Continuous Bodily Tooth Movement and its Histological Significance.

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The purpose of this study was to investigate the changes taking place in the supporting tissue of teeth which were moved bodily with a continuous force. Earlier observations on the subject have been more or less casual. The investigation of C. BREITNER (1930) on tissue changes of the jaw joints, reveals that the teeth used for anchorage had been submitted to a minor bodily movement. As these teeth were deciduous molars in apes, their movement was hindered by proximal contact. Further, MARSHALL (1932) has experimented with *ribbon arch appliances* on incisors in apes, and consequently with forces of a more intermittent character. Up to date I have found no report of experiments on continuous bodily movement.

In this connection it should be mentioned that former investigators usually have moved teeth used for experiments with springs or ligatures applied directly to the coronal portion of the tooth. If such experiments are conducted over a longer period, the teeth moved will be tipped, GOTTLIEB and ORBAN (1931), A. M. SCHWARZ, (1932).

Several investigators consider bodily movement as a whole, intermittent or continuous, as less biological than other methods. The systematical Roentgen investigation of treated cases carried out by KETCHAM (1929), greatly supports this point of view. However, neither the force nor the time used was indicated in this study. In addition, where root resorptions are concerned, BECKS (1936) emphazises the rôle played by secondary factors of endocrine nature, such as hypothyroidism.

On the other hand, OPPENHEIM (1936) has shown that methods leading to tipping of a tooth may cause displacement of the apical portion of the root in an opposite direction. Fig. 51 p. 64 in OPPENHEIM'S study reveals, that this opposite displacement of the apical portion had damaged the root to such an extent that the pulp tissue was almost exposed. It should be noted that the force applied was not measured.

The chief purpose of the present investigation was to make an histologic analysis of the changes observed in the periedental tissues after continuous bodily tooth movement. An attempt is made to answer the following questions:

1) Does continuous bodily tooth movement imply direct or indirect bone resorption?

2) What are the changes produced in the supporting structures of the apical portion of the tooth as compared with teeth submitted to a tipping movement?

3) To what extent is bone apposition observed in a case where the tooth is moved labially?

Personal Investigations.

Six teeth were moved continuously and bodily in a dog, approximately 2 years old. Three teeth were moved mesially, one distally and two labially. In addition, one tooth was moved mesially with a spring applied directly to the crown of the tooth. This tooth serves as a control and will be compared with the other material.

The force used for bodily movement was approximately 20—30 gms, during the first eight days, then it was increased to the amount of force indicated for each experiment.

The dog had suffered from distemper and was somewhat underweight. In addition the animal had a crossbite in the incisor region. This malocclusion had produced a considerable widening in the anterior region of the lower jaw. The gingivae were somewhat hypertrophic with deep pockets around the incisors.

The animal was fed on a diet as adequate as possible, but containing no hard substances. To prevent untoward traumatic effects during mastication, the bite was slightly raised by cementing caps on several molars. Part of the work had to be done under an anaesthetic. For this purpose Pernocton was used, injected intravenously.

The histologic material was fixed partly in Maximow's solution, partly in Mueller-Formol, decalcified in 5 % nitric acid, embedded in Cedukol, sectioned and stained chiefly with Hematoxylin-Eosin, Gram-Weigert's fibrin-staining and Heidenhain's Azan-staining.

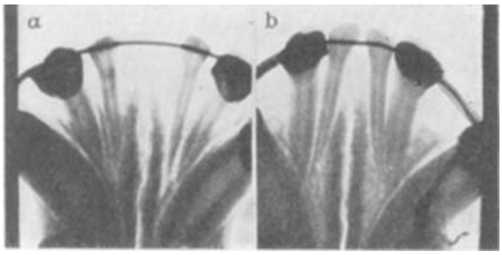

Fig. 1. Roentgen of the front teeth of the lower jaw, a before and b after the experiment was finished. The two first incisors were extracted before the experiment started, as seen in a.

First Experiment.

Mesial Movement of 4 Incisors in the Lower Jaw.

As seen in Fig 1. a, the two first incisors in the lower jaw were extracted before the experiment started. This was done to obtain more space for a mesial movement. The third incisors were provided with bands and horizontal tubes in which was placed a labial arch fixed to the canines. The mesial movement was produced by coil springs applied in such a way that the force could be measured. The force was kept constant and measured every 8 days. The experiment lasted 130 days.

In Fig. 2 are shown the 4 incisors of the lower jaw which were moved mesially. The right third incisor, B, was moved bodily with a continuous force of 85 gms, while the left third incisor C, was moved with a force of 50 gms. When measured from the median suture it seems that the right incisor was displaced to a greater extent than the left incisor, in other words, the displacement is approximately proportional to the amount of force applied. The two second incisors were moved indirectly. In Fig. 1 b, as well as in Fig. 2, it is seen that these teeth are slightly tipped and moved indirectly by proximal contact with the two third incisors. Fig. 2 shows that the two second incisors approximately have reached the alveolar region of the first incisors.

Histologic examination. A study of the histologic sections reveals that the left third incisor, moved with a force of 50 gms, as well as the left second incisor, moved indirectly, had no resorptions at all. Along the mesial side of the root of the right second incisor a few minor cement defects are observed, while the third incisor

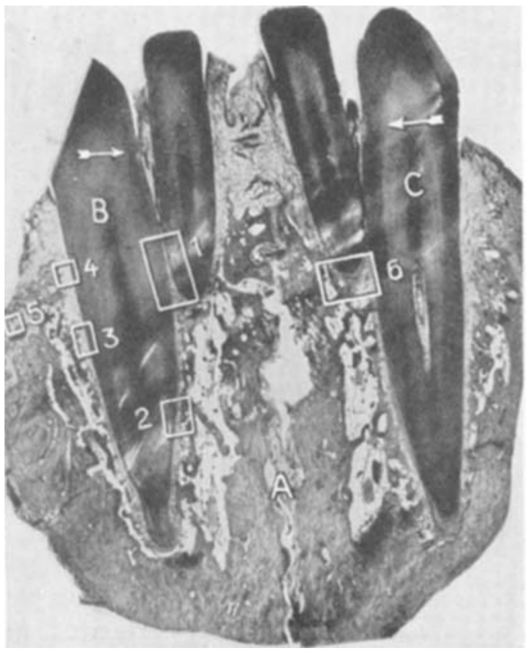

Fig. 2. A general view of the teeth seen in Fig. 1. The right third incisor, B, was moved bodily with a continuous force of 85 gms., the left, C, was moved bodily with a continuous force of 50 gms. The two 1. incisors were extracted before the experiment started. Here the two second incisors are seen tipped against the median suture, A.

moved with a force of 85 gms, had a somewhat larger resorption area in the middle of the root at the pressure side, seen in Fig. 3. This resorption apparently is due to the rather strong force applied. It is likely that the root surface has come into close contact with the bone wall of the alveolus. A necrotic pressure area is produced, whereby subsequently indirect resorption has caused resorption of bone tissue and root substance as well. As soon as the thin bone wall between the second and third incisor is eliminated, reparative processes have deposited cellular cementum layers into the resorption lacunae, C.

