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Biologic Orthodontic Therapy and Reality

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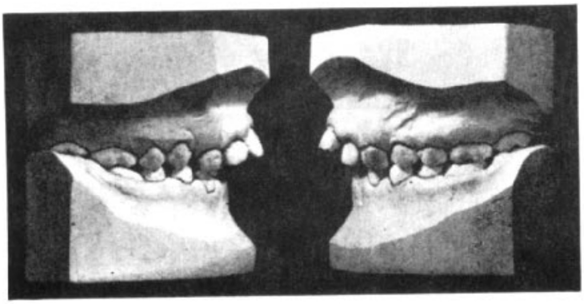
(*Continued from* VOL. V, NO. 4)

The *second case,* a girl of sixteen, in which the two upper premolars had finally to be extracted because of lack of room, is shown in Fig. 75. This case has been treated by one of my pupils, with the expansion-arch exclusively, and the premolars were, as to be seen in Fig. 75, III, ligated to the archwire by a ligature encircling a lingually running wire. No protective band was put on the right first premolar. The ligatures were not carefully enough handled, so that their breakage occurred relatively often and, as a consequence, backward-movement was produced. Therefore, we find cementum-resorptions on the lingual side, also.

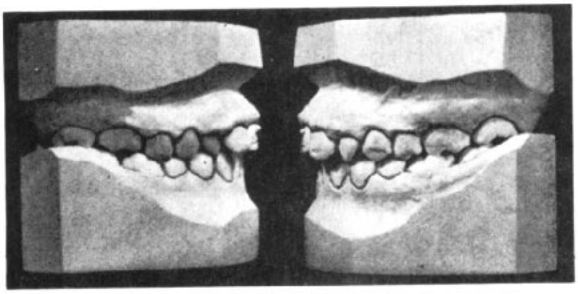
As normal width and form of the lower jaw and also normal mesio-distal relations had been attained, no further room could be gained for the normal alignment of the canines and to bring the four front teeth into normal contact with the lower incisors, either through further expansion or through further distal-movement of the buccal teeth. After a treatment of one and one-half years, the extraction of 4/4 was therefore decided upon and was performed. The alignment of the upper six front teeth is still in progress.

Specimen XIII. In Fig. 76 we see the left upper premolar. As a result of the buccal-movement (simple arrow), we find resorption, a, which is in full stage of repair, like the appertaining resorption, a^1, in the apex-sphere, which is shown in Fig. 77, in higher magnification.

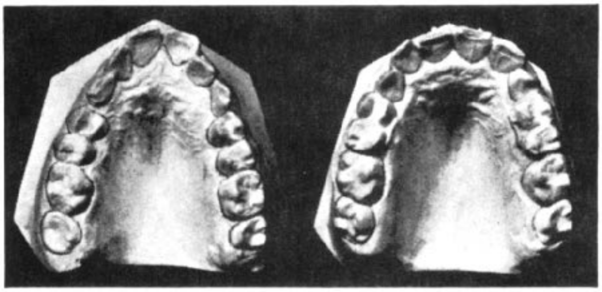
As a result of the breaking of ligatures and the backward movement which this involved, the resorption, b, Fig. 76, and the appertaining resorption in the apex-sphere, b^1, Fig. 76, were caused. These latter resorptions,



I



II



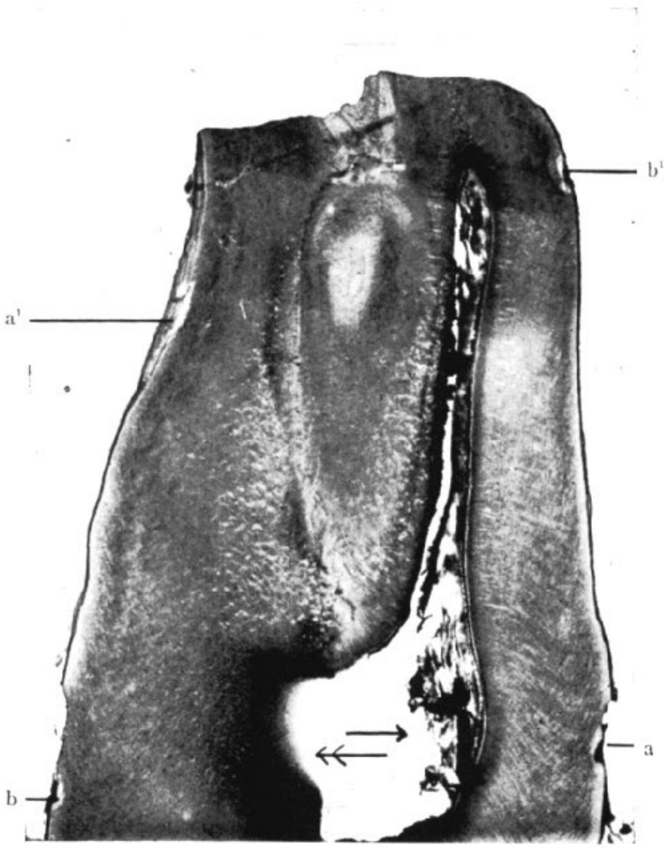
III

Specimen XIII (Figs. 75 to 78) Figure 75

I, before treatment; II, after expansion and gaining normal mesiodistal relations; III, occlusal view before and after expansion and just before the extraction of 4/4.

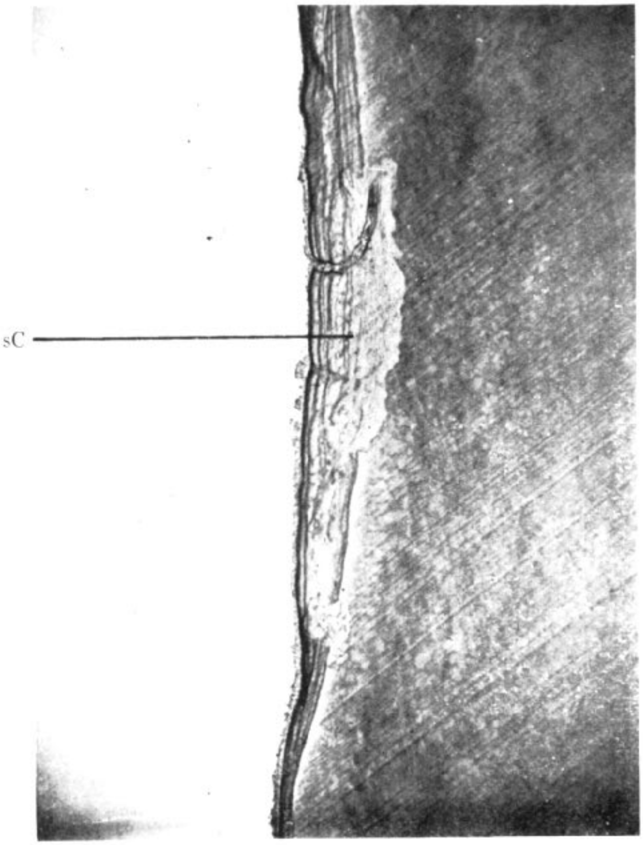
b and b^1, are incomparably shallower and of smaller extent than the resorptions caused by using the lingual arch under the same conditions, (Fig. 66 and also Figs. 69, 71 and 72). In the further course of the series, the cementumresorption on the lingual side, produced by backward movement, has always, if present, the same size, (b, Fig. 78).

