ULTRASONIC DETECTION OF DISTAL TRANSVERSE SCREW HOLES IN INTRAMEDULLARY NAIL AND INTERLOCKING ACCURACY OF LOCKING SCREW

Yoshihisa MINAKUCHI
Faculty of Engineering, Yamanashi University, Kofu-shi, Japan
Hideki NUMOTO
Orthopaedic Surgery, Isawa Kyoto Hospital, Isawa-cho, Yamanashi, Japan
Hiroo YAMAUCHI
Orthopaedic Surgery, Jyuntendo University, Bunkyo-ku, Tokyo, Japan
Mahesh C. Bhardwaj
Ultran Laboratories, Inc., Boalsburg, Pennsylvania, USA
Kou UEHARA
Faculty of Engineering, Yamanashi University, Kofu-shi, Japan

ABSTRACT

The position of a distal transverse hole in intramedullary nail inserted into the pig femur specimen was detected using the ultrasonic pulse echo method. At the peak position of the echo height reflected from the intramedullary nail, a locking screw was penetrated toward the transverse hole. It was found that the locking screw was inserted with a high accuracy.

1. INTRODUCTION

It is not easy to insert a locking screw into the distal transverse hole for fixing the intramedullary nail and the broken human bone as shown in Fig.1. Generally, the X-ray image [1-4] is used in conjunction with a target device. But the X-ray exposure has very crucial problem for doctors and patients. In order to overcome this problem, an ultrasonic wave [5] was considered for determining the screwing point. However, the practically useful method is not yet investigated sufficiently.

In this paper, the detection of a distal transverse hole in intramedullary nail inserted into the pig femur specimen was carried out by the ultrasonic pulse echo method. After the locking screw was penetrated toward the transverse hole, the cross section of the specimen was observed using the X-ray image and the interlocking accuracy of locking screw was investigated.

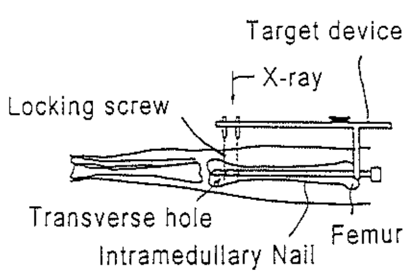

Fig.1 Detection of a distal transverse hole using X-ray image

2. PRINCIPLE OF ULTRASOUND

Figure 2 shows the measurement principle of the ultrasonic method in which the ultrasonic wave emitted from a normal probe propagated through the living body. When an ultrasonic wave arrives perpendicularly at a boundary surface between dissimilar media, part of the wave is reflected and the other part is transmitted. The relation between the echo height and the time is shown. The distance l_i between each boundary surface is given as

$$li = v_i \times \frac{t_i}{2} \quad (i = 1,2,3,\cdots) \cdots\cdots\cdots\cdots (1)$$

where v_i is the wave velocity and t_i is the round-trip propagation time.

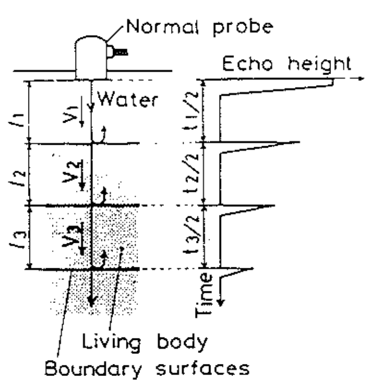

Fig.2 Principle of ultrasound

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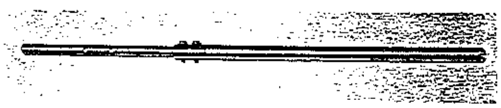
3. DETECTION OF THE TRANSVERSE HOLE IN INTRAMEDULLARY NAIL INSERTED INTO PIG FEMUR

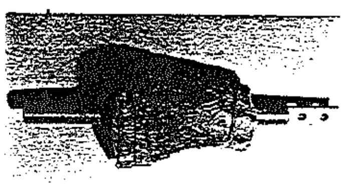
We tried to detect the hole of the intramedullary nail inserted into the pig femur. Figure 3 shows the intrarmedullary nail and the pig femur specimen inserted with the nail. To fix the nail and the femur, the rubber plates of 5mm thickness were put into both sides of the femur and the nail was inserted at the center of the rubbers. Moreover, both sides of the bone were tightly sealed using thin transparent plastic so as not to leak the bone marrow. The nail is a bar made by brass with the diameter of 12mm and two holes of 5mm.

Figure 4 shows the experimental scene. The specimen was immersed in the water at 36℃ and the normal probe(frequency:2MHz, transducer diameter:13mm) was set up on the water surface of 40mm apart from the intramedullary nail. The nail is used in conjunction with a target device(ACE Med.).

Figure 5 shows the measurement model of the echo by linear scanning method.