Further, Fig. 3 reveals that the blood capillaries are hyperemic and in a state of transformation, B, in other places more compressed as in the upper part of the picture. As a whole, the peridental tissue is fairly rich in cell elements, but the fibres lack a functional

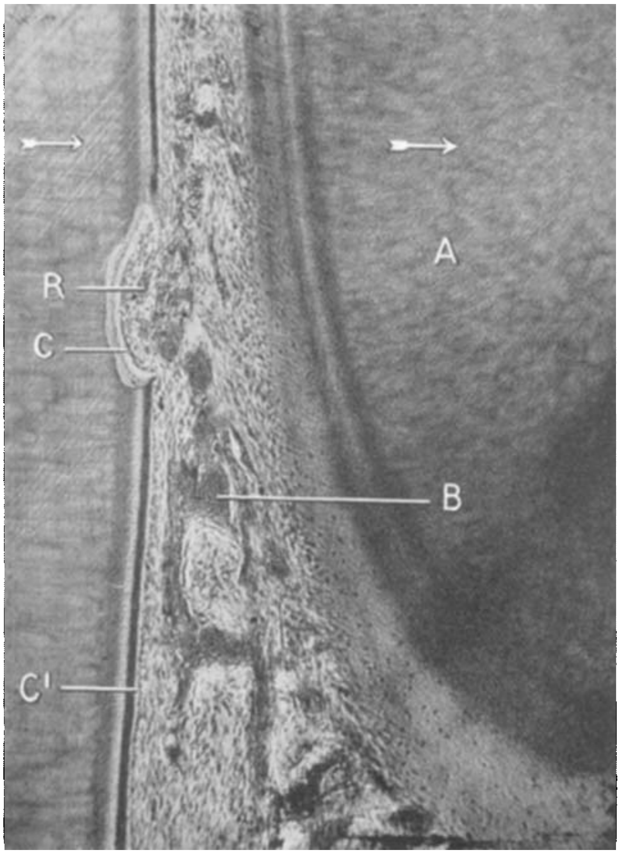

Fig. 3. The area indicated 1 in Fig. 2. The blood capillaries are widened and in a state of transformation, B, of a more normal form in the resorption area, R. C, uncalcified cementoid layer with cementoblasts in the portion of the root where the pressure is relieved.

arrangement. In the upper part, where the tissue is compressed between the root surfaces, there is no cementoid layer along the root surface of the third incisor, while such is noted in the lower part where the peridental tissue is less compressed, C^1.

In the apical portion of the root of third incisor, Fig. 4, a more even resorption line is observed. Along the bone wall are found Howship's lacunae, B, with osteoclasts, O. The peridental tissue is arranged parallel to the root surface with blood capillaries compressed between the fibre bundles along the root surface.

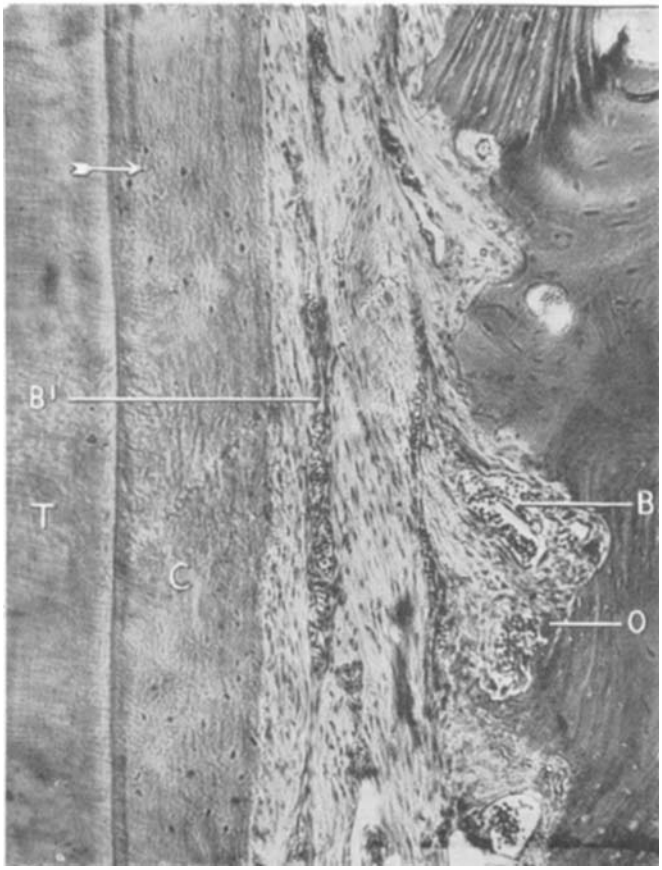

Fig. 4, indicated in 2 Fig. 2. Lacunary direct resorption of the bone tissue with osteoclasts O. The capillaries considerably widened along the bone wall, B, compressed along the root surface, B[1]. The peridental membrane as a whole is fairly rich in cells. C, layers of cellular cementum, at places bordered with lines of cementoblasts.

Contrary to this, the blood capillaries are widened and hyperaemic along the resorption lacunae where the pressure apparently is diminished.

At the distal or tension side of the third incisor, B, Fig. 2, it is seen that the thickness of new bone deposited, gradually diminishes apically. This fact reveals that the tooth has been somewhat tipped in spite of a, mechanically seen, bodily movement. The resistance created by the relatively long root of this tooth may account for this condition.

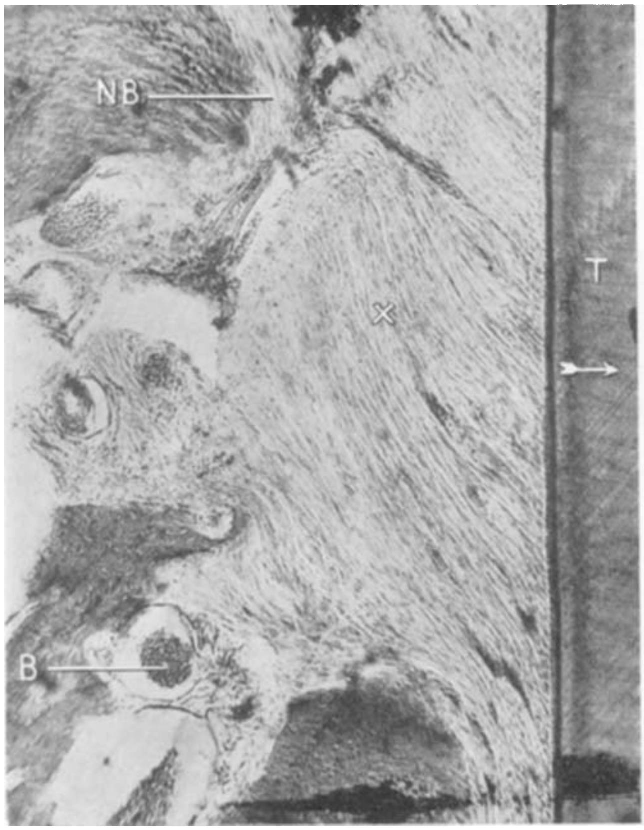

Fig. 5. Indicated in 3, Fig. 2. The tension side of the third right incisor. Uneven formation of new bone layers, NB. Along the old bone widened blood capillaries, B. The strong fibres partly show a decrease in the cell number. T, the root of the third incisor.