While the mesiodistal extent of the resorption by the relapse movement in Specimen XII measures 1.7 mm., (some single slides of the specimen have certainly been lost), the calculation in this case (0.016 x 44 i.e., the number of the slides in which the resorption is to be seen in uninterrupted succession), shows a mesiodistal extent of 0.70 mm. This smaller extent of width



Specimen XIII (Figs. 75 to 78) Figure 76
Magnification 11; primary direction of movement is indicated by the single arrow; backward movement by the double arrow; a and a^1, resorptions through the primary movement; b and b^1, resorptions through the backward movement.

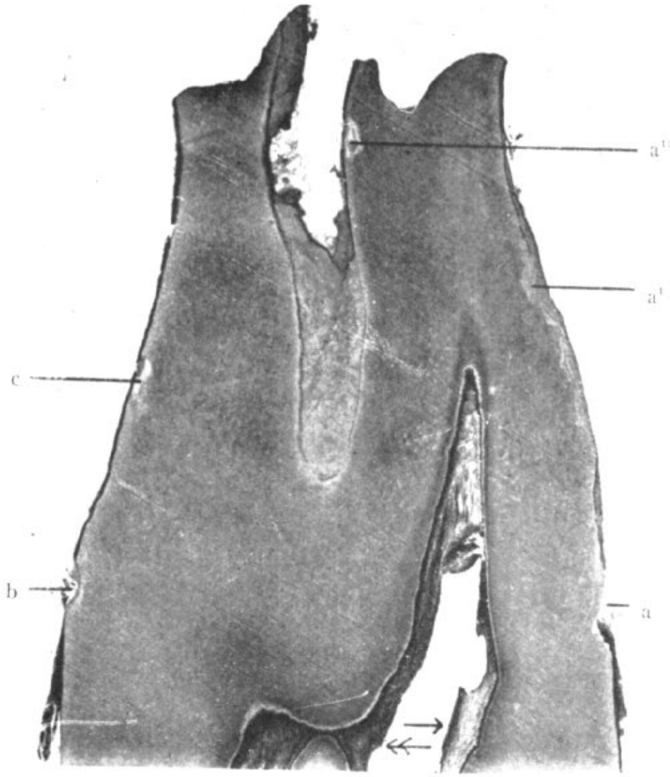
is explained by the fact that if the tooth is guided by a ligature, such a strong deviation of the force-direction to mesial or distal (which mostly is responsible for the mesiodistal diameter of the resorption), never can happen. No plausible explanation can be given for the formation of the small resorption on the lingual side, c, Fig. 78, at about the middle of the root.



Specimen XIII (Figs. 75 to 78) Figure 77
Point a^1 of Fig. 76 in higher magnification (40); sC, secondary cementum.

On the buccal side in Fig. 78, there is, in addition to the already ascertained resorption near the enamel cementum border, a, another extended, fully repaired resorption, a^1, which occupies the entire middle third of the root. That may be attributed to a more parallel movement of the tooth. It has a length of 3.5 mm. with a total root length of 9.5 mm. This resorption can be seen and followed in 29 slides and has, accordingly, a width of (0.016 x 29) 0.46 mm.**

On the whole, the damages produced in the cementum with the use of the archwire and ligature are unproportionately smaller than those in Speci-

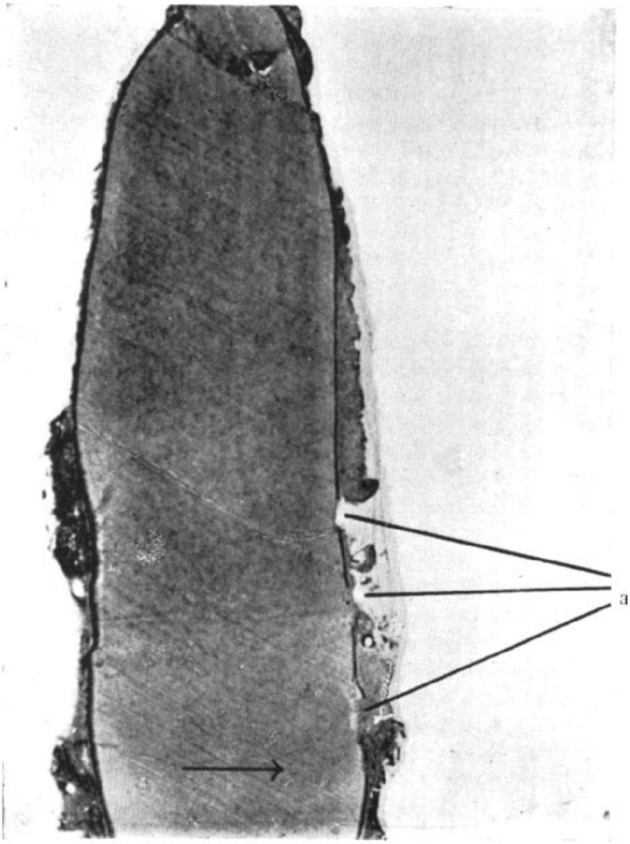


Specimen XIII (Figs. 75 to 78) Figure 78
Magnification 8; primary direction of movement is indicated by the single arrow; backward movement by the double arrow; a, a[1] and a[11], resorptions created during the primary movement; b, resorption through the backward movement; c, resorption of unknown origin.

men XII, effected through the influence of the continuous force of the spring. The changes in the pulp, as far as ascertainable in the defective preserved remainder of the pulp, are unproportionally smaller than in Specimen XII.

