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BONE GROWTH ALTERATIONS RESULTING FROM APPLICATION OF CO_2 LASER BEAM TO THE EPIPHYSEAL GROWTH PLATES

An Experimental Study in Rabbits

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The CO_2 laser beam was used to create defects 3 mm in depth in the distal growth plate of one femur in a group of 59 rabbits. In most of the 32 rabbits in which the defect was created on the lateral aspect of the epiphyseal plate the procedure resulted in the subsequent development of valgus deformity and shortening of the femur. In most of the 27 rabbits in which defects were produced both medially and laterally to the epiphyseal plate there was a subsequent marked shortening of the bones. Histological studies revealed that the laser-induced defects of the growth cartilage led to epiphysiodesis and premature disappearance of the epiphyseal growth plates.

Key words: carbon dioxide laser; epiphysiodesis; epiphyses; growth cartilage

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Studies performed by Verschueren et al. (1975) showed that the use of the carbon dioxide laser beam for osteotomy results in healing without delayed union or pseudoarthrosis, and work done in our Experimental Surgery Unit has shown that bone defects produced by laser beams subsequently fill with new bone. These observations led to the hypothesis that application of the laser beam to the epiphyseal growth plate would produce a defect which would become replaced by bone and would thereby induce an alteration in bone growth. The present study was undertaken to determine the validity of this hypothesis.

MATERIAL AND METHODS

The experimental material of this study comprised a total of 59 rabbits from 3–4 weeks of age and weighing 800–900 g. In each animal the right distal femoral epiphysis was treated with the laser beam, the left side thus serving as a control. The animals were divided into two groups. In one group (32 animals), an almost semi-circular defect 3 mm in depth was produced on the lateral side of the epiphyseal growth plate, exposed through a small incision in the skin (Figure 1A). In the other group (27 animals) similar defects were produced both on the medial and lateral aspects of the epiphyseal growth plate (Figure 1B). The animals were sacrificed from 10 days to 16 weeks after induction of the defect. Both femurs were then dissected out, X-rayed and measured. Sections of the distal portions of both femurs were prepared and examined microscopically.

Anesthesia during the operation procedure consisted of intravenous administration of Nembutal (pentobarbitone), 30 mg per kg of body weight.

The "Sharplan 791" CO_2 laser apparatus* was used with an output of 7–10 watts.

* Produced by "Laser Industries Ltd.", Israel.

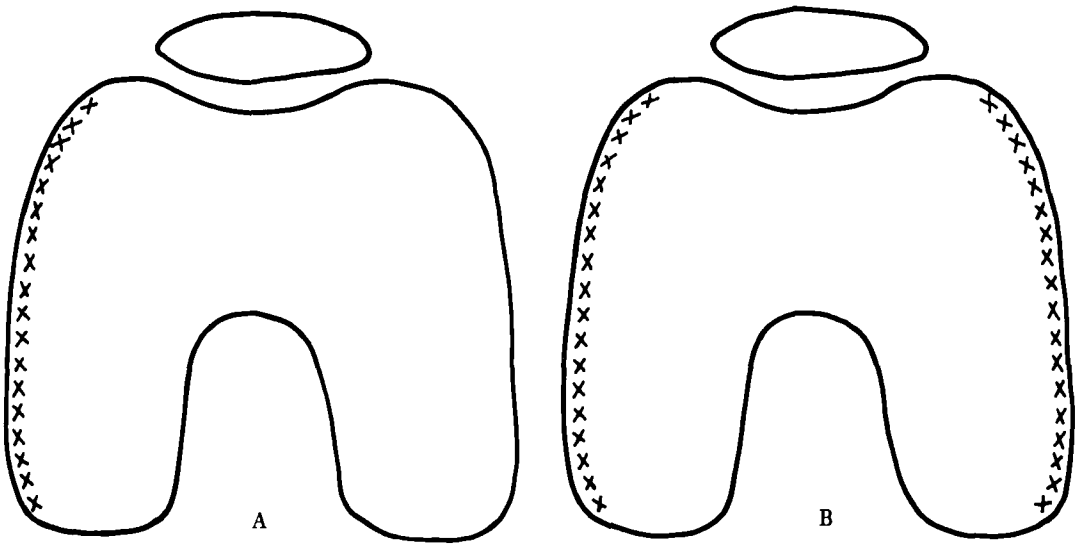


Figure 1A, 1B. Schematically-drawn horizontal sections of the distal femoral epiphysis at the level of the growth plates. The crosses indicate the extent of the defects in each group of animals.

RESULTS

Macroscopic findings

Alterations in the growth of the femurs were found in 54 of the 59 rabbits. Among the 32 in which the defect was produced on the lateral aspect of the epiphyseal growth plate, 29 showed the development of a valgus deformity which became evident at the end of the third week and was maximal 12 weeks after the procedure.