In the apical portion at the tension side, there is a more functional arrangement of the fibers. The capillaries along the bone wall are hyperaemic with some bleedings, while more compressed along the root surface. In some places are found layers of new bundle bone deposited, with a border of osteoid tissue lined with osteoblasts.

In some portions the fibers seem stretched, but at the same time there is an uneven formation of new bone tissue, Fig. 5. *It* is possible that this lack of bone apposition to a certain extent is due to the poor condition of the gingival tissue as a whole.

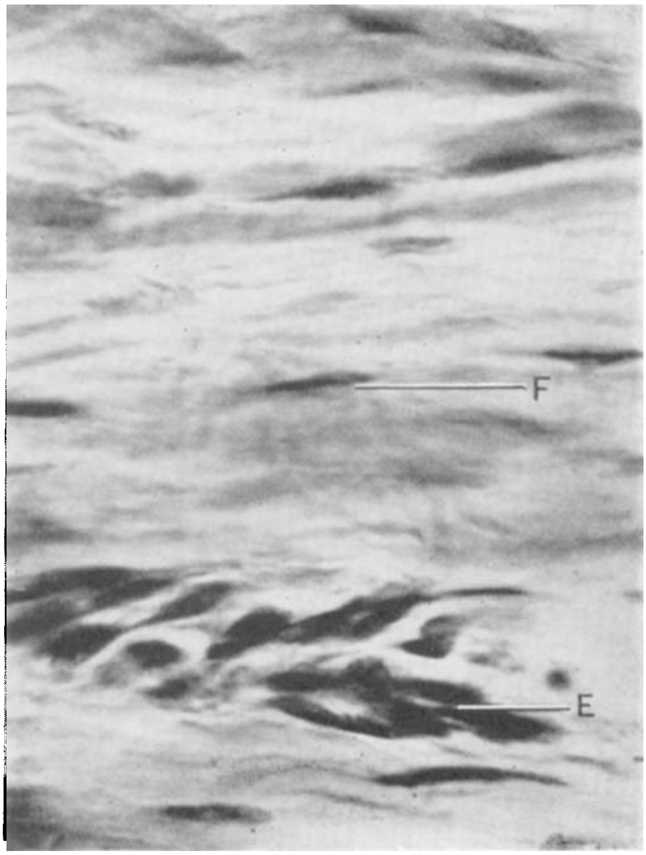

Fig. 6. Area indicated × in Fig. 5. Collagenous fibrous tissue with a few compressed and elongated fibroblasts. E, elongated epithelial rest observed a considerable distance from the tooth moved.

Fig. 6, taken from an area X in Fig. 5, reveals that the fibers are stretched and elongated, but contain rather few cells. The cells are elongated and compressed between the fibre bundles. This illustrates that a considerable elongation of connective tissue fibers may be obtained, even if there is not a proport˙onal increase in cell elements. Other parts of the same tension side show layers of new bone, bordered with a line of osteoblasts, Fig. 7.

Distal to this bone layer, which terminates the bone tissue mesial to the canine, some strong fibres are inserted, forming a sort of

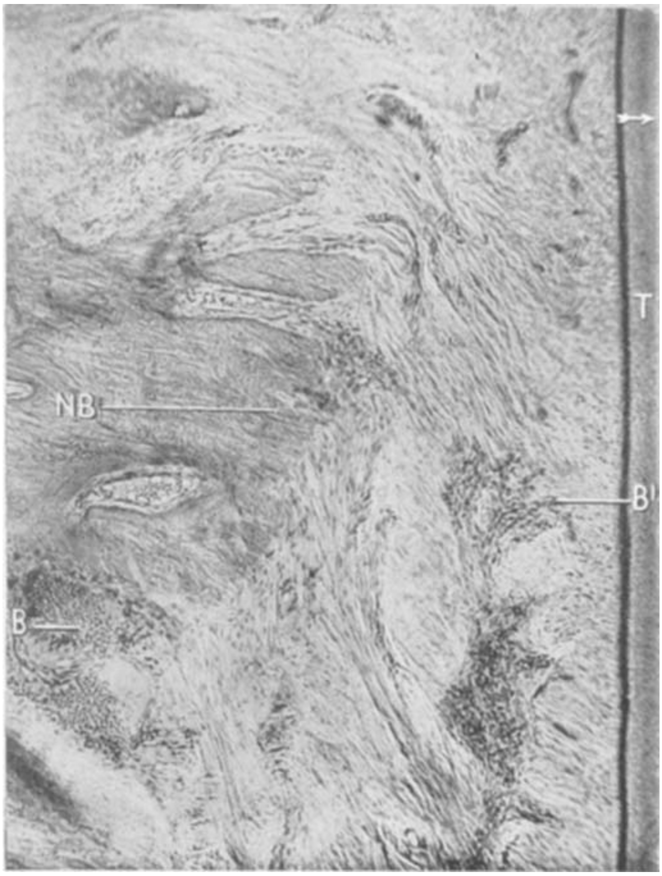

Fig. 7. Indicated in 4, Fig. 2. NB, new bone layers partly bordered with chains of osteoblasts, B, hyperemic blood vessels along the old bone wall. B^1, blood capillaries in a state of transformation near the root surface.

frenulum. These fibres pass over on the lingual side of the alveolar process. In this area the bone tissue has been resorbed by osteoclastic bone resorption as shown in Fig. 8. It is likely that this resorption has been produced incident to the tooth displacement possibly by an altered tension of the fibrous tissue. It may there-

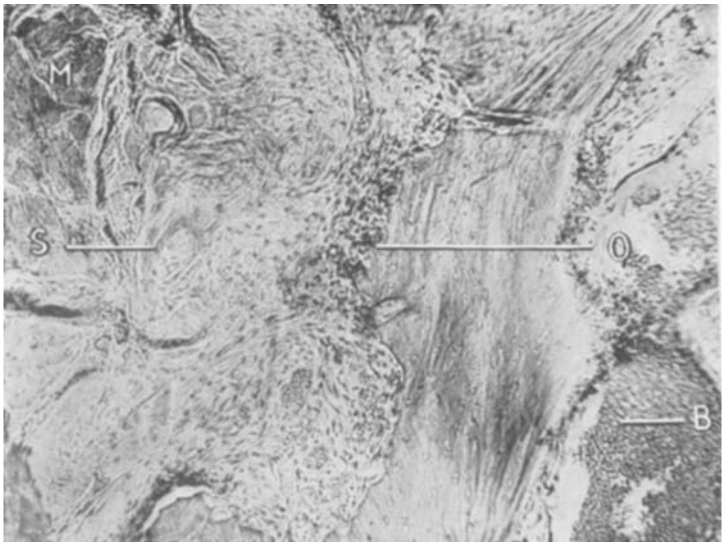

Fig. 8. Seen in 5, Fig. 2. S, strong fibrous tissue mesial to the right lower canine with some muscle fibers, M. There is a resorption line at O. B, hyperemic blood vessels in the marrow spaces.

fore be considered as a compensatory resorption. Similar resorptions were observed in some cases at the outer labial bone wall, subsequent to rotation of teeth, (1939). The bone tissue in those cases apparently was resorbed and transformed according to the new position of the teeth.