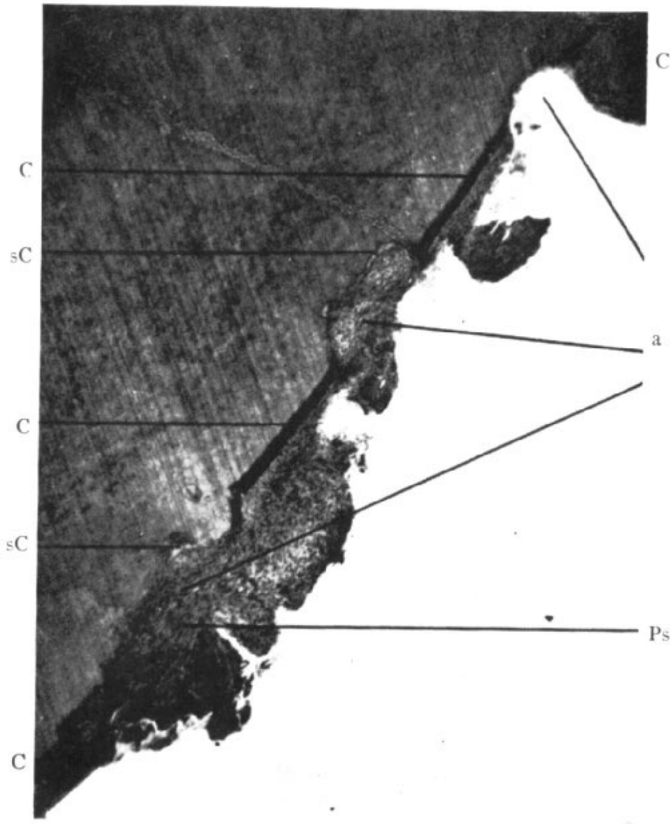
** The series of this specimen being complete, the calculated measurements are to be taken as quite exact.

Thus an almost normal odontoblast layer can be ascertained for long stretches in Fig. 76 and also in Fig. 78. The picture of active stasis together with the formation of vacuols is not ascertainable in this specimen. The visible damages to the pulp were exceptionally small—smaller than in all other specimens.



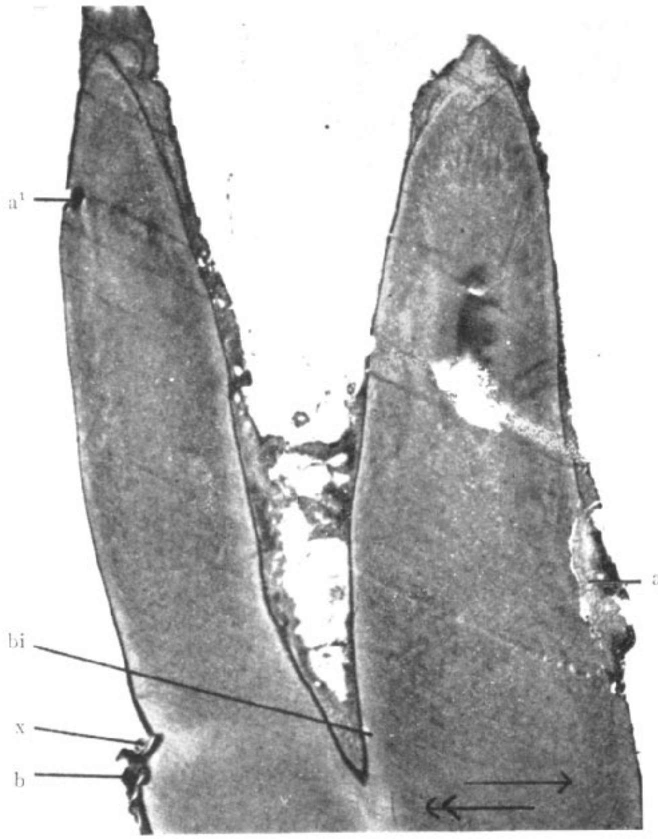
Specimen XIV (Figs. 79 to 85) Figure 79
Magnification 8; direction of movement is indicated by the arrow; a, cementum-resorptions.

Specimen XIV. The buccal root of the right premolar of the case treated with the expansion arch, (Fig. 75), is shown in an outline picture in Fig. 79. Three terminations of a great resorption, (a, Fig. 79), are visible on the buccal wall of the root in the direction of movement (arrow), which, in higher magnification, are shown in Fig. 80. In the further course of the series we find the same resorption, (a, Fig. 81), confluent into one great resorption which, in Fig. 82, is shown in higher magnification. Corresponding to this resorption produced by the primary movement, (single arrow, Fig. 81), is the resorption a^1 in the apex sphere on the palatal root.



Specimen XIV (Figs. 79 to 85) Figure 80
Points a, of Fig. 79; magnification 40; C, cementum; a, cementumresorptions; sC, secondary cementum; Ps, remnants of the periodontal membrane.

The corresponding resorption on the buccal root in the apex sphere is only to be seen in the later course of the series, (a^1, Fig. 83), and has here greater dimensions. Owing to the break of the ligature, the backward movement of the tooth caused the formation of small resorptions corresponding to the lingual alveolar crest, (b, Fig. 81), and in the proximal root furrow, corresponding to the lingual side of the buccal root, (bi, Fig. 81). A resorption in the apex sphere, caused by this backward movement of the tooth, is not to be seen in this slide, but is visible to the same small extent in later

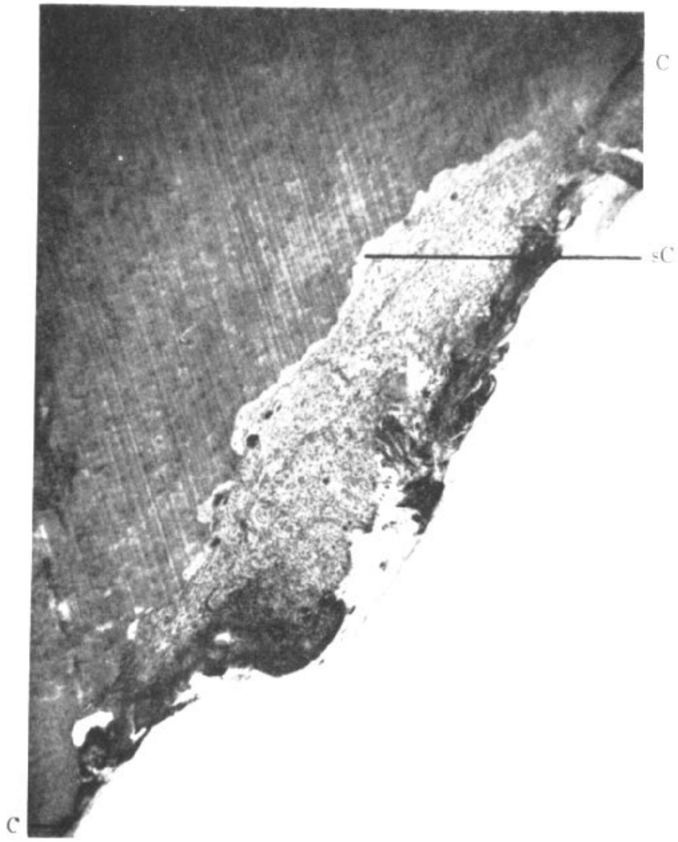


Specimen XIV (Figs. 79 to 85) Figure 81

Magnification 5; primary direction of movement is indicated by the single arrow; the three resorptions, a, of Fig. 79, confluent into one great resorption, a; the corresponding resorption in the apical region at a¹; by the backward movement, on account of the breakage of the ligature, the resorptions b and bi have developed; x is not a resorption but an inflexion (fold) of the cementum.

