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# United States Patent [19]

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Akhter et al.

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[54] **APPARATUS FOR STUDYING THE EFFECTS OF COMPRESSIVE AND TENSILE BENDING STRAINS ON BONES**

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[51] Int. Cl.<sup>6</sup> ..... **A61B 5/103**

[52] U.S. Cl. .... **128/782**

[58] Field of Search ..... **128/774, 779, 782**

[56] **References Cited**

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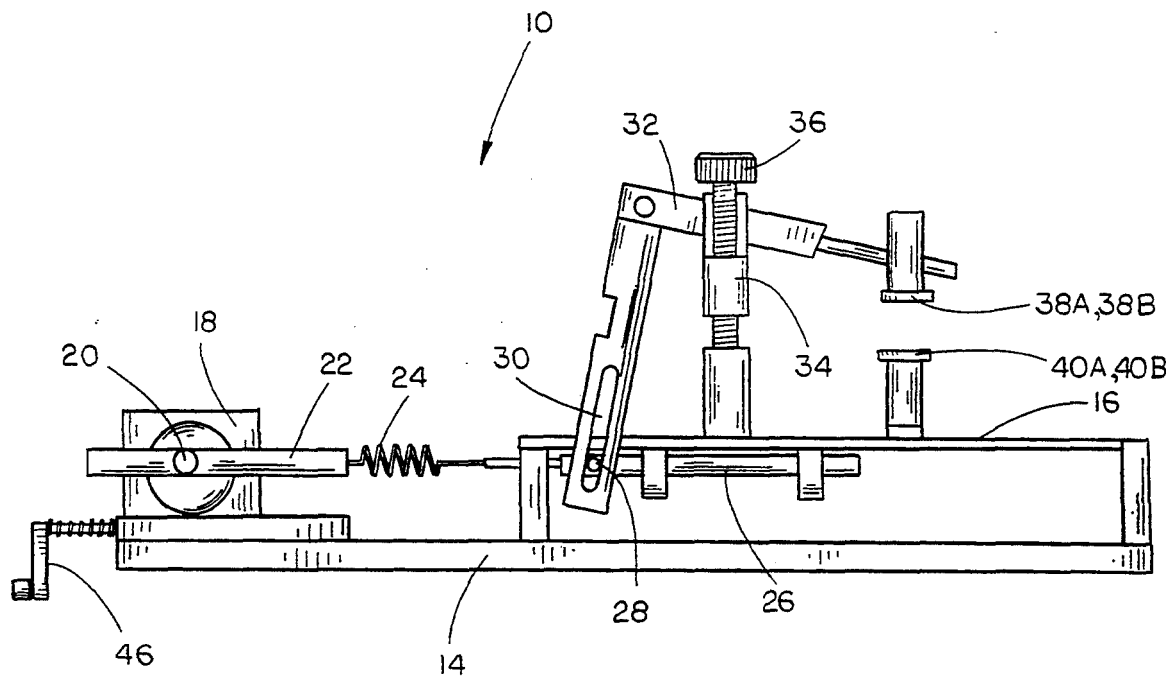
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[57] **ABSTRACT**

An apparatus for applying compressive and tensile loads on bones having a frame with a work surface and a stepper motor. The stepper motor is operably connected to a rotational force to linear force converter which is in turn connected to an articulating arm for applying force to a first pair of pads. A second pair of pads is mounted to the work surface such that a bone may be placed across the second pair of pads such that either end of the bone is supported by the second pair of pads and such that the activation of the stepper motor causes the upper pair of pads to exert compressive bending strain on the lateral surface of the bone and such that the lower pair of pads exert tensile bending strain on the medial surface of the bone. A method of modifying hard tissue morphology is also described.