In the present case, similar bone changes seem to take place. The bone wall gradually is eliminated from the distal side, while there is apposition of new bone layers at the inner side adjacent to the root of the third incisor. A similar resorption is observed symmetrically in the corresponding portion of the bone tissue distal to the left third incisor. Whether this compensatory bone resorption occurs according to certain natural laws, can only be decided by studying a great number of similar cases.

The changes observed in the supporting tissues of the left third incisor are as a whole similar, except that there were no root resorptions. A detailed description of this tissue will therefore be omitted.

The second incisors. These teeth were moved indirectly subsequent to the displacement of the third incisors. A few minor defects are observed along the root surface of the right second incisor at the pressure side.

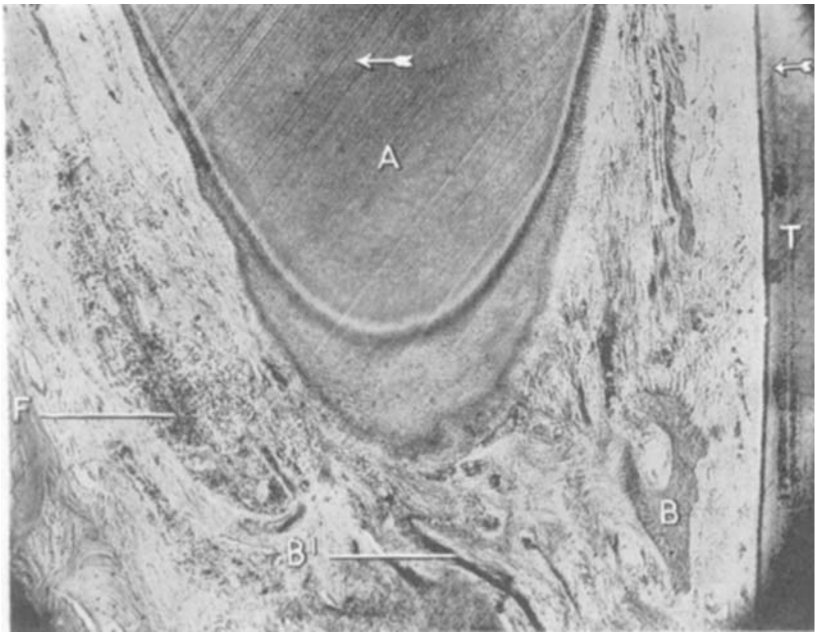

Fig. 9. Indicated in 6 Fig. 2. A, left second incisor indirectly displaced against the fundus alveolaris of the extracted first incisor. Slow healing of the extraction socket with an accumulation of plasma cells and lymphocytes, F. B[1], blood vessels stretched in the direction of the tooth movement. B, remains of old bone tissue between the second and the third incisor, T.

There are no resorptions along the root surface of the left second incisor.

In Fig. 9 is shown the position of the apical portion of the left second incisor. Apparently the animal had a lowered resistance against infections. In the fundus alveolaris of the extracted first incisor an accumulation of plasma cells as well as lymphocytes is observed, F. There is very little callus formed in spite of the considerable time elapsed since the experiment started. Similar cell accumulation is not found in the fundus alveolaris of the right second incisor. Here also the new bone formation is more advanced.

Second Experiment.

Mesial Movement of the Second Premolar and Distal Movement of the Third Premolar.

The Roentgen shows the right second premolar moved mesially and the third premolar moved distally by using reciprocal an-

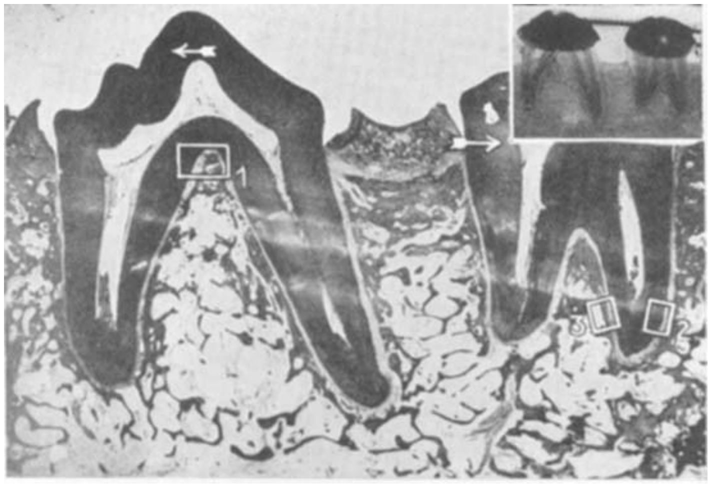

Fig. 10. Right second and third premolar moved in the direction indicated by arrows. The roentgen shows the teeth with appliance in situ. The force used was 45 gms.

chorage, Fig. 10. The appliance consisted of bands with horizontal tubes. A short piece of a wire provided with a coil spring was placed in the tubes. The force used, 45 gms, was kept constant and measured every 2 weeks. The experiment lasted 47 days.

Histologic examination. There is a striking resemblance between the picture created in the supporting tissues of these teeth and the changes observed during eruption of teeth or physiologic tooth wandering. This is true where permanent teeth are concerned, Stein and Weinmann (1925), Kronfeld (1938), as well as in cases where deciduous molars are displaced mesially subsequent to eruption of 6-year molars, Westin (1942). No pressure areas are found in the peridental membrane at all.

Fig. 11 reveals an area from the septum of third premolar, which was moved distally. At NB, new layers of bundle bone are observed with a border line, L, against the old bone, B. To the right, lacunary resorption is taking place. The peridental membrane as a whole reveals a tissue somewhat edematic, but of a rather functional arrangement. In this case, as well as in the two cases already described, it is noted that the tooth, while displaced bodily as a whole, has undergone a slight tipping movement at the same time. This is seen when the thickness of the bone layers deposited at the tension side of the coronal portion of the

Fig. 11. Indicated in 1 Fig. 10. The septum of third premolar. To the left layers of bundle bone, NB. At R, lacunary resorption with osteoclasts. The tissue is partly edematic and fairly rich in cells.

root is compared with the thickness of the new bone layers in the apical region. As this tooth has comparatively long roots, obviously the same mechanical resistance is created in this case, causing a minor tipping of the tooth.

The second premolar. It is found that this tooth has been moved bodily without a secondary tipping movement.