slides, (b^1, Fig. 83). The resorptions caused by the relatively rare backward movement, (b, Fig. 81 and b^1, Fig. 83), are of a very small extent and depth, which remains the same in the whole course of the series. To the great resorption a, Fig. 84, in the direction of the primary movement (single arrow), corresponds the shallow resorption, a[1], in the septum, whereas the resorption b[1], Fig. 84, was produced by the backward tilting movement.

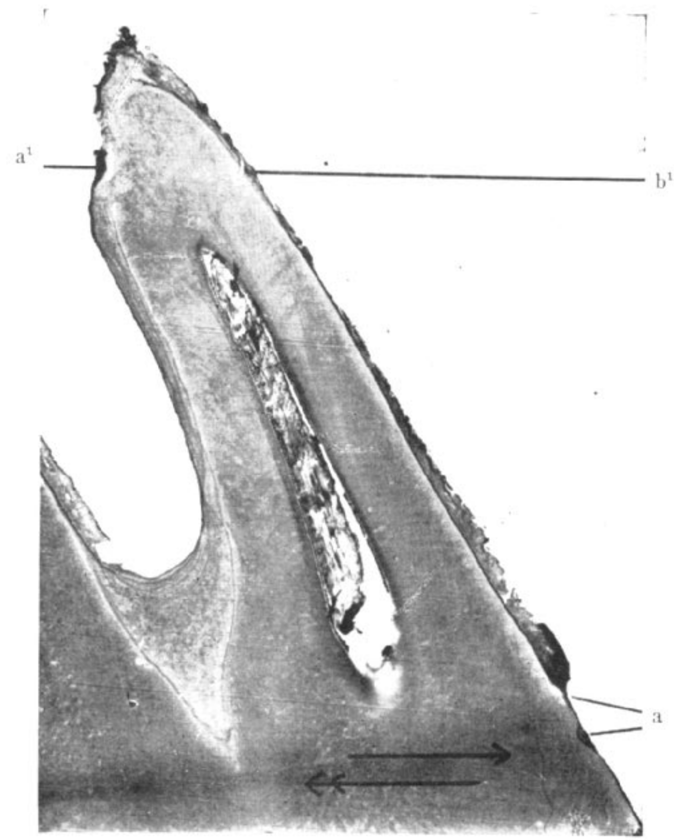
Towards the end of the series the sections are tangentially and are



Specimen XIV (Figs. 79 to 85) Figure 82
Point a, of Fig. 81; magnification 40; C, cementum; sC, secondary cementum.
Specimen XIV (Figs. 79 to 85) Figure 83

only reproduced for orientation on the reconstruction model. Thus, we see in Fig. 85 at a, the resorption brought about by the primary movement (single arrow), to which corresponds resorption a[1], while the resorption b[1] was caused by the backward movement.

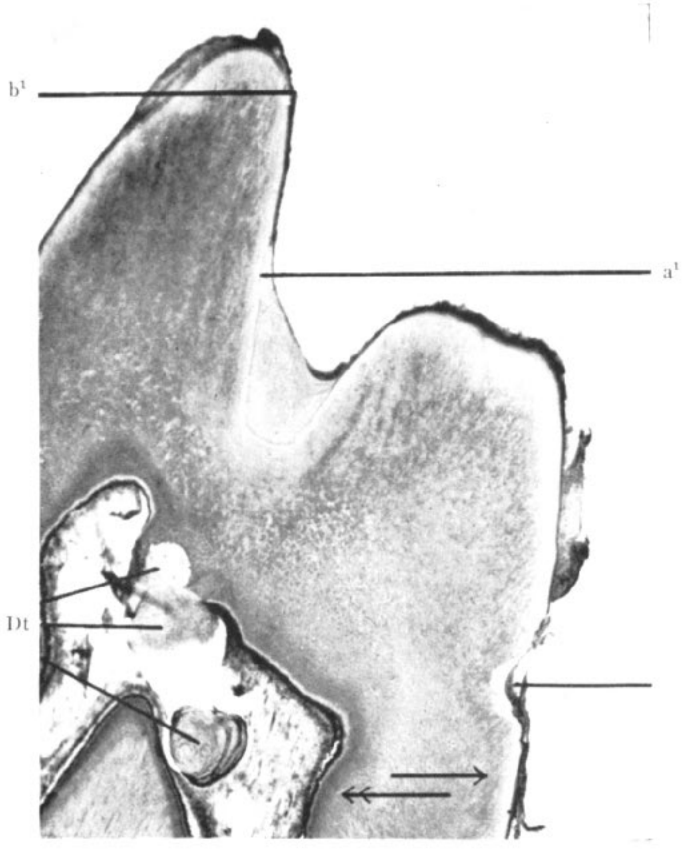
Although the damages to the pulp in this specimen are more strongly developed than in Specimen XIII, they do not anywhere nearly reach the degree which we could ascertain in Specimens XI and XII. In the crown pulp, however, one free and two wallstanding denticles have been formed, (Dt, Fig. 84).



Specimen XIV (Figs. 79 to 85) Figure 83
Magnification 6; primary direction of movement is indicated by the single arrow; a and a¹, resorptions belonging together and caused by the primary movement; b¹, resorption caused by the backward movement (double arrow).