When compared with the control femurs, the operated femurs were shorter (Figure 2), at 16 weeks there being an average shortening of 5.2 mm. In three animals in this group there was no difference between the treated and control sides. Among the 27 rabbits in which the defect had been induced both medially and laterally, the most prominent finding was the marked shortening of the operated femurs in 25 animals, which reached an average of 8.8 mm 16 weeks after the procedure. The metaphyseal region of the operated femurs appeared to be expanded, with callus formation on the medial and lateral aspects (Figure 3). In four animals there was a valgus deformity of the distal femoral epiphysis in addition to the shortening. In two animals in this group there was no difference between the treated and control sides.

Microscopic findings

In both groups of rabbits the defect of the epiphyseal growth plates was found to have been replaced by bone which formed a bridge between the epiphyseal and metaphyseal parts of the femur and which resembled the callus formation seen at fracture sites (Figure 4). Evidence for the formation of these bone bridges was already found in the animals sacrificed as early as 10 days and by 3 weeks they were seen to be fully formed. From 5 to 7 weeks after the procedure the epiphyseal plates were found to be narrowed and the number of cells in the cartilage columns decreased, in comparison with the control side. In animals sacrificed 9 weeks or more after the operation, there was no epiphyseal cartilage on the operated side (Figure 5A) whereas on the control side it was still present, corresponding with the animal's age (Figure 5B). In some specimens there was a thin cortical plate of bone

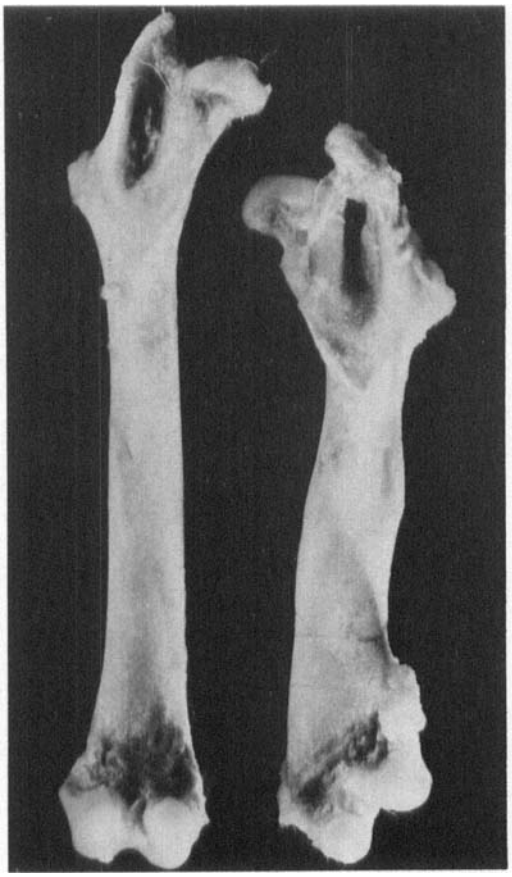


Figure 2. Normal control femur (on left) and operated femur (on right) 16 weeks after creation of lateral defect. Operated femur shows shortening and valgus deformity.

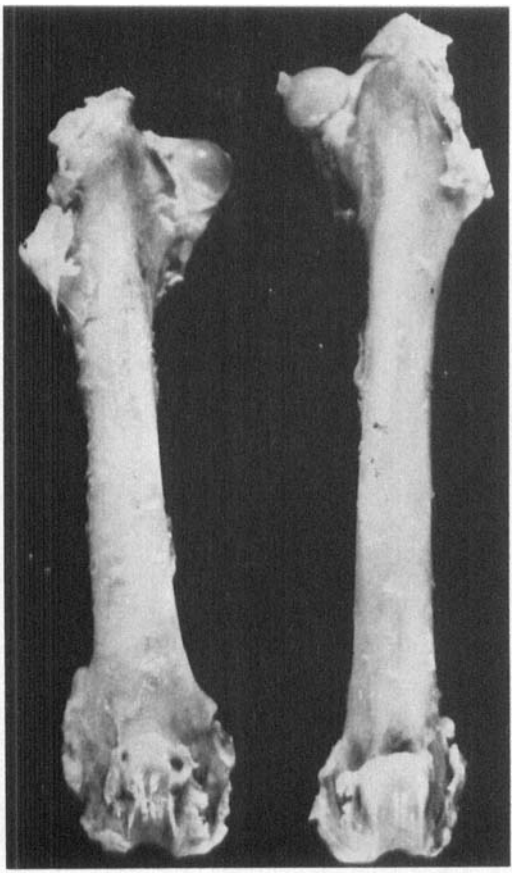


Figure 3. Normal control femur (on right) and operated femur (on left) 8 weeks after creation of medial and lateral defects. Note shortening of the operated femur and callus formation on medial and lateral aspects of metaphysis.

replacing the epiphyseal growth plate. In the four animals that developed valgus deformities after the creation of bilateral defects, bone bridges were found only on the lateral aspect of the plate while none developed on the medial side, which had normal epiphyseal cartilage. In the five animals in which there were no alterations in bone, the defects were all filled by epiphyseal cartilage and there was no difference between the histological appearance of the control and operated femurs.

