Creating distraction at the knee joint: a treatment option for osteoarthritis

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Abstract

Our client, Kim Skinner, is a physical therapist who treats many patients who suffer from knee osteoarthritis, a painful and degenerative disease caused by the deterioration of the articulate cartilage in the knee [1]. Recent studies have shown that joint distraction (the forced separation of the two bony ends of a joint) can improve, if not restore this deteriorated cartilage [1]. Our team has designed an at-home device to perform distraction on the knee in hopes of prolonging its life. Testing of this device has proven successful in applying a distraction force significant enough to separate the joints in the knee. With further work we are hopeful that this product will be made available to all those who suffer from knee osteoarthritis.

Introduction

•Osteoarthritis (OA) is a painful degenerative disease that affects millions of people world-wide.

•OA is the breaking down of the cartilage in between joints, and therefore causes the bones to rub together and cause pain [1].

•Joint distraction is a procedure that gradually separates the two bony ends of a joint for a specified amount of time using an applied force [2].

•Recent studies have shown that distraction of joints allows the cartilage between the joints to grow back and thicken [3].

•Our client asked us to design and fabricate the first non-invasive knee traction device.

•It is hopeful that such a device will prolong the life of the knee and possibly eliminate the need for surgery.

Figure 1: A diagram of the progression of osteoarthritis in the knee joint.
http://www.woodwardmedical.com/knee-osteoarthritis.html

Design Criteria

- Apply a maximum force of 311.4 N (70 lb) to distract the knee joint
- Maintain distraction for 20 minutes
- Last a minimum of 15 years
- Keep the knee at a 30° angle from horizontal ("open-pack" position)
- Fit patients of varying weight and size
- Not distract hip or ankle joints
- Must be light-weight and simple for at home use

Force Analysis

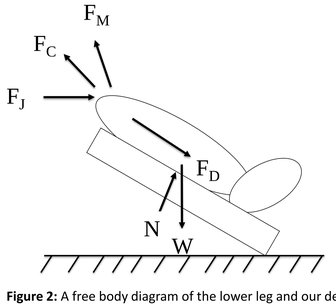

Figure 2: A free body diagram of the lower leg and our device.

•F_C : tensile force from ligaments in the knee

•F_M : tensile force of the quadriceps muscle

•F_J : joint force

•F_D : traction force from the device

•W : weight force of the lower leg

•N : normal force exerted on the leg from the device

•F_C, F_M, F_J all modeled as 0

•F_D modeled as 70 lb (31.8 kg)

•W varies on the patient's weight

Final Design

Figure 3: Overall structure of final design including vinyl fabric, two inch thick padding and triangular structure made of 2x4 wooden beams.

•Height = 19", Length = 32 7/8", Width = 11"

•Cushioned padding with blue vinyl cover

Figure 4: Taut wire rope and knee strap shown on a patient's leg being distracted.

Wire Rope, Knee Strap

•Steel cable with breaking strength up to 2,000 lbs

• Athletic strap wrapped around bottom of knee. Fitted with wire clips to attach steel cables to strap.

•Pulleys with 3" outside diameter

•Custom made steel axle to house pulleys

Hand Pump, Gauge, Cylinder

•Air cylinder with outside diameter of 1.31" and a maximum force of 103 lbs.

•Avenir Air Source Frame Pump to apply pressures up to 100 psi

•Rubber tubing to deliver air from pump to cylinder, with maximum pressure of 200 psi

•Gauge with pressure range from 0 to 30 psi

Figure 5: Back view of air cylinder with hose and wire attached.

Future Work

•Construct a lightweight, collapsible device using plastics or metal

•Construct a strap and cable system that is adjustable to accommodate patients varying in height and weight

•Create a barrier to keep the cables in their pulley slots during patient setup

•Strengthen the connection between the hand pump and the adaptor to increase product durability

•Develop a release mechanism to release pressure in air pump after distraction

Testing & Results

Ratings	Average	Std. Dev.
Overall	4.25	0.57735
Comfort	4.4375	0.629153
Usability	4.125	0.718795

Table 1: Values averaged from 16 test subjects. Rating scale is from 1-5 with 1 corresponding to a low rating, and 5 as the highest.

•Testing was performed in the basement of ECB.

•16 random test subjects

•Age range: 18-22

•Weight range: 120-210

•Height range: 5'4"-6'2"

•Average force applied: 63.7 lb

•Used device for 5 minutes

•Test subjects given a form asking them to provide their age, weight and height, as well as sex.

•Asked to provide 3 rankings from 1 to 5 (1 corresponding to a low rating, 5 to a high rating)

•Future testing will include X-ray scans of patient using device to compare to scans without device

•Scans will be used to determine the separation of the joints during distraction

Discussion

Testing:

•The lowest scoring category included in our survey was usability.

•Judging from comments received, probable cause of low score could be attributed to a difficulty in using the leg strap

•Slight leak in connection between pump and cylinder also hindered testing because it was difficult to maintain a constant force

•The highest scoring category in our testing was patient comfort.

•Test subjects were pleased with the padding added to the wooden structure, as well as the vinyl fabric used to cover the top of the structure

•During testing, we received many comments indicating that the device is successful in separating the joints in the knee.

•Positive feedback was received in all three categories

Budget:

•Overall budget was $500

•Total cost of our device was $296.42

Limitations:

•Inability to find a hand pump with similar threads to our adaptor

•No available gauge with readings in pounds of force

Acknowledgements

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References:

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[3] Nishino T., et al. *Joint distraction and movement for repair of articular cartilage in a rabbit model with subsequent weight bearing*. Journal of Bone and Joint Surgery. Vol 92-B. Issue 7. 2010. http://web.jbjs.org.uk/cgi/content/short/92-B/7/1033