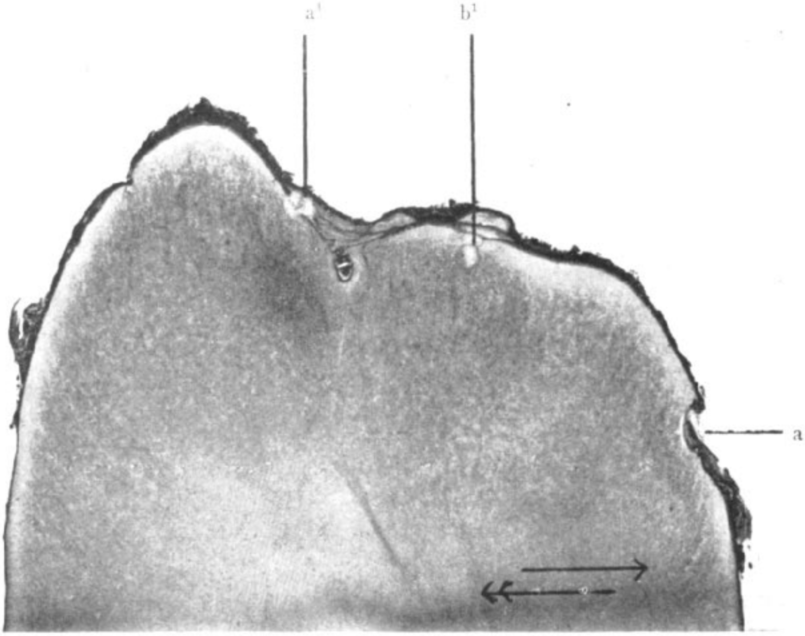
Because of the completeness of the series, a reconstruction model of this tooth has been made and is shown in Fig. 92.

Specimen XV. The relatively rare histological finding of a genuine root resorption is reproduced in Fig. 86, although the specimen, placed at my disposal, does not clearly give the single details, as the tooth had been preserved dry for many months. It deals with one of two lingually located central incisors which were inexpertly moved by the expansion arch labially and retained for some months by two soldered bands. After the removal of the bands, both teeth were so immensely loosened that one tooth had to be



Specimen XIV (Figs. 79 to 85) Figure 84
Magnification 7; a and a¹, resorptions caused by the primary movement (single arrow); by the backward movement (double arrow), the resorption b¹ was caused in the apical region; Dt, denticles.

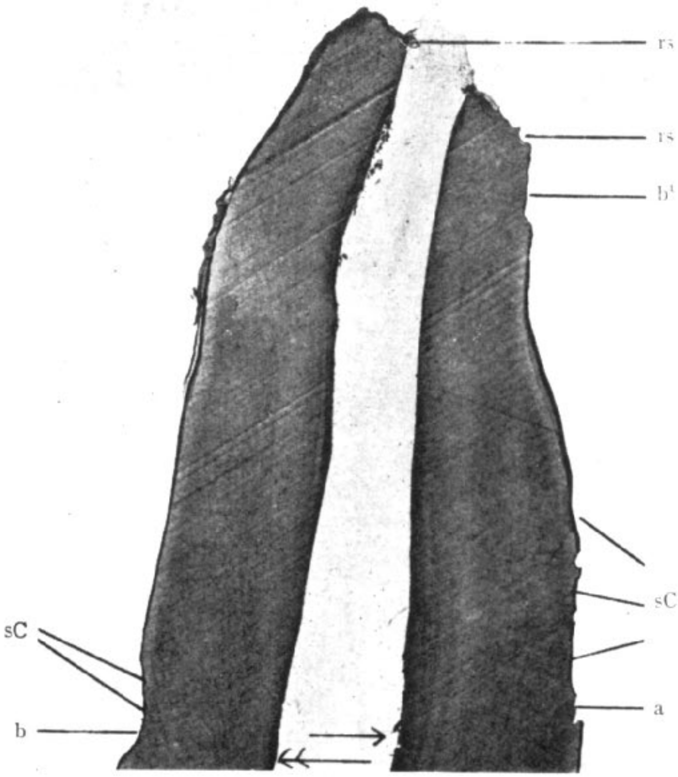
extracted immediately, and the second one, also, after some weeks. The X-ray picture showed intact conditions at the apex before the treatment. The root resorption, which opened widely the root canal, was therefore the result of the orthodontic treatment. The resorptions, (a, Fig. 86), were caused by the labial movement (single arrow). The corresponding resorption in the apex sphere is not visible in this slide. By the backward movement (double arrow), the cementumresorptions, b and b[1], were formed, the latter passing at X into the root resorption, (rs, Fig. 87). This was in the stage of repair, as can be concluded from the deposition of secondary cementum, (sC, Fig. 87). Further details, (apart from the visible secondary cementum formation in the resorptions, sC, Fig. 86), are, from above mentioned reason, not ascertainable. It may be only referred to as a pos-



Specimen XIV (Figs. 79 to 85) Figure 85
Magnification 8; a and a¹, resorptions resulting from the primary movement (single arrow), b¹, from the backward movement (double arrow).

sibility that cementumresorptions can pass into genuine root resorptions, (X, Fig. 87), both of which, as already often pointed out, are, etiologically, strictly to be separated.

Specimen XVI. Even if not to be attributed to orthodontic movement, still another specimen may be demonstrated. This originates from a procedure which is frequently used in the daily practice, namely, the filling of cavities provisionally with Hillstopping, often with the intention of leaving such a filling for a long time, with the object of obtaining, by its gradual swelling, separation of the teeth, which sometimes amounts to one or more millimeters. This specimen deals with a lingually standing lower bicuspid in which caries had developed at the neck. Hillstopping was placed in the cleaned-out cavity and left in situ for three months. By this filling the

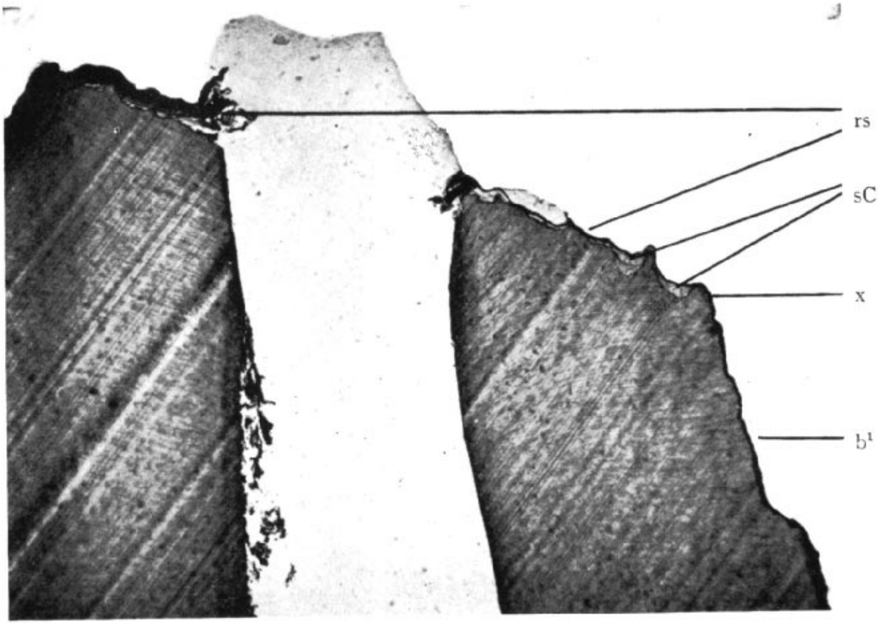


Specimen XV (Figs. 86 and 87) Figure 86
Genuine root resorption, rs; magnification 12; by the primary labial movement (single arrow) the cementum-resorption, a, was caused; by the backward movement (double arrow) were caused the cementum-resorptions, b and b[1]; sC, secondary cementum.

