A Mechanical Device for the Reduction of Distal Radius Fracture

L. Priya, N.Venkatesh Kumar, M.SanjayBalaji, C.V.Revanth

Abstract: Distal radius fracture is one of the most common fractures that occur to a person or a child who undergoes any accidents or has any bone diseases. There are several ways of treating this fracture. It involves relocating the fractured bone by a process called reduction. A novel method of reducing the radial bone using a mechanical device has been proposed where it decreases the number of surgeons, time required to reduce the distal radius fracture and seeks to improve the accuracy of reduction. This paper describes the mechanism of reduction, design considerations and the disease conditions for which the device could be used.

Keywords: Distal radius fracture; reduction; internal fixation; external fixation; K-wires; Aluminium; C-arm; Fluoroscopy.

I. INTRODUCTION

A distal radius fracture is a common bone fracture of the radial bone in the forearm. Because of its proximity to the wrist joint, this injury is often called a wrist fracture. The fractured hand is immobilised during treatment. Sometimes surgery is needed for complex fractures. Specific types of distal radius fractures include Colles' fracture, Smith's fracture, Barton's fracture and Chauffeur's fracture. As a generic term for distal radius fracture "Colles' fracture" is used to avoid confusion among the names applied to specific patterns of fracture.

The most common cause of this type of fracture is a fall on an outstretched hand. In adults this fracture is the consequence of moderate to severe force such as a fall from a substantial height or a motor vehicle accident. The risk of trauma is raised in patients with Osteoporosis and other metabolic bone diseases[1]-[7].

The distal radius fracture is treated by a procedure called Reduction. Reduction is a surgical procedure to restore the fracture or realigning to the right position by displacing the bone with the application of certain amount of force. Reduction could be classified as open reduction and closed reduction. Closed reduction is a procedure to reduce a broken bone without surgery. It allows a bone to grow back together. When this procedure is done as soon as possible it works well. The fractured area of the patient is first anesthetized with hematoma block, local anaesthesia, sedation or a general anaesthesia. Manipulation are done by placing the arm under traction and unlocking the fragments [8],[9].

Various surgical tools and implants are used in orthopaedic applications. Few such tools are K-wires, internal and external fixators, nails, plates and rods. The K-wires or Kirschner wires or pins are sharpened, smooth stainless-steel pins. They are used to hold the bone fragments at the injury site. In order to keep the reduced bones and soft tissues at a distance from the injured place a surgical treatment called External fixation is done with the use of K-wires and fixators. This treatment provides unimpeded access to the skeletal and soft tissue structures for the initial assessment and also for secondary treatments that are required to fix the bone continuity and a functional soft cover [10]-[15].

Depending on the type of deformity the deformed bone is then reduced with appropriate closed manipulations. A splint or a cast is applied to immobilize and protect the broken bone. A C-arm or any other imaging medical equipment is used tocheck the fracture site and to ensure the reduction was successful.

In Open reduction the fractured fragments are seen directly by dissecting the tissues. And the same procedure done for closed reduction is made.The Fig.2 shows K-wires made of stainless steel. The Fig.1 and Fig.3 shows the X-ray images of a normal hand and a hand with distal radius fracture respectively.The Fig.4 and Fig.5 shows the X-ray images of hand post internal fixation external fixation respectively.

Fig.1 X-ray image of a normal hand

Fig.2 Kirschner wires

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Dr.L.Priya, Department of Biomedical Engineering, PSG College of Technology, Coimbatore, India, e-mail: priya.god81@gmail.com, Phone number: +91 979 1818 444.

Dr.N.Venkatesh Kumar, Associate professor, Department of Orthopaedics, PSG Institute of Medical Sciences and Research, Coimbatore.

M.SanjayBalaji, C.V.Revanth, UGStudents, Department of Biomedical Engineering, PSG College of Technology, Coimbatore.

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Fig.3 X-ray image of a hand with distal radius fracture

Fig.4 X-ray image of hand post internal fixation

Fig.5 X-ray image of hand post external fixation

Treatment of distal radius fracture using casts is usually successful with healing and return to the normal function as expected. Some residual deformity is common but this often reforms as the child grows. In the elderly, distal radius fractures heal and may result in adequate function after reduction. In younger patients the injury requires greater force and results in more displacement particularly to the articular surface. Unless an accurate reduction of the joint surface is obtained, these patients are very likely to have long term symptoms of pain, arthritis and stiffness.