The pressure side from the mesial root is seen in Fig. 12. There is an even lacunary bone resorption, where osteoclasts are visible along the bone wall. The blood capillaries are of a normal size and form and the periedental tissue is of a fairly normal arrangement.

At the tension side of this root, an even layer of new bone is found deposited, bordered with lines of osteoblasts, NB. Along the root surface is found an uncalcified layer of cellular cementum bordered with cementoblasts.

In the apical portion of these two teeth, there are no signs of necrotic areas, and the space left between root surface and bone tissue is of normal width.

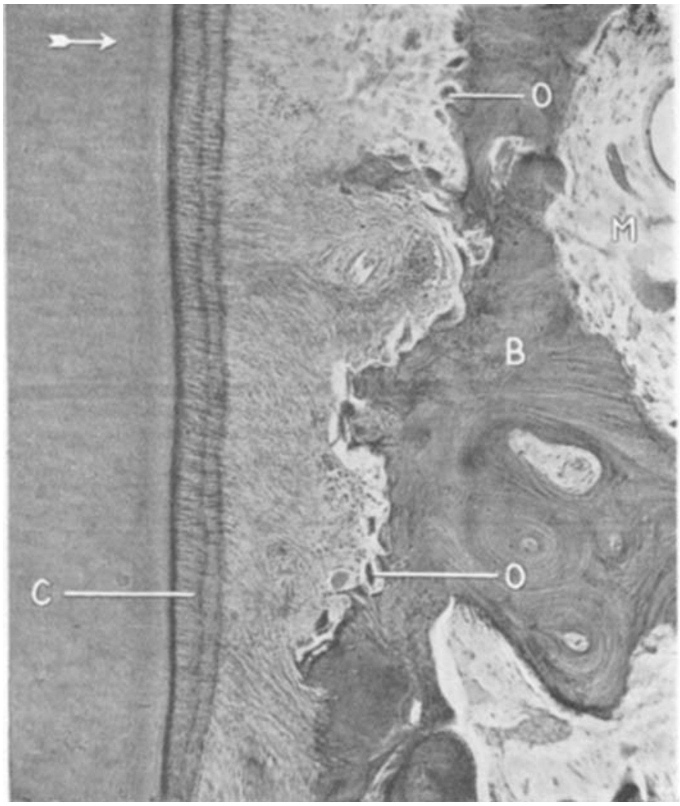

Fig. 12. Seen in 2 Fig. 10. Pressure side of the mesial root of the second premolar. Direct bone resorption with a line of osteoclasts, O. No cementoid layer at the surface of the root, which is covered with old cellular cementum, C. The capillaries in the peridental membrane are of normal size and form. In the marrow spaces partial transformation of fat marrow into fibrous tissue.

Third Experiment.

Bodily Labial Movement of Left Upper First Incisor and Right Upper Second Incisor.

The experiment required a rather complicated appliance, illustrated in Fig. 14. Two short extensions, soldered to bands on the respective incisors, were placed in tubes soldered to transversal wires. A parallel and stable displacement was obtained by using two such tubes for each extention. These extentions were moved by adjustable springs of which the force could be measured.

Fig. 16. Pressure side indicated in 1, Fig. 15. T, the root of first incisor. There is edema of the peridental membrane with capillaries in a state of transformation along the root surface. A tipping of the tooth would probably have caused root resorptions, here the root surface is intact. Direct resorption of the bone wall with osteoclasts lining the marrow spaces, O. L, border line between old bone, B, and new bone layers deposited at the outer surface of the labial bone wall, NB. X, border line in the deposited new bone layers.

is as a whole edematic. The blood capillaries are of a normal form and size — apparently the bone tissue has been resorbed directly from the peridental tissue. There is lacunary resorption with osteoclasts along the bone wall, 0, also lining the open adjacent marrow spaces.

At the outer side of the labial bone wall, layers of newly formed compensatory bone tissue are observed, NB. The periosteum is thick with rather few cells. The new bone layers have an even contour, bordered with chains of osteoblasts, especially visible in the region of the limbus alveolaris. In this region the new bone layers are thick, while decreasing toward the apical base.

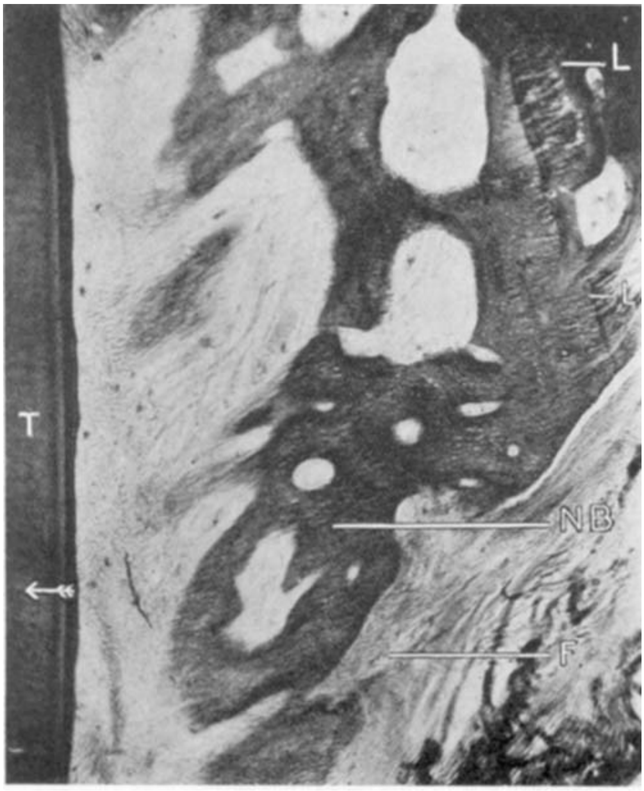

Fig. 17. Tension side indicated in 2, Fig. 15. The free gingival fibres are heavily stretched. NB, new bone layers deposited according to the direction of the fibres with new marrow spaces, L, border line between old and new bone tissue.

When examining the peridental membrane along the labial bone wall, it is observed that bone resorption gradually diminishes apically. In the apical region apposition of new bundle bone layers is found which indicates that the tooth has been slightly extruded as well. Because of the minor tooth movement in the apical region, there is a normal space left between the root surface and the bone wall. There is a normal arrangement of the blood vessels and nerve tissue entering the apical foramina.

At the tension side, new bone layers are found deposited, according to the direction of the fibers. It seems that the free gingival fibers are heavily stretched, Fig. 17. The new bone layers diminish in thickness apically, indicating that the root has been more displaced in the coronal portion.

Fig. 18. Tension side of the second right incisor moved bodily for 130 days with a continuous force of 68 gms. L, border line between new bone, NB, and old bone. At NM, marrow spaces formed around the blood capillaries, here fairly hyperemic, more compressed along the root surface. The tissue as a whole is rich in cells.

Second right incisor. The tooth was moved labially by a similar arrangement as shown in Fig. 14. It has a longer root and the force used was 68 gms for 130 days. Also in this case the tooth felt firm when the appliances were removed shortly before the animal was killed.