bicuspid was pushed to the lingual. Technical difficulties in placing the permanent filling were the cause of preferring extraction rather than the insertion of a defective filling. The specimen was placed at my disposal and the histologic examination showed a fully repaired cementumresorption on the lingual pressure side, which is seen in Fig. 88 and magnified in Fig. 89. Even a movement taking place apparently at such a slow rate had caused damage to the cementum.

Reconstruction Models

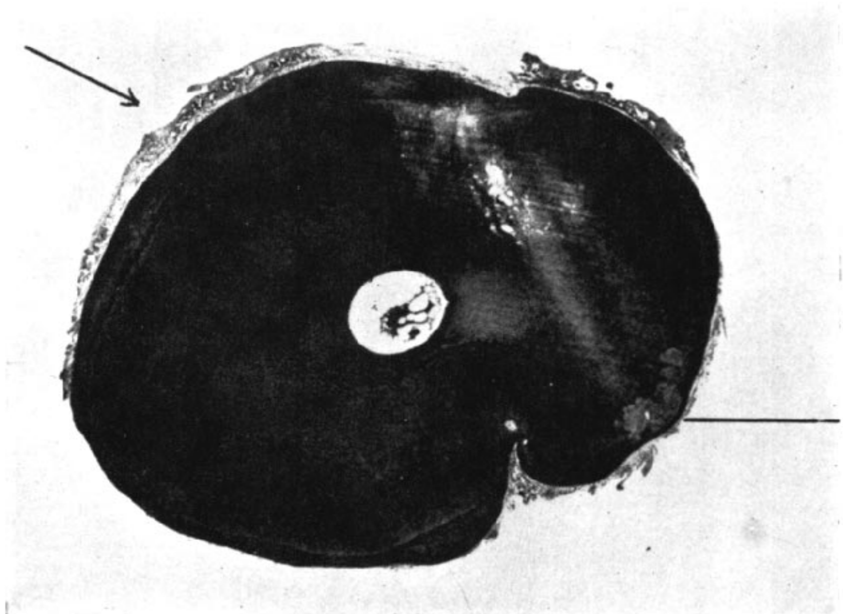
In order to rejoin to a plastic whole the various surface pictures, which change in the single microscopic slides, and to gain by it a clear and substantial idea of all that happened on the root surface, three cases were reconstructed after the method of G. Born[1], viz., Specimen VI, where the movement of the tooth was carried out by arch and ligatures; Specimen IX,



Specimen XV (Figs. 86 and 87) Figure 87
Point rs of Fig 85; magnification 40; b[1]; cementum-resorption passing into the root-resorption at X; sC, secondary cementum.

where the continuous force of the spring was set in action; and Specimen XIV, where the tooth, after a treatment of one and one-half years with expansion arch and ligatures, was extracted.

For the purpose of reconstruction, the slides in the present sequence are projected onto a sheet of paper in the darkroom by means of a mirror adapted to the ocular of the microscope, and the outer contours traced. The successively numbered paper sheets are covered with an even wax layer, corresponding, as to thickness, to the chosen magnification.** The wax plates are cut out according to the marked outlines, arranged in the correct serial order, one on top of the other, and waxed together with a hot knife along the borders and fixed by numerous pins pushed into the wax, preventing in such a way a shifting of the plates. After having smoothed the surface and borders of the model, this is rubbed with a piece of cloth wet with benzine and dipped in graphite powder to render the model current-conductible. It is then placed, for one or two days (according to the in-



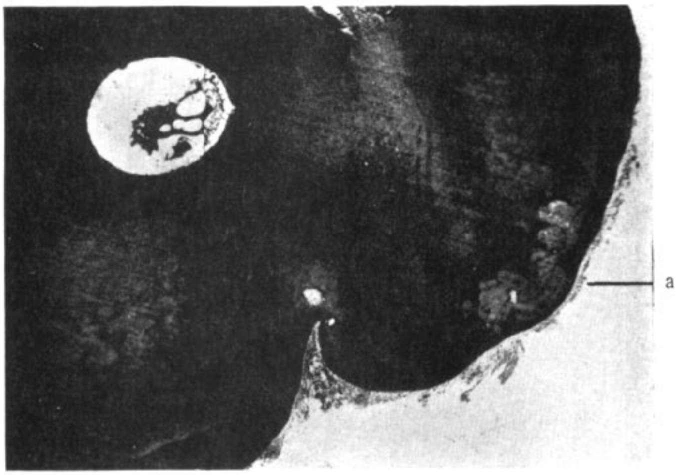
Specimen XVI (Figs. 88 and 89) Figure 88
Magnification 20; resorption of cementum, a, some distance below the crown, caused by separation of teeth by a Hillstopping filling; direction of movement of the tooth-crown is shown by the arrow.

tensity of the current power and concentration of the galvanizing liquid) in the copper bath whereupon a cover of copper ½ to ¾ mm. thick is deposited.

**To gain a model true to nature, the wax plates must be exactly so many times thicker than the microscopic slide than the chosen magnification of the microscopic picture. If, for instance, the microscopic slide is 0.02 mm. thick and the chosen magnification for the reproduction is 30-fold, the thickness of the wax-plate must be 0.02 x 30=0.6 mm. If only every second slide is marked out, as in our case, the thickness of the wax-plate must amount to 0.02 x 30 x 2 or 1.2 mm.

The accuracy of the model depends on the impeccable quality and completeness of the series.

