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TRANSMISSION OF FORCE TO BONE

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THE primary function of the skeleton is to support and house the soft tissues of the organism. To perform this function it has to be strong enough to withstand all the stresses to which it may be subjected whether they be due to muscular activity, gravity or any other forces. Alteration of the internal architecture as well as, but to a lesser extent, of the external surface, are seen as a result of altered stresses to the skeleton. This is evident in the bow legs of the cowboy, the enlarged size of the neurocranium in the hydrocephalus or the reduction of supporting bone around a tooth after loss of function.

The secondary functions of the tissue bone are related to general metabolism. The entire calcium and phosphorus metabolism is dependent on bone as a storehouse for these materials, while the greater portion of the spaces in cancellous bone is utilized for haemopoiesis or to augment the fat depots of the body.

The strength of the skeleton is derived from the specialised calcified portion of the bone. The soft tissue immediately adjacent to this structure is essential for the maintenance and the addition or removal of the calcified material. This function is dictated by the metabolic state of the individual and the nature of the stresses to which the bone is subjected.

The soft tissue immediately adjacent to the calcified portion, the periosteum and endosteum, would become anoxic if subjected for any length of time to a direct pressure higher than the local capillary blood pressure. Wherever bone is to be subjected to a direct force the periosteum must be protected or be replaced by a tissue which can withstand lengthy periods of high pressure.

Nature and Effects of Pressure on Bone

Bone is subjected to intermittent and constant forces which are transmitted to the calcified material as direct pressure or as tension or as a combination of these two. Since the former terms are relative, their interpretation has led to considerable controversy, most writers concentrating on the time factor and not the magnitude of the pressure. Perhaps the most important difference between an intermittent and constant force is their effect on the blood supply and thus on the metabolism of the periosteum or endosteum. A direct pressure to the periosteum will be intermittent if firstly the duration of such a pressure is shorter than the time taken for the avascular periosteum to become anoxic and secondly if the release of pressure is sufficient for an adequate blood supply to be re-established between the periods of pressure.

Within the limits of tolerance intermittent pressure on bone will be resisted and if increased within limits will even lead to the formation of new bone while a constant pressure which will interfere with the blood supply will lead to resorption at the site of application. The extensive resorption seen in the case of the pulsating aneurism is quoted as an exception to this statement. Weinmann and Sicher (1955). This example is however no exception since all the requirements of an intermittent force are not present. The aneurism does exert an intermittent pressure on the adjacent bone with every cardiac cycle but the difference is only that between the systolic and diastolic pressure; pressure is never completely released and it remains therefore at a constant level which is above the capillary blood pressure. Pressure exerted by the aortic aneurism on the periosteum of the adjacent bone must thus be classified as a constant force.

Transmission of Direct Pressure to Bone

The one site where a constant pressure may be applied directly to the periosteum through a very thin protective layer, is on the inner aspect of the pelvis and vertebral column by the pelvic contents. Such pressure could be increased considerably during pregnancy but the nature of this force, which obviously does not damage the periosteum has, however, not been determined.

The direct pressure of a muscle or tendon exerted on the periosteum during function may be high enough to interfere with its oxygen exchange. The maximal muscular contraction necessary to produce pressure of such a magnitude will also give rise to a relative anoxia in the muscle. Relaxation and a reduction in tension must follow. Direct pressures arising in this manner are thus intermittent in nature.

Other areas of bone which are subjected to a variety of direct pressure are protected by a layer of soft tissue in proportion to the pressures which may be applied. This is well illustrated by comparing the ventral surface of the foot or hand with the corresponding dorsal surface. The olecranon process of the ulna or portion of the tubercle and condyles of the tibia and the lower part of the patella were evidently not meant to act as weight bearing surfaces. If used as such a compensatory increase in the overlying soft tissue occurs to protect the periosteum.

Direct pressures of a high magnitude such as antigravity forces are transmitted through a growing long bone, or from bone to bone via different types of cartilage. Even though it has been shown that ossifying cartilage shows a much greater respiratory activity than non-ossifying articular cartilage. Whitehead and Weidmann (1959). The metabolism of this avascular tissue is such that it can withstand pressures which would have produced an anoxia and necrosis had the intervening tissue been unaltered periosteum.

Transmission of Masticatory Forces to Bone

The periodontal membrane may be considered as a specialized periosteum which has to transmit the forces of mastication from the teeth to the bones. Loss of this action due to loss of the teeth normally results in the complete disappearance of this membrane. The structure of the periodontal membrane and surrounding bone as well as the root form is thought to be determined by the nature of the forces acting on the teeth which have to be transmitted to the bone. Thus the changes that occurred in function from the simple conical tooth form of the homodont dentition to the complex crown form of the primate dentition have gone hand in hand with changes in root form, bone form and periodontal form.

The human upper central incisor may be used to illustrate the correlation which exists between the function of a tooth and its root form. Due to the shape of the crown of the upper central incisor and the angulation of this tooth, the main forces acting on it will be vertical and buccal during function. The root form of the upper incisor is roughly triangular so that two-thirds of the fibres of the periodontal membrane are attached from the palatal aspect of the root. In this way the periodontal membrane can more adequately resist the displacing forces acting on this tooth and transmit them to the surrounding bone.

The conclusion that a correlation exists between root form and bone form is derived from the fact that the maxillary molars have a larger root surface than their mandibular counterparts. This is said to have occurred because the warm blooded organism required a warming of the inspired air. The maxilla and associated bones help to perform this task as well as continuing with their masticatory function while the mandible remained primarily concerned with mastication and deglutition. Yet the forces exerted on the mandibular and maxillary molars must be equal and opposite during the mastication. While the functions of the maxilla were altered, the root surfaces of the maxillary molars increased to aid the transmission of the masticatory forces to a greater surface area of the now altered, more delicate maxilla.