Histologic examination. The wide layers of deposited new bone tissue on the lingual side reveal that the tooth has been considerably displaced, Fig. 18. The new bone tissue is deposited in tongue-like layers which are now transformed with formation of new marrow-spaces. The blood vessels are found somewhat dilated in the areas near the old bone wall while they are more compressed between the fiber bundles along the root surface. These layers gradually diminish in thickness apically.

The labial side of the tooth is shown in Fig. 19. New bone layers are deposited and the old bone has been completely eliminated. Here also it is seen that these new layers gradually diminish in thickness and disappear at the mesial and distal angles

Fig. 19. Pressure side. The mesio-labial angle of the second incisor. The labial bone layers, NB, consist of newly formed bundle-bone. The old bone is completely resorbed. L, border-line between new bone layers and old bone, B. The periosteum, P, is thick and shows partial decrease in cell number.

of the proximal roots respectively. Seen in a vertical direction, the deposited bone layers are thickest at the limbus alveolaris, diminish apically and disappear on a level slightly coronal to the apex of the tooth. Here the old bone layers are still fairly thick.

In the periosteum covering this area, the fibers are arranged more or less parallel to the bone surface. They run perpendicularly through the new bone tissue and continue into the peridental membrane. Osteoblast layers covering the bone tissue at the periosteal side are scarce, mostly observed near the limbus alveolaris.

In Fig. 20, where the old bone is eliminated by resorption, the new bone tissue is deposited, in some sections with two border lines, in others with only one. Here, an outer uncalcified layer of osteoid tissue is observed. In the peridental membrane, lacunary resorption with osteoclasts is found. While the peridental membrane has a normal appearance in the apical region, this tissue is more or less edematic at the middle and coronal portion of the root.

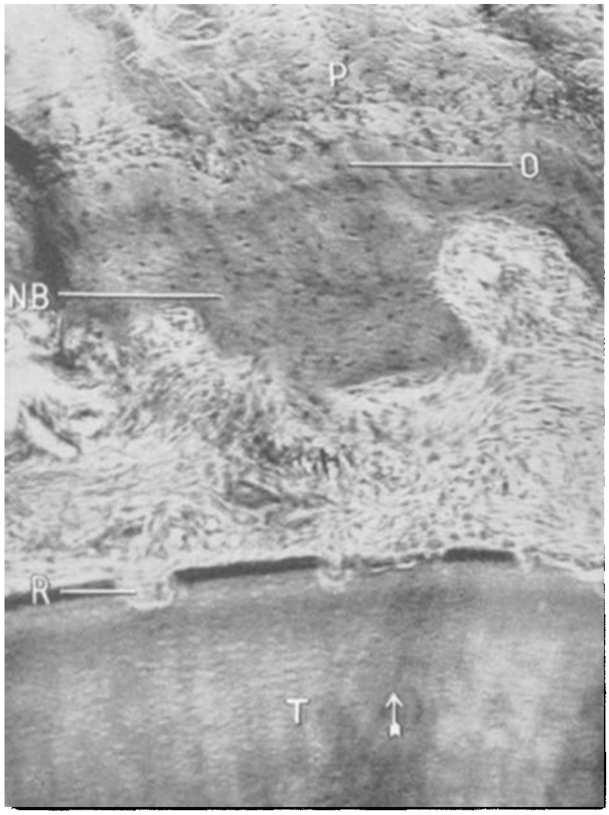

Fig. 20. The pressure side of the second right incisor. The middle portion of the root with some minor root resorptions, R. NB, newly deposited bone tissue with an uncalcified osteoid layer, O. P, the periosteum.

There is, however, actually no sign of necrotic areas. At the pressure side between the middle and coronal portion of the root, minor root resorptions are observed. These are partly repaired with cellular cementum. They are seen as small notches in the cementum and at some places they pass into the dentine.

Comparing the thickness of the deposited new bone tissue, it is observed that the coronal portion of the root has been displaced more than the apical portion. There has, however, been no movement of the apical portion in an opposite direction.

The teeth which were described here, have been moved bodily with a continuous force. Of these teeth two revealed root resorptions, while 4 had an intact root surface.

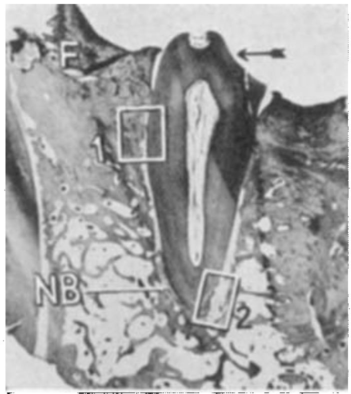

Fig. 21. The lower left first premolar moved with a spring activated 45 gms, during 38 days. F, the lateral frenum. NB, the mesial portion of the root where newly deposited bone layers are observed, *indicating that the root tip* has been moved in a distal direction.

Fourth Experiment.

Mesial Movement of the Lower First Left Premolar.

In order to see the difference between bodily and tipping movement, one tooth was moved with an appliance producing a tipping movement. A thin ligature was fixed from a hole in the incisal edge to a spring activated to a continuous force of 45 gms.

The anatomy of the dog was of importance here, as the tooth when moved mesially would rest against the lateral frenum, of which some strong fibres run over to the lingual portion of the alveolar process. This frenum apparently has delayed the tooth movement to a certain extent.

Histologic examination. A general view of the tooth with surrounding structures illustrates that the peridental membrane is relatively wide at the distal apical portion of the root, Fig. 21, 2. The area seen in Fig. 22, represents the mesial pressure side in the coronal portion of the root near the limbus alveolaris. Here it is observed that the root surface is in close contact with the bone wall. The peridental membrane is of a hyalin, partly necrotic condition. Before the tooth can be moved further, the necrotic area, N. Fig. 22, must be resorbed by undermining resorption from the adjacent marrow spaces. Because the bone tissue is compact with well developed Haverian systems and few marrow spaces, this undermining resorption apparently will take a considerable time. In this section reparative processes are taking place in the former resorption lacunae, as a sign of the static condition of these changes. While other sections reveal osteoclasts and active resorption, here the tissue changes actually are formative.

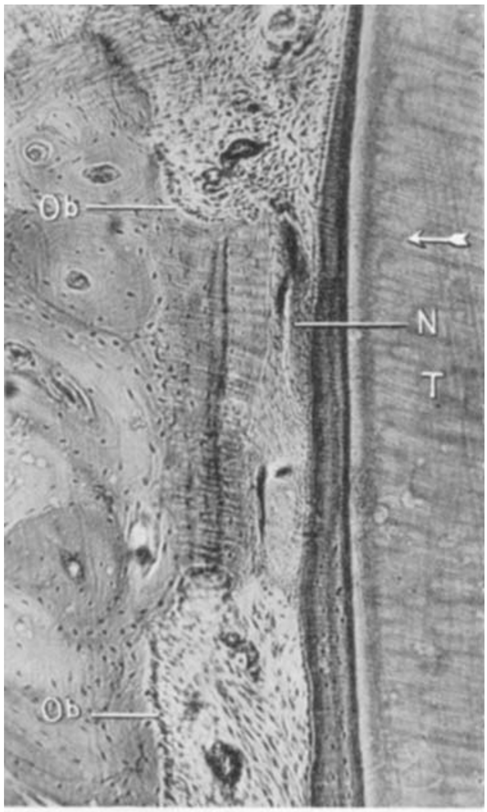

Fig. 22. Pressure side seen in 1, Fig. 21. At left compact bone tissue with Haverian systems. N, partly necrotic, partly hyalinized tissue of the peridental membrane hindering a further movement of the tooth. Ob, osteoid tissue with lines of osteoblasts indicating that there is a delay in the tooth movement.