(a) Nail



(b) Pig femur

Fig.3 Nail and pig femur specimen

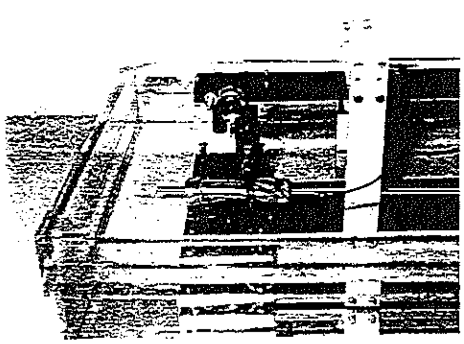


Fig.4 Experimental Scene

The normal probe was moved linearly every 0.1 or 0.2mm toward the y-direction using a handle. The wave velocity through the water was set at 1500m/s. Then, the echo position and echo height were measured by the echo waveform reflected from the nail surface. The center of the hole was investigated by the echo height.

Figure 6 shows an example of the echo waveform reflected from the specimen. The marks of ①, ② and ③ indicate the echoes from the outside of femur, the inside of femur and the nail surface, respectively. It is clarified that the echo from the nail can be obtained by the ultrasound.

Figure 7 shows the change of echo height to the measuring position by the linear scanning method. The central position of

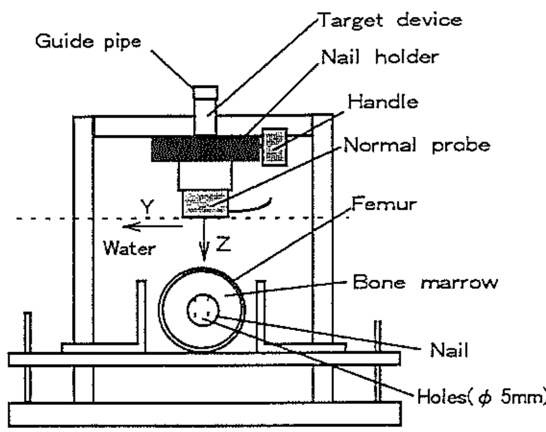


Fig.5 Measurement model of echo by linear scanning method

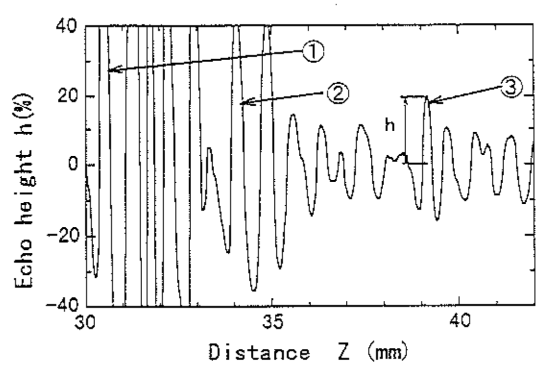


Fig.6 Echo waveform from outside of femur, inside of femur and nail surface

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the transverse hole was located at the peak of the echo height. Because it is that the distance between the normal probe and the nail surface is the shortest propagation path of the sound wave and the echo from the above nail surface is the largest power. Moreover, the transverse hole is made at the center position of the nail. In this case, as three echo heights are same values, the hole center of the nail was determined as the second position. When center at the y-direction, the echo height became smaller.

After determining the hole center of the nail, the normal probe was removed from the experimental device. At that position, the locking screw was penetrated toward the transverse hole along a guide pipe in Fig.5.

Figure 8 shows the scene that the locking screw was penetrated into the pig femur. In order to investigate the interlocking accuracy of the screw, the cross section of two pig femur specimens were observed from the front and upper sides by X-ray image.

Figures 9 and 10 show the X-ray image results when the pig femur specimen was made in the neutral and distal positions of