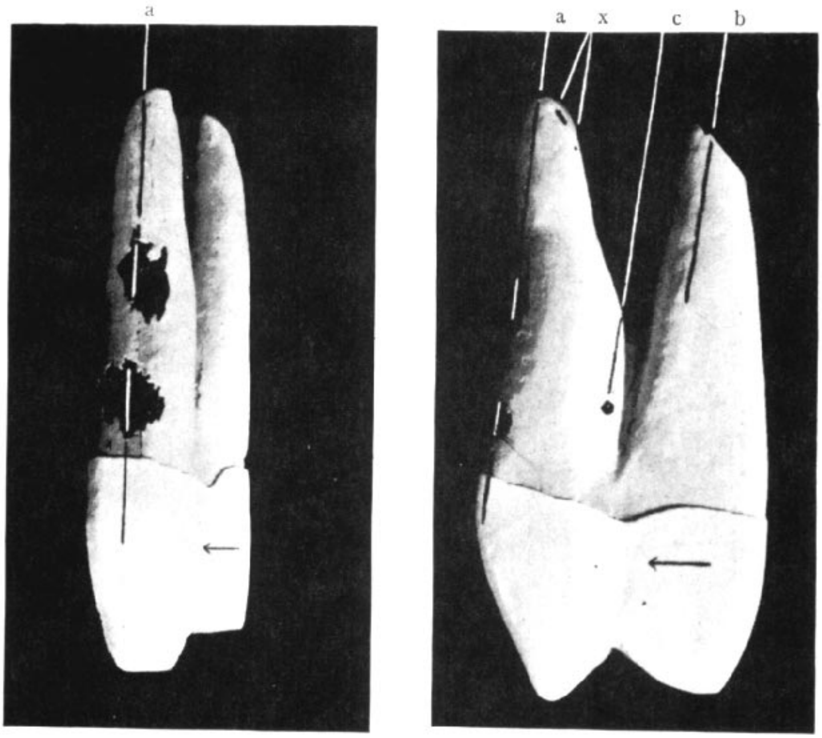
In Fig. 90, I, we see the buccal side and in Fig. 90, II, the distal approximal surface of the upper left bicuspid, (Specimen VI, Fig. 23), which in intervals of seven to fourteen days, by means of arch and ligature, was moved buccally in the direction of the arrow. Corresponding is the localization of the two large cementumresorptions. The lower resorption reaches deeper into the dentin than the upper one, as it is to be seen in Fig. 90, II. The resorbed areas are quite irregularly bordered and exhibit, as one sees in the course of the series and on the original reconstruction model, a



Specimen XVI (Figs. 88 and 89) Figure 89
Point "a" of Fig. 88; magnification 40.

hill-like ground-surface, depending upon the sometimes flat and sometimes deeper reaching resorption. Section a, in Fig. 90, I, and Fig. 90, II, respectively, corresponds to the slide, Fig. 23, of this work. The smaller visible resorptions x, in Fig. 90, II, were not reproduced as microscopic slides. The other root end is partly lacking. To the section b, Fig. 90, II, the just slightly indicated loss of substances at the artificial sloping of the root-end corresponds the microscopic slide d, Fig. 23, and also Fig. 26, in higher magnification. The visible resorption c, Fig. 90, II, which also has not been reproduced as a microscopic slide, was brought about by the occasional renewal of force or a change of ligature, which produced a deviation of the buccal force-direction to distal.

Model II. The reconstruction models shown in Fig. 91 correspond to Specimen IX, the lower left bicuspid which, by means of a spring, was moved lingually. The view is from mesio-lingual (I) and from mesio-buccal (II). The not extensive but deep resorption, near the alveolar crest and produced by the active lingual movement (single arrow), is shown in Fig. 91), I, section a, and corresponds to the histologic slide, Fig. 40. The visible cementum isle, (nC, Fig. 40), which interrupts the resorption, is also dis-



I II

Fig. 90. Reconstruction model of Specimen VI, corresponding to Figs. 23 and 25. Direct movement is indicated by the arrow; I view from buccal; II view from the approximal surface. For details see the text.

tinctly to be seen in Fig. 91, I, nC. The resorptions on the opposite apex-end are indicated at x, Fig. 91, I, and shown in full extension at x, Fig. 91, II. They are surface-like, much extended, and, in only one place, greatly deepened. This place lies in the section a, Fig. 92, II, and corresponds nearly to the point y. In this section we observe a small, uppermost and a great, middle resorption which is followed by a great stretch of intact cementum, until finally the lowest, third, resorption appears. To this section a, Fig. 91, II, corresponds the histological slide, Fig. 45. To the point y, Fig. 91, II, which penetrates the deepest into the dentin, corresponds the histologic slide, Fig. 46. Toward the crown, the histologic slides at this place show normal cementum, for, as it is to be seen in Fig. 91, II, the

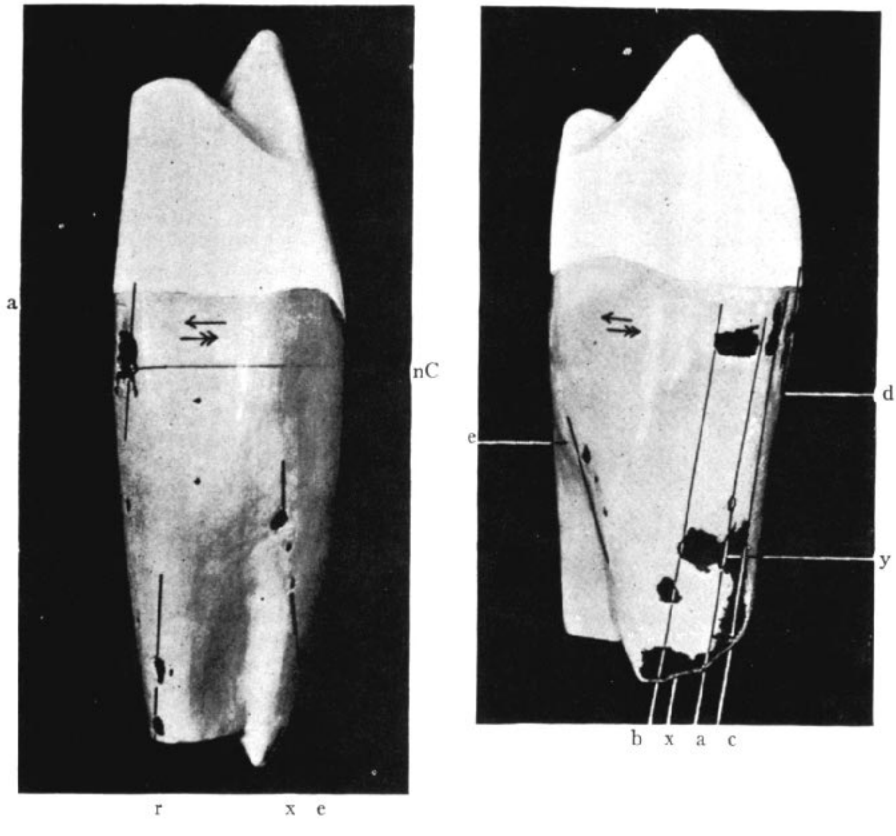


Fig. 91. Reconstruction model of specimen IX; direction of active lingual movement is indicated by the single arrow; direction of relapse movement by the double arrow; I view from mesiolingual; II view from mesiobuccal. For retails see the text.