This necrotic area apparently acts as a fulcrum, the whole tooth forming a two-armed lever with its longest arm lying apical to this area. The present condition illustrates that the apical portion of the root may be pressed in an opposite direction when the tooth is tipped, Fig. 23. Several pressure areas have been formed along the distal apical portion of the root. Some of the bone tissue as well as the root surface is removed by resorption, the whole peridental space being widened.

At the mesial side of the root, there has been apposition of new bone layers to compensate the distal movement of the root tip.

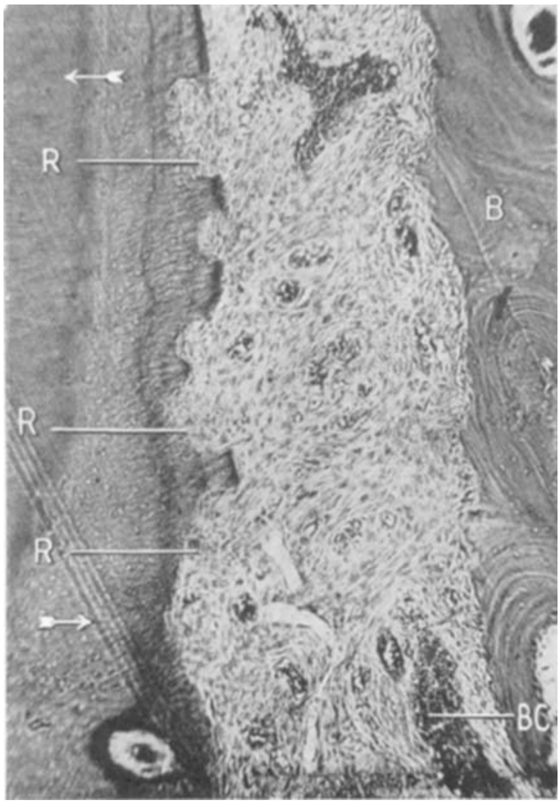

Fig. 23. Indicated in 2, Fig. 21. R, root resorptions of the distal apical portion of the root incident to a distal movement of the root tip. The peridental membrane is considerably widened, following the bone and root resorption. BC, widened blood capillaries. B, the alveolar bone wall which is compact with Haverian systems, here exhibiting a resorption line.

Discussion.

As previously mentioned, the animal was about 2 years old. There seems however to be no reason to include the age as a factor where root resorptions are concerned. By comparing the control tooth (4. experiment) with the teeth moved bodily, it is apparent that the method used and not the animal's age is of importance.

Of the six teeth moved bodily only two were injured by root resorptions, while the control tooth which was tipped, exhibits necrotic pressure areas and more resorptions.

One may claim that the animal was in poor physical condition, and did not get an optimal diet. These factors possibly are responsible where the condition of the gingiva and the slow healing of the extraction socket are concerned. However, it does not seem likely that they have had any influence on the root resorptions. If so, more teeth would have been resorbed. But there seems to be a direct relation between the amount of force used and the degree of resorption. In two cases where the force ranged from 68—85 gms the roots were resorbed, but not in cases where the force ranged from 40—55 gms, not considering the control-tooth.

When A. M. SCHWARZ divided the orthodontic forces into 4 grades, he did not take any reservations where the axial position of the tooth during treatment is concerned. It was presupposed that the tooth concerned should be moved by methods leading to a tipping of the tooth. My own experiments demonstrate that the orthodontic force can be considerably increased, without resorptions occurring, provided the tooth is moved bodily. How long the force is active seems to be of less importance, but using a continuous force may result in stasis of the blood capillaries and hyalinization of the collagenous fibres with a diminution in the number of cells.

In several cases the root surface was moved close up to the alveolar bone wall without directly touching it, there was however no sign of root resorption, Fig. 16. This seems to imply that there must be a direct contact between the bone and root surface to cause root resorptions (GOTTLIEB and ORBAN, 1931). Resorptions can not completely be prevented by moving teeth bodily, but the experiments show that resorptions can be kept within a certain minimum by this type of tooth movement.

Here it should be mentioned that these experiments were performed without including the normal tooth function as a factor. No teeth were allowed to contact their antagonists during mastication. The untoward effects produced upon the supporting structures of the teeth during mastication constitute an additional factor of great importance (STUTEVILLE, 1936). To what extent this factor may influence the tissue changes here reported, can only be determined by new experiments. It is however likely that a tooth displaced while resting in a horizontal tube, is less exposed to injuries of the peridental tissue than a tooth which is moved without being supported in any way.

In the present experiments there was a decreased apposition of new bone apically. It is likely that this is a result of the slight tipping movement undergone by the teeth moved labially. Apparently the thickness of the new bone layers is proportional to the degree of resorption from the inside of the peridental membrane.

Where the changes occurring in the apical base area incident to a labial displacement are concerned, experiments in human material are apparently required. The outer labial bone plate in dogs is thick and often sclerotic, while in the man it is as a rule very thin. Pulp tissue reactions and changes in the bone tissue of the apical base, must therefore be studied in experiments made on human material.

Another question, which could not be clarified by the usual histological technique, is how the periodontal fibres elongate when submitted to continuous tension. The fibres of Sharpey, which are collagenous sinew tissue (BERGERSEN, WEIDENREICH), do not elongate readily on the application of intermittent forces (HÄUPL, 1935).

If a tooth is to be displaced over a longer distance, this is done more readily by continuous forces. Then the question arises, where in this collagenous tissue this elongation does take place? Does it occur by a splitting or branching out of the fibres, similar to the changes occurring in the supporting tissue of continuously erupting front teeth in the rodents? Does an interstitial elongation exist, to a certain extent independent of the cellular function, or does the elongation of the collagenous fibres entirely depend on cell activity? New experiments and other methods may possibly contribute to clarify these questions.

In my first experiment here reported, some fibres were observed in a hyalin state. There was a decrease in the cell number, and the cells appeared elongated and compressed. According to FREUDENBERG and GYORGY (quoted from WEIDENREICH) such decrease in the cell number may depend on disturbances in the cell metabolism. In this case, the chronic inflammation of the gingivae may have caused local disturbances in the tissue changes. There was nevertheless a considerable elongation of these fibres, while the bone formation was uneven and diminished.