**1 Claim, 2 Drawing Sheets**



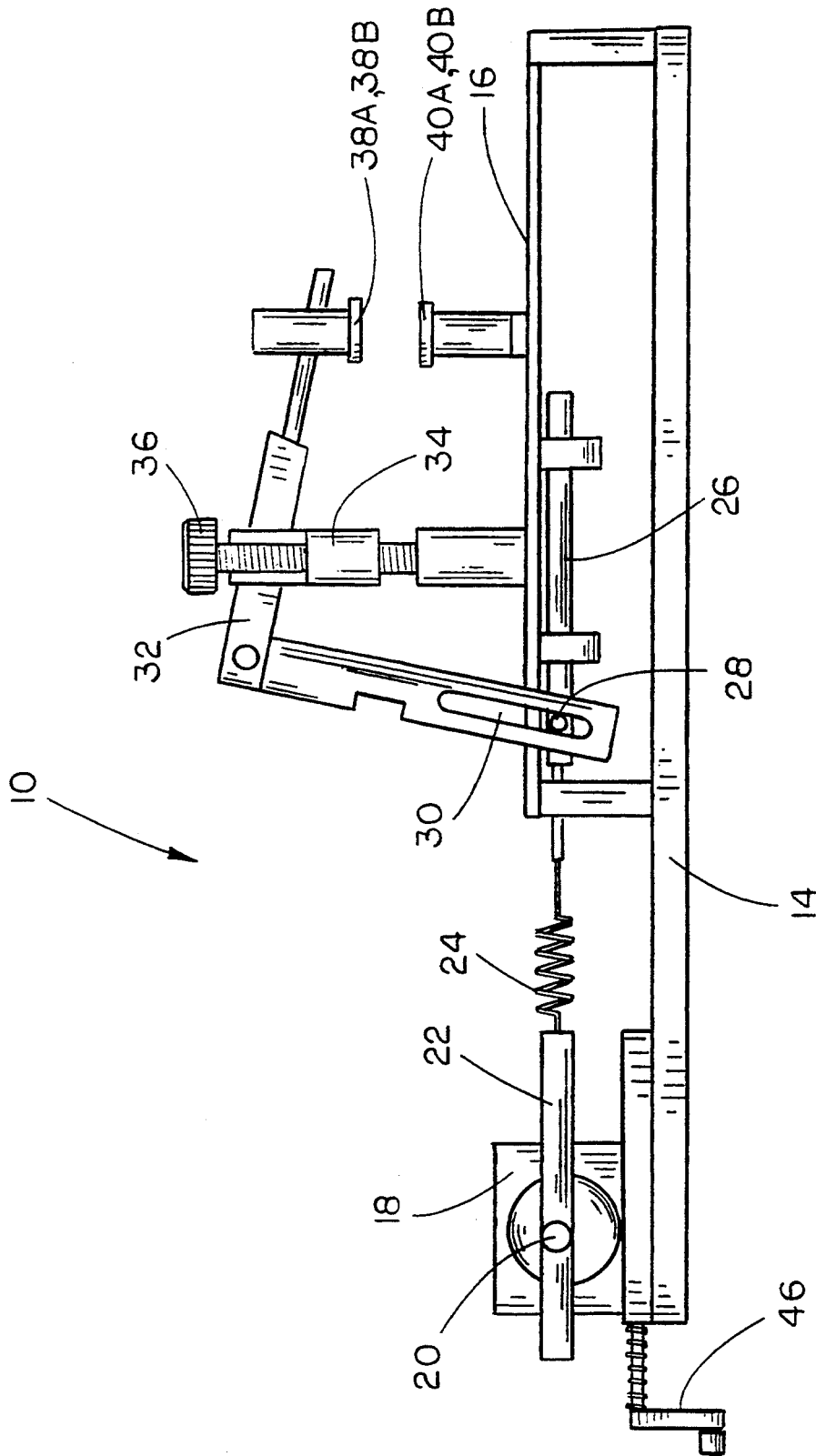


FIG. 1

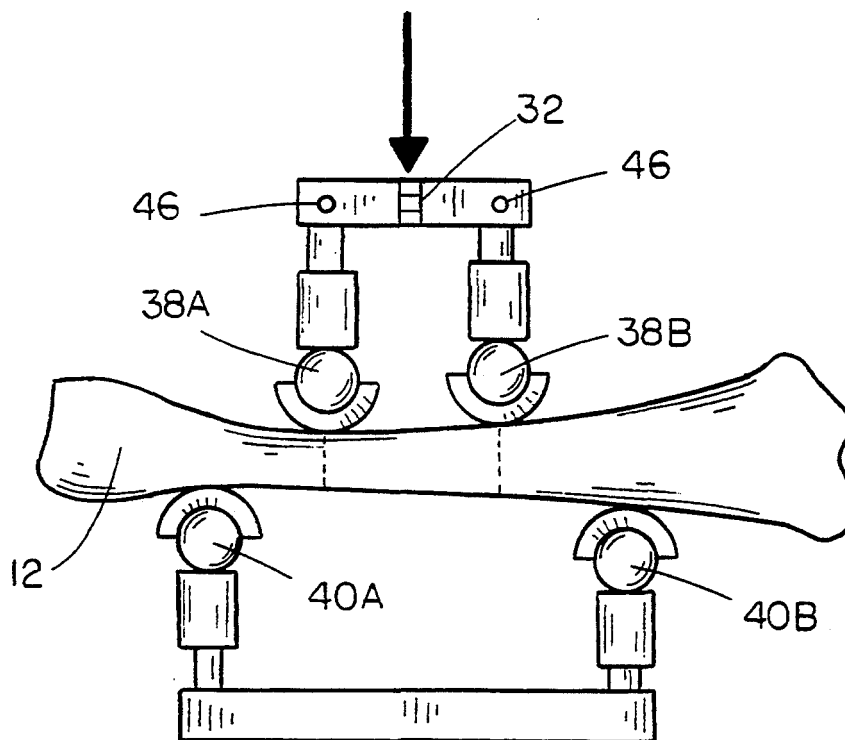


FIG. 2A

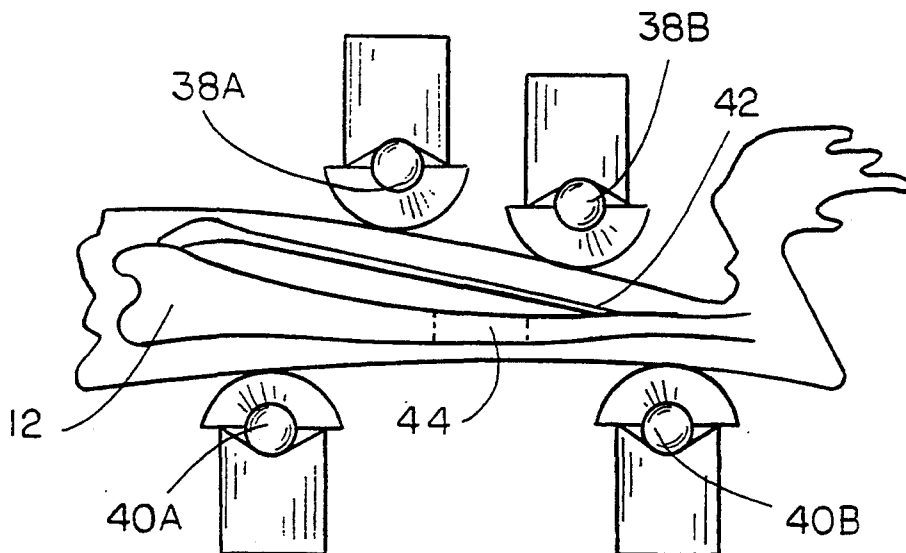


FIG. 2B

## APPARATUS FOR STUDYING THE EFFECTS OF COMPRESSIVE AND TENSILE BENDING STRAINS ON BONES

### GOVERNMENT RIGHTS

The present invention was partially funded by a grant from the United States government.

### SPECIFICATION

Authorization Pursuant to 37 C.F.R. 1.71(d) and (e)

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### CROSS REFERENCES

#### Related Applications

The present application is an original patent application.

### TECHNICAL FIELD

The present invention is generally related to load applying apparatus and more particularly to a novel method and apparatus for studying the effects of imparting controlled compressive and tensile loads on bones.

### BACKGROUND ART

The in vivo bone response to mechanical stimulus is not well defined. In order to determine and analyze the response an apparatus and method for inducing the stimulus is necessary. Unfortunately, heretofore, neither a suitable method nor apparatus was available for studying the short and long term effects of such stimulus. The morphology of hard tissue exposed to mechanical stimulus may best be determined via a quantifiable method of applying both compressive and tensile forces to hard tissue.

### DISCLOSURE OF INVENTION

The apparatus of the present invention provides a method of applying compressive and tensile loads on bones. The apparatus of an exemplary embodiment includes a frame with a work surface and a stepper motor. The stepper motor is operably connected to a rotational-force-to-linear-force converter which is in turn connected to an articulating arm for applying force to an upper pair of pads. A lower pair of pads is mounted to the work surface such that the bone of an animal may be placed across the lower pair of pads such that either end of an animal bone is supported by the lower pair of pads, and such that the activation of the stepper motor causes the upper pair of pads to exert compressive bending strain on the lateral surface and the lower pair of pads exert tensile bending strain on the medial surface of the bone such that the apparatus may be utilized to cause both tensile and compressive loads. A method of modifying hard tissue morphology is also described.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation of the present invention illustrating the primary components of a preferred embodiment; and

FIGS. 2A and 2B are partial front elevational views illustrating an exemplary apparatus for utilizing the invention according to a preferred method.

### MODES FOR CARRYING OUT THE INVENTION

The present invention teaches a novel apparatus for studying the effects of controlled bone exercise. The apparatus may be used in an exemplary embodiment, to study the in vivo bone response to mechanical stimulus (bending strain).