The surgical tools and implants used for medical applications must be biocompatible and should not induce any ill effects to the patients. High corrosion resistance, durability, lightweight, radiolucent are the most important properties the surgical tools must possess. Materials like titanium alloys, stainless steel alloys and aluminium alloys are the most widely used alloys. Depending upon the degree of severity and cost of treatment different alloys are chosen. Aluminium is a low-cost biocompatible metal and its being used in hospitals widely [16]-[18].

II. MATERIALS

The designed mechanical device for the reduction distal radius fracture was made of 1060 grade aluminium. This alloy has high corrosion resistance, light weight and radiolucent properties that are needed for the surgical procedure. Also, this material can be sterilized as many times as needed. The properties of the material don't change in time. The composition of 1060 grade aluminium is shown in the Table 1.

Straps made of Velcro are wrapped around the palmar region and the radio-ulnar region to keep the hand fixed in position. Except for the small finger, the thumb and the index, middle and ring fingers are wrapped using Chinese finger straps to keep it intact.

The Chinese finger straps are made of nylon material which is used conventionally in surgeries. These straps attached to the fingers are connected to the T shaped screws to provide traction.

Table 1: Material Composition of 1060 grade Aluminium

Metal name	Composition (%)
Aluminium	99.6
Copper	0.05
Iron	0.13
Magnesium	0.03
Manganese	0.03
Silicon	0.03
Titanium	0.03
Vanadium	0.05
Zinc	0.05

III. METHODOLOGY

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The hand length and hand width combined constitutes the hand size. The average hand length and width for male are nearly 190mm and 85mm respectively. The average hand length and width for female are nearly 170mm and 75mm respectively. Keeping these values into consideration the Wrist reduction device was made.

A. Design and Implementation of Wrist Reduction Device

The designing and implementation of the Wrist reduction involved several steps. Initially the model of the device was designed using PTC Creo, CAD software. Then a prototype of the model was done using 3D printer. The prototype was made of polylactic acid. The functionalities of the device were tested to know if it suits the required constraints. After few modifications the final Wrist Reduction Device was made using Aluminium alloy.The Fig.6 explains the designing and implementation of Wrist Reduction Device in the form of flowchart. The designed Wrist Reduction Device is shown in the Fig.7. The Wrist Reduction Device is made to produce load by adjusting the center radial adjuster. It can also withstand high loads as much the hand could handle.The dimensions of various components in Wrist Reduction Device are tabulated in Table 2.

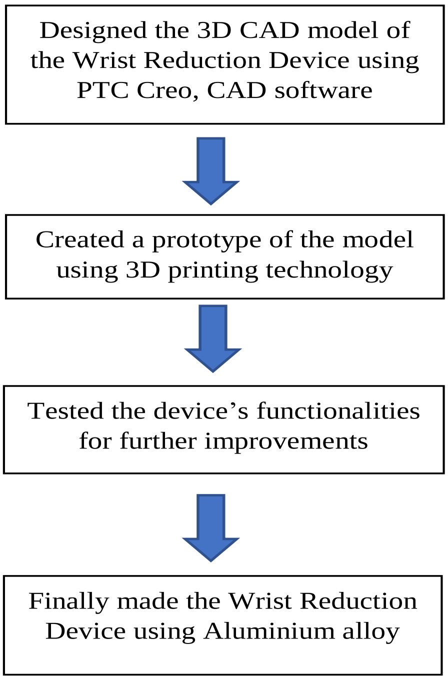

Fig.6 Flowchart of designing and implementation of Wrist Reduction Device

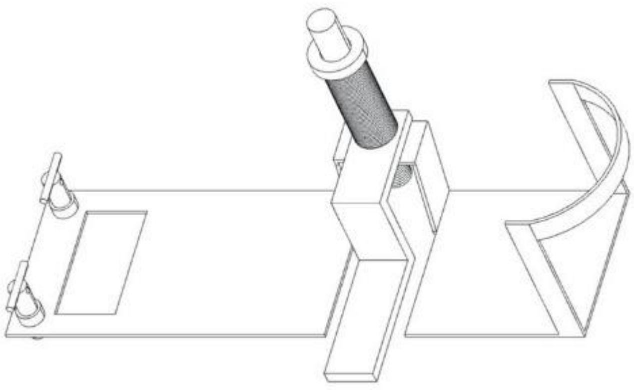

Fig.7 The 3D CAD model of the designed Wrist Reduction Device

Table 2: Dimension of various components

Parameter	Dimension (mm)
Pitch of the external thread	1.5 mm
Pitch of the internal thread	1.0 mm
Thicknesss of the Wrist and Base plates	3.0 mm
Length of the Wrist plate	150 mm
Length of the Base plate	140 mm
Width of the Wrist plate	65 mm
Width of the Base plate	65 mm