On the other hand, a similar proliferation of the fibrous tissue is shown in Fig. 18. Here the tissue is rich in cells and there is normal bone formation according to the movement of the tooth. This seems to imply that there is a relation between the number of cells observed and the amount of new bone deposited.

Conclusion.

In the present paper are described histological sections from 6 teeth which were moved bodily during from 3—5 months. The appliances consisted of bands with horizontal tubes in which were placed short arches provided with coil springs. Two teeth were moved labially and four teeth were moved mesially or distally.

A tooth which was moved mesially with a force of 85 gms showed a small root resorption area (fig. 3) and another tooth moved labially with a force of 68 gms had small resorptions in the middle portion of the pressure side. The four other teeth moved with forces ranging from 45—55 gms had no resorptions at all. That the root surface was so little injured may be ascribed to the fact that the teeth were moved bodily and not tipped. A bodily movement with light forces seems to imply a more even tension of the peridental fibres all along the root surface. As a result, when the forces used are kept within a certain limit, pressure areas are apparently not created to the same degree as in tipping of a tooth. As a second factor must be considered that the teeth moved were out of occlusal contact all the time. The experiments are therefore, until compared with experiments in human material, more of theoretical than of practical value.

As a control, one tooth was moved with a tipping movement in mesial direction for 38 days. This tooth had a necrotic pressure area in the mesial middle portion of the root (fig. 22) and resorptions of the distal apical portion (fig. 23). The force used was 45 gms.

The results may be summarized in the following:

1) Provided light forces are used, continuous bodily movement of teeth seems to imply root resorptions to a lesser degree than in cases where teeth are moved with approximately the same or even lighter forces, but not bodily.

2) All teeth were more displaced in the coronal than in the apical portion of the root. This may be ascribed to the mechanical resistance created in teeth with long roots.

3) In these experiments the apposition at the outer labial bone surface was of a thickness decreasing apically and approximately proportional with the degree of resorption from inside of the alveolar bone wall.

Zusammenfassung.

In der hier vorliegenden Arbeit werden histologische Schnitte von 6 Zähnen beschrieben, die im Laufe von 3—5 Monaten parallelverschoben worden waren. Die Apparatur bestand aus Bändern mit wagerechten Röhren, in denen kurze, mit Spiralfedern versehene Bögen angebracht waren. Zwei Zähne wurden labialwärts und vier mesial- oder distalwärts verschoben.

Ein mit einer Kraft von 85 g mesialwärts verlagerter Zahn zeigte an einer kleinen Stelle Wurzelresorption (Abb. 3), und ein anderer, mit einer Kraft von 68 g labialwärts verschobener Zahn wies kleine Resorptionen in der Mittelpartie der Druckseite auf. Die vier übrigen Zähne, die mit einer zwischen 45 und 55 g schwankenden Kraft verschoben worden waren, zeigten keinerlei Resorption. Dass die Wurzeloberfläche so wenig beschädigt war, dürfte dem Umstand zuzuschreiben sein, dass die Zähne parallelverschoben und nicht gestürzt worden waren. Eine Parallelverschiebung mittels geringer Kraft scheint eine gleichmässigere Spannung der paradentalen Fasern an der ganzen Wurzeloberfläche zu geben. Folglich entstehen, wenn die verwendete Kraft innerhalb gewisser Grenzen gehalten wird, Druckzonen nicht in demselben Ausmasse wie beim Stürzen eines Zahnes. Als ein zweiter Faktor ist zu bedenken, dass die verschobenen Zähne die ganze Zeit über dicht in Okklusionskontakt kamen. Die Versuche sind deshalb, ehe sie mit Versuchen an menschlichem Material verglichen worden sind, mehr von theoretischem als von praktischem Wert.

Als Kontrolle wurde ein Zahn 38 Tage lang einer stürzenden Bewegung in mesialer Richtung unterworfen. Dieser Zahn zeigte an der mesialen Mittelpartie der Wurzel eine nekrotische Druckzone (Abb. 22) sowie Resorptionen an der distal-apikalen Partie (Abb. 23). Die verwendete Kraft betrug 45 g.

Die Ergebnisse können folgendermassen zusammengefasst werden:

1. Falls eine geringe Kraft zur Verwendung kommt, scheint fortlaufende Parallelverschiebung von Zähnen in geringerem Aus-

masse Wurzelresorptionen zu erzeugen, als wenn die Verschiebung mit ungefähr der gleichen oder sogar geringeren Kraft, aber nicht parallel stattfindet.

2. Bei sämtlichen Zähnen war die Kronenpartie der Wurzel stärker verschoben als die Spitzenpartie. Dies dürfte dem mechanischen Widerstand zuzuschreiben sein, den Zähne mit langen Wurzeln bieten.

3. In diesen Versuchen nahm die Anlagerung an der äusseren, labialen Knochenoberfläche apikalwärts an Dicke ab und entsprach ungefähr dem Grade der Resorption an der Innenseite der Alveolarwand.

Résumé.

Dans une introduction l'auteur constate qu'en ce qui concerne la réaction du tissu provoquée par un redressement orthodontique, peu d'observateurs ont traité le déplacement parallèle continu. Dans cet article on a décrit des sections histologiques de 6 dents déplacées parallèlement pendant 3 à 5 mois. L'animal utilisé était un chien de deux ans.

Les appareils consistaient de bagues avec tubes horisontales et arcs vestibulaires pourvus de ressorts à boudin. Une dent qui a été déplacée avec une force de 85 grs, a montré une résorption radiculaire du côté de la pression (fig. 3) et une autre dent déplacée avec une force de 68 grs, a montré une résorption minime également du côté de la pression. Les autres dents qui ont éte déplacées avec des forces variantes de 45 à 55 grs, étaient sans résorptions. Que les dents montrent si peu de lésions radiculaires peut être expliqué par le fait qu'elles n'ont pas été inclinées, mais étaient déplacées parallèlement. Il paraît que les fibres du ligament ont subi une tension plus proportionnée et il s'établie donc moins facilement des zones de compression dans le tissu péridentaire.

Une dent de contrôle qui a été redressée de la façon habituelle avec un seul point d'attaque dans la partie coronale de la dent, a demontré une zone de compression nécrotique du côté de la pression (Fig. 22) et une résorption assez étendue de la partie apicale par le fait que la racine a été forcée dans la direction opposée (fig. 23).

Ce qui a été constaté peut être résumé comme suit:

1. Le déplacement parallèle des dents avec des forces légères ne paraît pas amener tant de résorption radiculaire qu'au cas

où la dent a été déplacée avec une force correspondante ou inférieure mais sans être déplacée parallèlement.

2. Toutes les dents étaient plus déplacées dans la partie coronale de la racine que dans la partie apicale. Ceci peut être attribué à la résistance mécanique provenant de dents avec des racines longues.

3. L'apposition extérieure du tissu osseux produite par pression sur la paroi alvéolaire vestibulaire était d'une épaisseur inférieure au niveau de la partie apicale et en ce cas proportionnelle au dégré de résorption du côté intérieur de la paroi alvéolaire.

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