By turning first to FIG. 1, wherein the major components of an exemplary embodiment are illustrated, the operation of the apparatus will become known. In a preferred embodiment a frame having an upstanding flat work surface is provided. A stepper motor and programmable controller operable at 200 steps per revolution (available from Superior Electronics, Bristol, Conn.) is mounted to the frame. The drive shaft of the motor is operably connected to a force converter. The converter (rotating arm) is adapted to convert the rotational energy of the motor to linear energy. The converter is connected to a spring which is in turn connected to a slide bar (slidably mounted on the undersurface of the work surface). Pivotably connected to the slide bar (via a pin [slide bar pin] and slot [lever arm]) is a lever arm strain gauge. The lever arm is adjustably and pivotably connected to the work surface via a lever arm support. An adjustment screw is provided in the support for adjusting the height of a first pair of loading pads (see FIGS. 2A and 2B).

Mounted on the work surface is a lower pair of coaxing loading pads. The lower pair of pads is mounted 23 mm apart and the upper pair of pads is mounted 11 mm apart (in an embodiment adapted to study the effect of mechanical stimulus on rat tibia). The upper pair of loading pads are pivotably mounted such that both pads are maintained in contact with the soft tissue surrounding the bone to be loaded. According to a preferred method the upper pair of loading pads is set such that one of the pads applies force just ahead of the tibio-fibula junction and such that an undisturbed loading zone of approximately 8.5 mm is produced in the rat tibia. By activating the stepper motor and programmable controller the upper loading pads produce a compressive bending strain on the lateral surface of the rat tibia and the lower loading pads produce a tensile bending strain on the medial surface of the rat tibia.

In accordance with a preferred method the apparatus is utilized to (1) induce precise and unique (non-physiologic bending) loads on rat tibia and (2) to provide a method of studying the bone response to the controlled loading. The apparatus has been utilized to induce bending strain to the right tibia of rats (average weight 330 g). The apparatus utilizes the programmable stepper motor to control the frequency and number of loading cycles. In an exemplary embodiment the apparatus may be set to deliver load levels at intervals of 5N. Whereas the specific materials from which the apparatus is formed is not critical to the invention, the apparatus of the exemplary embodiment

was manufactured from aluminum and the bending load is imparted via four loading pads fabricated from surgical tubing (surgical tubing was utilized so as to better distribute the load while also minimizing soft tissue injury).

As may be seen (FIG. 1) the apparatus of an exemplary embodiment utilizes a lever system which converts and magnifies horizontal axis linear displacement to vertical axis linear displacement. In a preferred embodiment the lever arm is equipped with a strain gauge 50 (available from Micro Measurements Group, Raleigh, N.C.). Such a gauge may be utilized to monitor load delivery. In an exemplary embodiment there are five settings on the motor arm which may be utilized to selectively impart 40, 35, 30, 25, and 20N loads. The load frequency (or load rate) is controlled via the stepper motor controller.

Whereas the invention has been shown and described in connection with a preferred embodiment thereof, it is apparent that many additions, modifications and substitutions may be made which are within the intended broad scope of the appended claims. For example, different linkages might be employed to impart the four point load. Thus, there has been shown and described an apparatus for applying compressive and tensile bending loads to bones and a method for utilizing the same.

We claim:

1. An apparatus for applying compressive and tensile bending loads on bones comprising:

(a) a frame having a work surface;

(b) driving means for producing rotational force at controllable frequencies mounted to said frame;

(c) conversion means connected to said driving means for converting rotational force to linear force;

(d) articulating arm means having a first end operably connected to said conversion means and a second end pivotably connected to at least a pair of upper pads, each member of the pair of said upper pads being spaced at a sufficient distance from the other member of the pair so that the two members of the pair of said pads provide contact at distinct points on the upper lateral surface of an animal bone located below said upper pair of pads;

(e) at least a pair of lower pads mounted on said work surface such that an animal bone may be placed across and supported by said lower pair of pads at points between the distal and proximal bone ends, each member of the said lower pair of pads being spaced at a sufficient distance from the other member such that the points of contact between the lower surface of the said bone and the members of said lower pads are closer to the proximal and distal ends of the bone than the points of contact between the upper surface of the bone and the members of said upper pair of pads; whereby, activation of the said driving force causes said upper pair of pads to exert compressive bending strain on the lateral surface of said bone and simultaneously causes said lower pair of pads to exert tensile bending strain on the medial surface of said bone.

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