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COMPRESSION PLATING: EXPERIMENTAL STUDY OF THE EFFECT ON BONE FORMATION RATES

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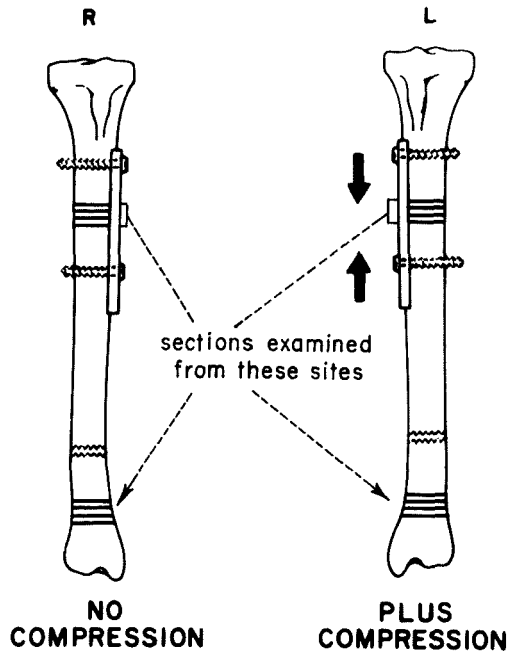
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The use of compression plates in the treatment of certain fractures of long bones and in the treatment of some cases of non-union is clearly beneficial (Anderson 1965, Müller et al. 1965). The benefits of compression plating may be related to (1) enhanced apposition, (2) increased stability, (3) increased new bone formation or a combination of these. Many clinical examples illustrate increased bone formation resulting from increased stress, such as the hypertrophy of a fibula grafted to replace a portion of a tibia or humerus in a young patient. Eighty years ago Wolff (1892) published examples of cortical hypertrophy on the concave or compression side of malunited tibias. Saville & Smith (1966) showed that increased load led to increased skeletal mass in the hind limbs of quadrupeds which were made bipedal. Chamay & Tschantz (1972) found in adult dogs increased bone formation in the ulna subjected to increased dynamic stress. Schenk & Willenegger (1964) showed that the skeletal renewal rate was markedly increased underneath a compression plate applied to fix an osteotomy in the dog's radius compared to the rate in the intact control radius. The present study was undertaken to determine if the stimulus to new bone formation following application of a compression plate was, in fact, caused by the compression.

METHODS AND MATERIALS

To study the effect on skeletal renewal of the application of a compression plate without introducing the confusing and variable features of fracture repair, compression plates were applied to intact bones of adult mongrel dogs (Figure 1). The plates were a miniature version of the A.O. compression equipment used in man. Maturity of the dogs was established by roentgen evidence of complete closure of

Figure 1. Drawing of the application of compression plate to the intact right and left tibias of mature dogs. Compression was added to the plate on the left tibia but not on the right.



the epiphyseal plates at the knee, elbow and shoulder. All dogs had a two-week period of conditioning in our animal farm prior to starting the study.

Bone formation rates were assessed by using the long-duration, dual, color-coded tetracycline technique (Harris et al. 1968). Two specific control values were essential for the accurate interpretation of the effect on bone formation rates of the compression from the compression plate. First, the level of bone formation prior to the application of the plate was required. Daily administration of oxytetracycline (65 mg/kg/d) provided a label of all new bone deposited throughout the skeleton during the 12 weeks prior to application of the plates. Data regarding the bone formation rate following plate application were obtained from intravital labelling of the skeleton with daily administration of demethylchlortetracycline (40 mg/kg/d) for the 12 weeks after surgery.

Secondly, knowledge of the effect of simply applying the plate without compression was required. This was obtained by applying the compression plates plus compression to the intact left tibia and applying identical plates to the right tibias in the identical manner but without adding the compression.

An additional phase of this study examined the influence of distraction on bone formation rates by employing the identical experimental design except for the substitution of distraction plates for the compression plates.

The plates were applied subperiosteally on the antero-lateral surface of the tibia. Both plates were applied during the same anaesthesia. Particular care was taken to apply the plates to homotypic sites in each tibia. In the compression series compression forces, ranging from 24–55 inch-pounds at the time of plate application, were applied to the compression device using a torque wrench. In the distraction

series the distraction forces ranged from 12 to 22 inch-pounds at the time of plate application as measured by a torque wrench. The dogs were ambulatory without a limp the day following surgery.

After killing the dogs, blocks of bone were obtained from the areas of the tibias underneath the plates and from the distal portion of the tibial diaphyseal regions, away from the screw hole used to fix the compression or distraction device. From these blocks, undemineralized sections were cut on a Gillings-Hamco Bone Sectioning machine and ground by hand to a thickness of 50 micra. These sections were studied under ultra-violet illumination, using a grid-counting technique to determine the total amount of bone present, the porosity, the amount of bone deposited during the control period and the amount of bone deposited during the first 12 weeks after application of the plate.