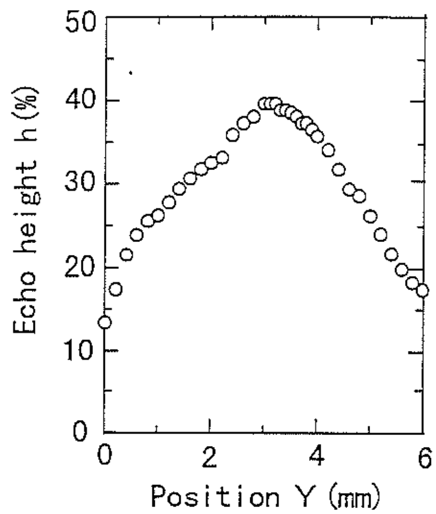


Fig.7 Echo height to the measuring position

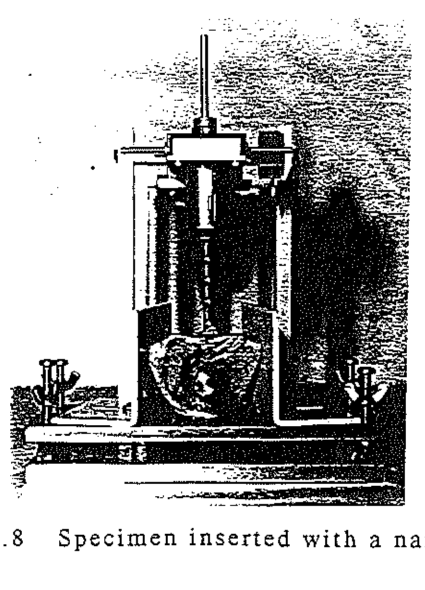
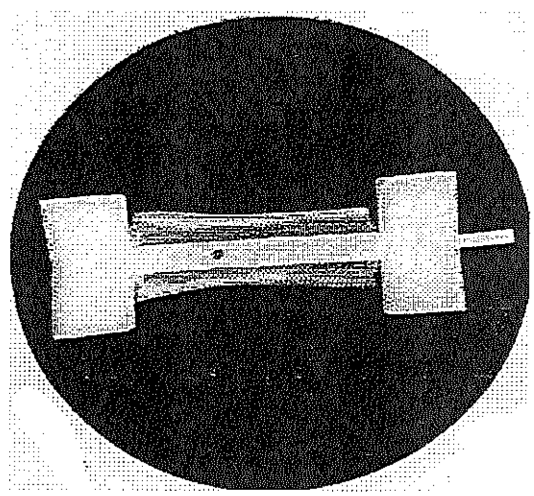
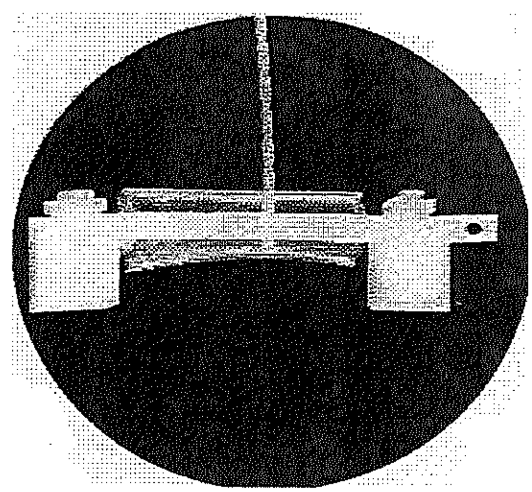


Fig.8 Specimen inserted with a nail

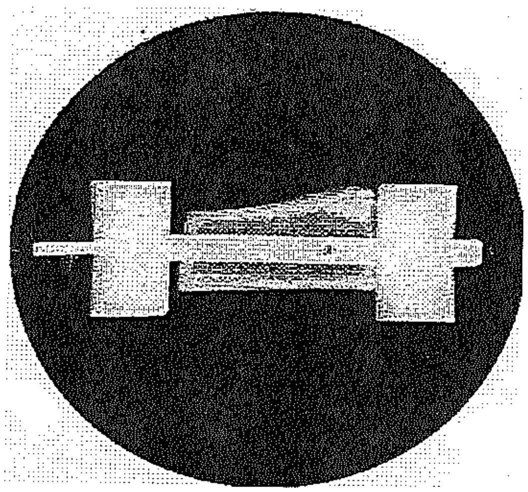


(a) Upper side

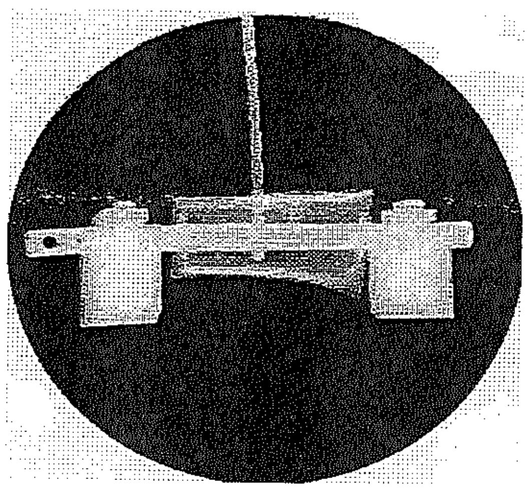


(b) Front side

Fig.9 Cross section of the femur by X-ray (Specimen 1)



(a) Upper side



(b) Front side

Fig.10 Cross section of the femur by X-ray (Specimen 2)

the femur. As shown in Figs.9 and 10, the locking screw perfectly penetrated into the transverse hole. As these results, it was found that the locking screw was inserted with a high accuracy.

4. CONCLUSIONS

(1) The central position of a distal transverse hole in intramedullary nail inserted into the pig femur specimen can detect using the ultrasonic pulse echo method.
(2) The central position of the distal transverse hole is determined at the peak position of the echo height reflected from the nail surface.
(3) The locking screw can insert into the hole center with a high accuracy.
(4) The proposed ultrasonic method is very useful in protecting operators and patients from the X-ray exposure.

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