X-ray findings

Roentgenological examination revealed normal trabecular structure with signs of callus formation in the treated area of the femurs.

DISCUSSION

The specific properties of the CO_2 laser beam make it a superior instrument with which to achieve a very fine incision (Kaplan & Sharon 1976, Kaplan et al. 1973). It has a wave length of 10.6 microns and emits light energy which is totally absorbed by water so that it can vaporize tissue at its focal point while leaving the adjacent tissue virtually unaffected. The thermal damage produced is minimal and when it is used with a low power output, practically nil. Soft tissues can

be incised with a low power output of less than 10 watts while for hard tissues such as bone power output of at least 30 watts is required. Thus when a low-power laser beam is applied directly to epiphyseal cartilage it damages the cartilage selectively without affecting the adjacent bone.

The experiments carried out by us showed that when part of the epiphyseal plate is destroyed by means of the CO_2 laser the normal adjacent bone acts like that at a fracture site and the defect is therefore filled by newly-formed callus which replaces the growth cartilage and leads to cessation of bone growth. Furthermore, a premature disappearance of the treated growth plates and subsequent bone shortening were also observed in most of the experimental animals. In explanation of the latter phenomenon, it may be assumed that the bone bridges, which are firm enough so that they will not break, counteract the longitudinal traction forces exerted by cartilage columns, thus causing an opposing pressure on the growth plates. Gelbke (1951) and Sijbrandij (1963) showed that pressure applied to the epiphyseal plates leads to an inhibition of growth and disappearance of the growth cartilage, observations which are compatible with the results obtained in our experiments.

In those femurs that remained unaffected by the procedure, the defects were filled by epiphyseal cartilage which apparently served as an interposing material and thus prevented the formation of a bone bridge. This regeneration of the growth plates taking place before a bone bridge could be formed, while still unexplained, is a phenomenon which has

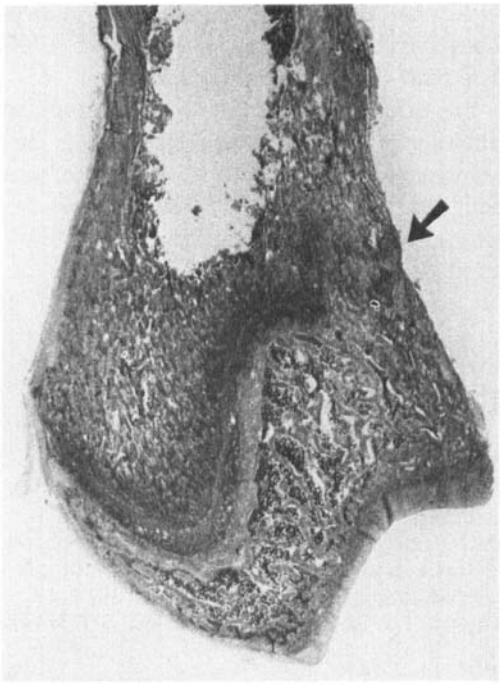
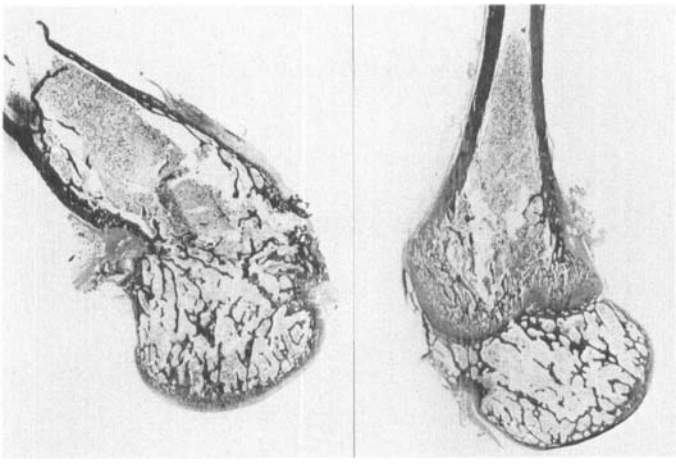


Figure 4. Histological section of distal part of the femur 3 weeks after creation of lateral defect. The arrow indicates the bone bridge between the epiphyseal and metaphyseal parts of the femur.



A B

Figure 5A. Histological section showing absence of epiphyseal growth plate 9 weeks after creation of lateral defect.

Figure 5B. Normal epiphyseal growth plate on opposite femur of the same animal.

been observed by a number of authors (Langenskiöld & Edgren 1949, Heikel 1960, Österman 1972, Langenskiöld 1975).

The information provided by this study on rabbits may well prove valuable in the further development of orthopedic procedures designed to correct certain types of deformities as well as inequalities in limb length.

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