RESULTS

Table 1 shows the results in Dog 3, an animal which had plates applied to both tibias but with compression force added only to the plate on the left tibia. The figures are given in the annual rate of new bone formation expressed as a percentage of total bone present. During the control period the formation rates in right and left tibia are equal and low. The application of the plate to the right tibia produced a massive increase in intracortical bone formation. No significant additional stimulus to bone formation occurred on the left tibia under the plate which also had compression added.

Table 2 gives the data from all four dogs which had compression plates. The application of a plate produced a massive acceleration of skeletal renewal, but the application of compression did not augment this rise.

Table 3 shows the result in Dog 12, which had distraction plates applied to each tibia but a distraction force added only to the plate on

Table 1. Bone formation rates in intact bone under the influence of a plate plus compression and a plate without compression.

A compression plate plus compression was applied to the intact left tibia. An identical plate was applied to the right tibia without adding the compression. Bone formation rates are given as per cent new bone formation per year.

DOG 3		
Bone formation rates		
	Right tibia	Left tibia
Control period	1.6	1.7
Experimental period	40	47

Table 2. Bone formation rates in four dogs treated with compression plates. A plate plus compression was applied to the intact left tibia. An identical plate but without compression was applied to the intact right tibia. Bone formation rates are in per cent new bone formation per year.

Dog No.	Side	Control period	Experimental period
3	L	1.7	compression 47
	R	1.6	plate alone 40
4	L	2.6	compression 69
	R	1.3	plate alone 62
6	L	6.8	compression 51
	R	9.8	plate alone 71
14	L	2.1	compression 90
	R	1.3	plate alone 56

the left tibia. The application of the plate was a massive stimulus to the bone formation rate, but the added distraction force neither augmented nor reduced this stimulus.

Table 4 shows the results in four dogs with distraction plates. No significant effect of the distraction is apparent on the rate of skeletal renewal.

Since porosity could not be measured for the baseline time period prior to plate application in these animals, the comparison of the porosity figures before and after plate application cannot be made. However, certain observations can be made regarding porosity. In the experiments using compression plates and in those using distraction plates porosity under the plates showed a tendency to be greater than porosity values from the same areas in 11 control dogs. However, at 12 weeks after plate application these differences were not significant.

Table 3. Bone formation rates in intact bone under the influence of a plate plus distraction and a plate without distraction. A distraction plate plus distraction was applied to the intact left tibia. An identical plate was applied to the right tibia but distraction was not added. Bone formation rates are given as per cent new bone formation per year.

DOG 12		
Bone formation rates		
	Right tibia	Left tibia
Control period	3.0	2.9
Experimental period	63	69

Table 4. Bone formation rates in four dogs treated with distraction plates. A plate plus distraction was applied to the intact left tibia. An identical plate but without distraction was applied to the intact right tibia. Bone formation rates are expressed as per cent new bone formation per year.

Dog No.	Side	Control period	Experimental period
5	L	21	distraction 35
	R	16	plate alone 30
7	L	25	distraction 111
	R	19	plate alone 65
12	L	2.9	distraction 69
	R	3.0	plate alone 63
13	L	1.4	distraction 41
	R	0.8	plate alone 51

No difference in porosity was discernible between the bone with a compression plate plus compression and that with an identical plate without compression. No significant difference existed between those bones under distraction plates with or without a distraction force added. No difference existed between the effect of distraction plates and compression plates.

DISCUSSION

The massive stimulus to bone formation under a compression plate is due to the application of the plate and not to the application of compression. Contrary to our expectation, the effect on bone formation rates of applying a plate with distraction is also dominated by the influence of the plate application and is not altered by applying distraction.

Perren et al. (1969) have shown that the compression force generated by application of a compression plate to an intact bone persists as long as 12 weeks, but gradually declines. Our experiments studied the effect of a progressively decreasing static load on bone and should not be interpreted as describing the effects of dynamic or intermittent loading of bone. Also, small responses of bone to compression might not be appreciated in our study because, if present, they would be overshadowed by the marked response of bone to the application of a plate alone.

A statistically significant rise in porosity was not seen, even under the distraction plate, at 12 weeks. Studies such as those of Uhthoff &

Dubuc (1971) show that such a rise in porosity occurs in experiments of longer duration.

SUMMARY

The effect on bone formation of applying compression via a compression plate was studied in four adult dogs. Bone formation rates were determined using the dual, color-coded, long duration tetracycline labelling method. To study this effect independent of the confusing elements introduced by fracture healing, the compression plates were applied to the intact bones, without fracture or osteotomy. Two controls were used. The first was the rate of bone formation prior to plate application. The second was the effect of the plate alone without compression. Using an identical surgical procedure a compression plate plus compression was applied to the left tibia and an identical plate was applied to the right tibia without adding the compression force.

A similar experiment was carried out in four other adult dogs, except that distraction was applied to the plate on the right tibia.

During the 12 weeks following the application of a plate and screws to the intact tibia of the adult dog, a marked stimulus to new bone formation occurred. The application of compression did not add to this increase. Distraction neither enhanced nor reduced this increase. Porosity tended to rise under all plates, with or without compression or distraction, but by 12 weeks had not reached a level of significant difference.

The major stimulus to new bone formation following compression plate application is the application of the plate and screws alone. Added compression has no discernible effect on this stimulus.

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