B. Mechanism of Reduction by the Mechanical Device

The mechanical Wrist Reduction Device has 2 plates. One for keeping the palmar region and other for placing the radio-ulnar region. These two plates are called Wrist plate and Base plate. These two regions are wrapped using straps or crepe bandages to avoid movements and keep the hand tight to the device.

In the first step, the thumb and the index finger, middle finger and ring finger are inserted into the Chinese finger straps. The fingers are fastened. The Wrist plate has two T shaped screws. After fastening, one nylon rope strapped to the thumb is attached to T shaped screw in front of it. Another nylon rope strapped to the three fingers is attached to T screw in front of it. The two T shaped screws are rotated to provide traction as required. The Wrist plate and Base plate are immovable and kept in horizontal direction while providing traction. The shaft with threads and a small circular nut present in the middle portion is interlocked. It keeps the plates fixed.

In the second step, the shaft is rotated to keep the Wrist plate in the required angle with respect to the shaft. The shaft is again interlocked with the nut. The Base plate and Wrist plate are made immovable again. As a result, ulnar deviation is done.

In the third step, the middle L-shaped part is raised and lowered by rotating the radial adjuster. As a result, the proximal fragments or the broken bone gets elevated. The broken bone gets aligned in the right position.

Either local anesthesia or general anesthesia is given to the patient prior to the reduction procedure. The bones of the hand are drilled to make bores of required dimensions. Then K-wires and fixators are inserted into the bones through the bores to keep the reduced bones in the fixed position. The position of the K-wires is monitored using a C-arm or fluoroscopy to guide it through the bones. After that a plaster of paris cast is made over the hand and the arm is allowed to heal.

This procedure can be done by a single surgeon alone.

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The chances of occurrence of fracture due to the usage of the device in older patients and in patients with Osteoporosis are very low since the device itself doesn't produce any force or amplify the applied on it. But it only translates the force applied by the doctor on the wrist. The Fig.8 shows a surgeon operating a C-arm equipment to view the fractured hand while doing Wrist reduction.

Fig.8 A surgeon operating C-arm equipment

C. Mechanism of Reduction by the Conventional Method

In the conventional method, more than two surgeons are required. Anaesthesia is provided to the patient prior to surgery. The patients hand is placed over a radiolucent table. Then traction is provided to the hand by a surgeon while another surgeon holds the radio-ulnar bones. Then ulnar deviation is done by one surgeon. Then one or two surgeons realigns the fractured bone to the original position by the reduction procedure. Then K-wires and fixators are inserted to the bone depending on the severity. These are guided by X-ray based imaging machines like C-arm or fluoroscopy. A C-arm is widely used to guide the K-wires. Then a palter of paris cast is made over the hand to heal.

IV. RESULTS AND DISCUSSIONS

Thus, a low cost mechanical device is a viable inclusion in the orthopaedics for reduction of broken wrist. By using this device, the human effort needed to reduce the broken wrist is reduced. The Front view of the Wrist Reduction Device is shown in Fig.9.The Top view of the Wrist Reduction Device is shown in Fig.10.The Front view of the Wrist Reduction Device with a patient's hand placed in the device is shown in Fig.11.