The exact mechanism whereby the forces applied to the teeth are transmitted through the periodontal membrane to the bone has not been established. It has been suggested that fluid pressure and the fibres of the periodontal membrane play an active part in this process.

The presence of numerous blood and lymph vessels in the periodontal membrane have led to the supposition that these vessels act as hydraulic chambers from which the fluid cannot escape rapidly if pressure is applied to the tooth. The validity of this theory must be questioned when the following points are considered:

(*a*) The greatest profusion of vessels is found in the apical area which is subjected to the least stresses. It is rare to have an absolute vertical vector of force on a tooth.

(*b*) Only a very small percentage of the available capillaries are patent at a given time when an organ or tissue is at rest, so the transfer of blood from the filled to the empty capillaries does not seem to be an effective hydraulic system.

(*c*) If the blood and lymph vessels were to act as hydraulic chambers then the pressure developed in them must be the result of the transmission of an equal pressure throughout the periodontal membrane. The use of an hydraulic system is therefore superfluous and would not relieve the pressure in the soft tissue of the periodontal membrane nor effect a gradual depression of a tooth when it is subjected to a vertical pressure.

Without any other mechanism, the arrangement of the fibres of the periodontal membrane supports the alternative supposition that they serve to transmit the forces applied to the teeth to bone and yet prevent undue pressure on the rest of the contents of the periodontal membrane.

The principal fibres of the periodontal membrane consist of non-elastic collagen fibres which are not arranged in a straight line from bone to tooth. Application of a force in a direction similar to that which the tooth is usually subjected will produce a limited movement of the tooth which is permitted by the straightening of the fibres, but restricted by the non-elastic nature of the collagen fibres.

The degree of restriction that the fibres of the periodontal membrane exerts on tooth movement varies with the direction of the force applied. The application of equal forces but in different directions will produce a different range of movement of the root in relation to bone. The least amount of root movement will occur when the vector of the force applied is similar to the forces evoked in the teeth during mastication.

TRANSMISSION OF FORCE THROUGH A SUTURE

In the skull where the major part of the growth is dependent on the sutures, a great variety of forces have to be transmitted from bone to bone through what is in the young, virtually two thickened layers of periosteum. The smooth suture lines of the foetal and infant skull bear little resemblance to the adult denticulate suture where the bones forming the boundaries of the suture interdigitate with one another. These interdigitations will, even without the help of the intervening periosteum resist displacement of the bones through a suture. The main function of these interdigitations may, however, be related to the transmission of force across a suture. Firstly they increase the area of contact between the adjacent bones and thus the pressure per unit area on the sutural soft tissue will be reduced. Secondly, the arrangement of the sutural fibres in relation to these interdigitations could enable the intervening soft tissue to convert any form of pressure through a suture into a tension force on the adjacent bones. Each individual interdigitation in a suture with its connective tissue bridge to the opposing bone may be compared with the root of a tooth and its periodontal membrane attached to the socket. The periodontal membrane converts the direct pressures exerted on the tooth into mild pressure and marked tension forces on the surrounding bone. This alteration of the direction of the force on the bone enables greater forces to be transmitted from bone to bone or as in the case of the periodontal membrane from tooth to bone while still not damaging the intervening soft tissue.

The metabolism of the osteogenic layer of cells surrounding bone will be affected if a constant pressure is applied directly to the endosteum, or periosteum. The mechanism whereby these cells are protected from such direct pressure varies throughout the body. Most periosteal surfaces are protected by varying thicknesses of superimposed muscle, connective tissue and skin. Cartilage which can withstand lengthy periods of pressure, due to its low metabolic rate, is utilized to transmit pressure through joints and growing bones. In the sutures, where a great deal of the growth of the skull occurs, the osteogenic layer of cells is protected by the denticulation of the bones and the arrangement of the connective tissue which consists mostly of the direct pressure into tension on this surface of the bone.

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PRIMORDIAL CYSTS

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ALTHOUGH the primordial cyst is a well recognised entity, not a great deal has been written about it. It is given brief mention by Kronfeld (1949) and Stones (1951). Thoma (1954) states that they are found most frequently in the mandibular third molar region and occur in the young although they may not be discovered for years. Bernier (1955), who refers to them either as primordial or as simple follicular cysts, considers them rare. He found only three cases out of 400 follicular cysts of all types in the files of the Armed Forces Institute of Pathology. Rushton and Cooke (1959) illustrate a specimen by means of a photo-micrograph, but do not describe it in their text.

HISTOGENESIS

The primordial cyst is a developmental abnormality. It is generally believed to arise from the enamel organ prior to the commencement of tooth formation. (Fig. 1). It is thought that the stellate reticulum breaks down to form the cyst cavity; that the internal and external enamel epithelia form the epithelial cyst lining; and that the fibrous cyst wall is formed from the dental follicle. Primordial cysts develop either from an enamel organ of the normal dentition or from a supernumerary bud.

The observations made in this report are based on the study of 22 cysts considered to be primordial in nature.

CLINICAL FINDINGS

The ages of the patients varied from 14 to 67 years, but the cysts occurred most frequently in the second and third decades. Ten cysts of this series of 22 came from patients between the ages of 14 and 27 years (Table 1). Males and females were almost equally affected (Table 2).