | 10        | CP        | Elbow         | 10                   | 7           | 5              |
| F       | F   | 34        | CP        | Knee          | 12                   | 14          | 4              |
| G       | M   | 73        | Trauma    | Knee          | 10                   | 12          | 4              |
| H       | M   | 27        | Trauma    | Knee          | 10                   | 12          | 4              |
| I       | M   | 37        | CVA       | Elbow         | 7                    | 7           | 4              |
| J       | M   | 41        | Trauma    | Elbow         | 30                   | 6           | 3              |
| K       | F   | 8         | CP        | Elbow         | 40                   | 6           | 3              |

contractures had been considered a problem for periods in excess of one year, whilst others had been recognised as such more recently than this.

### Discussion

The outcomes achieved in a variety of conditions and patients over short treatment periods in contractures which had existed over a range of periods were encouraging. In none of the patients was there failure to achieve correction, though in one case the improvement was only just outside the resolution of the contracture measuring system. The preliminary trial was undertaken with close clinical control and patients were selected because it had not been possible to apply more conventional physiotherapy. Previous *ad hoc* experience with the system had suggested that success should be achieved, so the results were to be anticipated, particularly as the device merely provides a more convenient means of applying long established widely applied physiotherapy stretching practices. The most likely explanation for the success in patients for which it had not been possible to achieve correction previously is that the treatment can be applied over considerably longer periods than is practicable with a direct physiotherapy input.

It was noticeable that the torque applied to elbow joints (6-8Nm) was higher than the 2Nm previously reported (Keeping and Major, 1999). No significance should be attached to this difference which is a reflection of particular patient circumstances and individual clinical opinions. It is significant that estimations of appropriate torque for elbow joints is consistently lower than for knees.

There are some obvious parallels between the CCD and serial plastering. Both seek to apply a corrective moment by direct mechanical means. However, serial plastering is unable to maintain its corrective moment as contracture is reduced and has to be re-applied with the joint stretched to its new limit. This is inconvenient in that it requires the patient to re-attend the clinic, and it ties up valuable resources at the Hospital. Initial cost of a CCD is likely to be greater than that of a single application of a plaster. However, successive re-applications of a plaster is an expensive option, particularly if proper consideration is given to overheads and staff time. Lehmkuhl (1992) reported that re-applications of plasters on an approximately 3

day cycle over a 3 to 6 week period was necessary to achieve effective correction. Re-application of plasters required two staff working for 1 to 1.5 hours. It is clear on that basis that CCD would, in comparison, be an economically viable option. The ability to specify periods of treatment each day also provides the possibility of the patient maintaining functional activity involving the limb with the affected joint when the device is removed. Daily hygiene and clinical inspection are also possible with a system which can be removed. Patient comfort is also likely to be enhanced by an ability to move the joint against the corrective moment in order to relieve cramp or cope with an unexpected functional requirement.

### Conclusion

The main purpose of the trial has been vindicated in that similar clinical outcomes to those demonstrated by the developers have been achieved by a routine orthotic supply service working in collaboration with clinicians faced with difficult joint contracture problems. It was not intended at the current stage of development to establish a full prospective clinical trial of the treatment system. The limited ambitions of the project and the successful outcome are nevertheless an important step forward in providing the confidence needed to support any future proposals for a full prospective trial of the system.

Physiotherapists who routinely apply stretching techniques will recognise that the system does not propose radically new treatment options, but merely provides a more convenient means of maintaining their routines over longer periods. Serial plastering and the CCD are clearly analogous and any clinical condition for which serial plastering is contemplated is equally appropriate for the CCD. The consistency of the success achieved without complications is greatly encouraging and supports continuing clinical application of the system in situations where more conventional clinical options are not possible, or may be inappropriate.

### REFERENCES

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