Fig.9 The front view of the Wrist Reduction Device

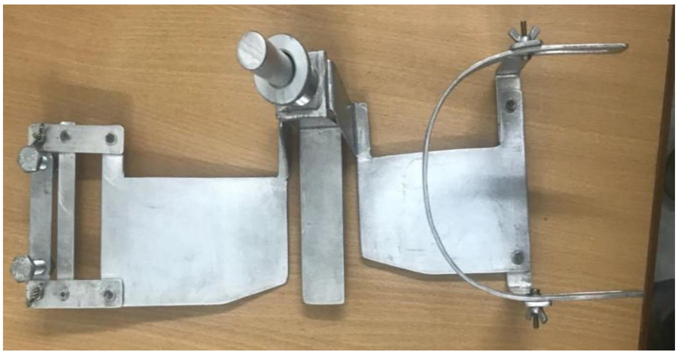

Fig.10 The top view of the Wrist Reduction Device

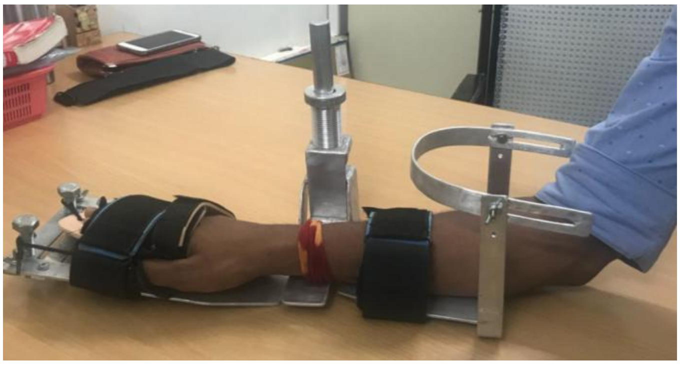

Fig.11 The front view of the patient's hand placed on the Wrist Reduction Device

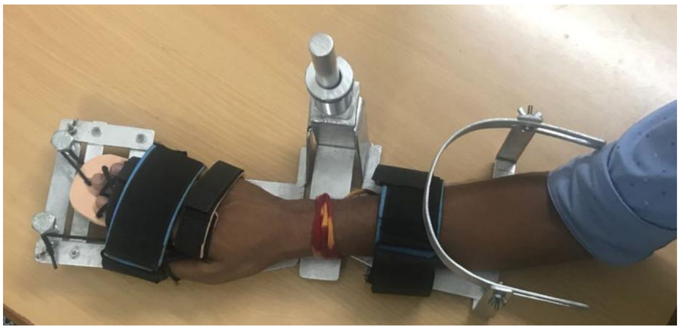

Fig.12 The top view of the patient's hand placed on the Wrist Reduction Device

The Top view of the Wrist Reduction Device with a patient's hand placed in the device is shown in Fig.12 shows the Wrist Reduction Device made of Aluminium. Comparison of conventional method and the mechanical based Wrist Reduction Device is to be done on the following aspects; Time taken for reducing the distal radius fracture, percentage of cases on which successful

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reduction is achieved, accuracy of reduction achieved and feedback from doctors is to be used for the purpose of concluding whether the proposed method is better than conventional method. This device could be used for both invasive and non-invasive reduction of fractures bone.

V. READINGS

Department of orthopaedics, PSGIMSR were evaluated and accepted the research study entitled "*Wrist Reduction device*" and Clinical trial is held for a period of six months at PSG Hospitals, Coimbatore.

- **Objectives:** To design a mechanical device to reduce the human effort needed to fix a broken wrist.
- **Background:** medical practice in PSG Institute of Medical Sciences and Research.
- **Participants:** 20 patients- with broken wrist.

This device is operated by the physicians and they have rated the device based on its performance, stability and device longevity. Table 3 shows the rating values evaluated by the medical staffs in the scale of 5.

Table 3:Physician's outcome towards the device

Number of Physicians	Performance	Stability	Longevity
Physicians 1	3.5	4	4.5
Physicians 2	4	5	4.5
Physicians 3	3	3.5	5
Physicians 4	5	4.5	4.5
Physicians 5	4.5	4	5

VI. CONCLUSION

The Wrist Reduction Device can be used as an alternative method to reduce the distal radius fractures which relies upon manual reduction procedures for reducing it. By using the wrist reduction device, the human resource and human effort required to reduce the distal radius fracture can be dramatically reduced and by doing so the time consumed to reduce the most commonly occurring fracture is reduced thus making the medical personal available to treat the patients when they are most needed. An additional axial pull adjustment can be added. The device can be adjusted to fit all lengths of hand. The pitch could be optimised. More clinical trials should be done for improving the device's functionality. The device costs around Rs.5500 (INR). It could be made available in the market and used by many doctors for the reduction procedure. It might decrease the medical expenses of the patient if used.

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