IRRADIATION OF THE EXTRACORPOREAL SHOCK WAVE TO THE IMMATURE LONG BONE CAUSES OVERGROWTH AND LOCAL INCREASE IN BONE MINERAL CONTENT

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INTRODUCTION: It has been suggested that children are likely to have post-fracture overgrowth by various researchers(1) (2). Furthermore, it is now apparent that periosteal division or stripping accelerates growth of long bone(3). On the other hand, extracorporeal shock wave therapy which was developed for lithotripsy is thought to be also useful to give dynamic loading to bone noninvasively. It was reported that the shock wave had an action to cause fracture and the degree of deformation of bone increased as the strength of energy or the number of exposure increased(4). And it was also reported that exposure of the shock wave to the bone of mature rabbits caused fracture of cancellous trabecula or periosteal lifting(5). In addition, it was reported that shock wave was effective for the treatment of non-union or delayed union after fracture(6), and this indicate that shock wave has a local bone induction capability. We came up with the idea that if it is possible to cause microfracture using the shock wave without causing displacement or to cause periosteal lifting, it is possible to lengthen immature bone. Furthermore, if the shock wave has a local bone induction capability at the stage of growth which is high in osteogenetic capability, it is also presumed that the shock wave has an action to increase bone mineral content (BMC). To verify the hypothesis that overgrowth or local increase in BMC is attainable by the exposure of the extracorporeal shock wave to the immature long bone, we conducted this study using rabbits.

METHODS: Fourteen male New Zealand White rabbits aged 9 weeks with the body weight of 1.0 to 1.2 kg were used for this study. Piezolith 2300TM(Richard Wolf Inc., Germany) was used to produce extracorporeal shock waves. Each 7 animals of the 14 animals were grouped into Group I and Group II. Extracorporeal shock waves were exposured on the center of the femoral diaphysis from lateral side. The strength and interval of the pulse were set to be 1000bar and 1Hz respectively. Shock waves were exposed on the center of the femoral diaphysis by 1000 pulses in Group I and by 5000 pulses in Group II. The animals were monitored for 6 weeks. If marked fracture was seen in the monitoring period, the animal was immediately sacrificed. The animals which didn't have marked fracture were sacrificed at 6 weeks after exposure. Then the femurs and tibiae were isolated and the lengths of them were accurately measured using caliper. Furthermore, soft X - ray photo of the longitudinal view and the lateral view of the isolated femur was taken and the breadth and longitudinal diameters of femoral diaphysis were measured by X - ray measurement as shown in Fig. 1. The breadth on Line a, b, c, d and e were measured. In the lateral view of the femur, the longitudinal diameter of the femur was measured on Line f. Furthermore, BMC of the fresh specimen was determined by means of DEXA method using QDR 1000TM(Hologic Inc., MA, USA). The areas divided by Line a, b, c, d and e shown in Fig. 1 were set as P, S1, S2, S3 , S4 and D from the proximal side and BMC in each area was determined. Statistical analysis was conducted using the unexposed side of femur as controls in each case by means of paired t - test.

RESULTS: No animal had fracture in Group I while three out of seven animals in Group II had oblique fracture in the femoral diaphysis. Therefore, statistical analysis of the length, breadth and longitudinal diameter of femur as well as of BMC was conducted in Group I in which no animal had fracture. Fig. 2 shows the comparison of the length of the femur and tibia between the exposed side and the unexposed side in Group I. The exposed femur was significantly longer than the unexposed femur. The difference of the length of the tibia which was not directly exposed to the shock wave was not taken to be statistically significant. Fig. 3 shows the comparison of the length of the breadth and the longitudinal diameter of femoral diaphysis between the exposed side and the unexposed side in Group I. The difference on Lines b, c, d and f was taken to be statistically significant. Table 1 shows the results of the determination of BMC by means of DEXA method. BMC in Area S2 was higher by 22.8 % in the exposed side than in the unexposed side, and the difference was taken to be statistically significant. BMC in the femur as a whole was significantly higher by 4.16 % in the exposed side than in the unexposed side.

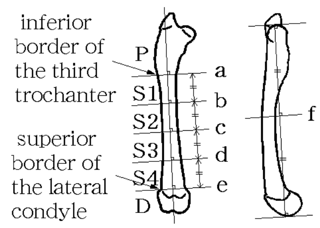

Fig. 1. Difinition of lines and areas

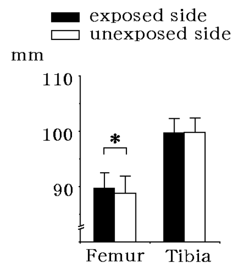

Fig. 2. The mean (+SD) length of the femur and the tibia * $p < 0.05$

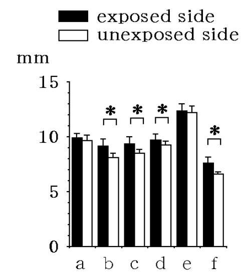

Fig. 3. The mean (+SD) breadth and longitudinal diameter of femur * $p < 0.05$

Table 1. BMC of the exposed and the unexposed side of the femurs

Area	exposed side (g)	unexposed side (g)	p value
P	1.092±0.099	1.118±0.081	NS
S1	0.562±0.044	0.514±0.027	NS
S2	0.534±0.070	0.435±0.018	0.013
S3	0.427±0.062	0.375±0.016	NS
S4	0.337±0.025	0.354±0.020	NS
D	0.729±0.064	0.738±0.058	NS
Total	3.682±0.137	3.535±0.182	0.019

Values are expressed as mean±SD. NS = not significant.

DISCUSSION: As a result of the study, it has been revealed that exposure of the shock wave significantly accelerates growth in length and in breadth of immature long bone if it is exposed under the conditions in which shock waves didn't cause fracture identifiable in the plain radiograph. It has also been revealed that BMC in a proximal area from the center of diaphysis becomes higher in the exposed side than in the unexposed side if the shock wave is exposed to the center of femoral diaphysis. These findings are thought to verify the hypothesis that exposure of the extracorporeal shock wave to immature long bone causes overgrowth and local increase in BMC. No researchers has ever discussed a technique to nonoperatively increase the length or size of the bone or to locally increase BMC, and if this technique becomes clinically applicable, its clinical significance is extremely high.

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