section "a" passes between two large resorptions. The section b, Fig. 92, II, corresponds to the histological slide, Fig. 47, where the topmost of the four present resorptions is just still being met, (b, Fig. 47). To the section c, Fig. 91, II, corresponds the histologic slides, Fig. 42 and Fig. 43, re-

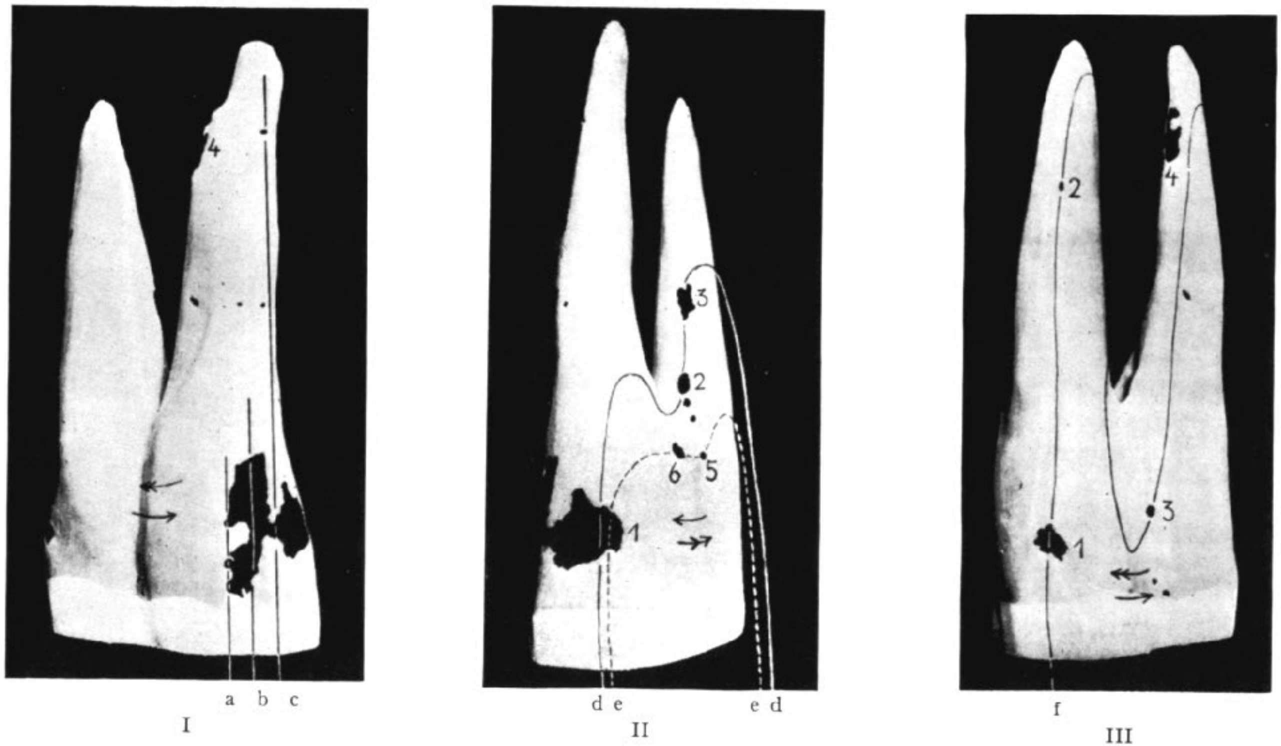


Fig. 92. Reconstruction model of specimen XIV. Direction of active movement is indicated by the single arrow; direction of relapse movement by the double arrow; I, view from buccodistal; II, view from buccomesial; III, view from distal. For details see the text.

spectively. The small visible resorption at b, Fig. 42, has become visible by just cutting the middle of the three resorptions situated side-by-side. To the lower part of the substance-loss, shown in section c, corresponds the large repaired resorption shown in Fig. 43. To section d, Fig. 91, II, corresponds the histological slide, Fig. 41, where the resorption produced by the relapse movement (double arrow), is shown on the labial side. The two resorptions on the apex, produced by this relapse movement, are shown in section r, Fig. 91, I, and correspond to the histological picture b[1], Fig. 42 and Fig. 44, respectively. The three resorptions situated already more in the root bi-

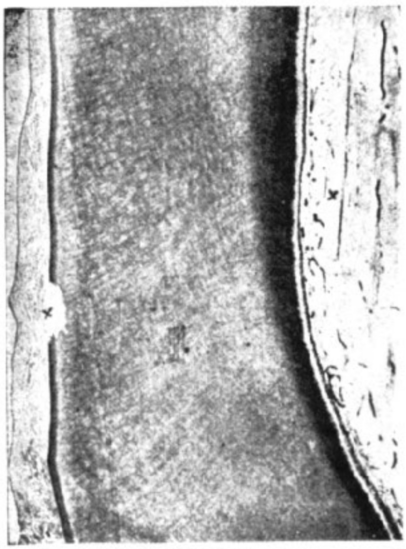


Fig. 93 (= Fig. 20 of G. Fischer)

furcation, section c, Fig. 91, I, appear also in section e, Fig. 91, II, and correspond to the histologic slide, Fig. 48. These and also some smaller and larger resorptions on the approximal surfaces must be attributed to a deviation of force. Still further visible resorptions on this reconstruction model are not discussed because the corresponding histologic pictures were not reproduced.

Model III. This is made from the upper premolar, treated one and one-half years with the expansion arch (Specimen XIV) and shown in Fig. 92.

The two reconstruction models first shown, correspond, in their reproduction, to the direct observation of the microscopic sections, as they (in following the course of the series) were always pursued in the microscope from the same side. Thus Specimen VI, to which the reconstruction model, Fig. 90, corresponds, has been cut from the distal approximal surface in a bucco-lingual direction. The tooth is fixed to the supporting base on its mesial approximal surface, which was damaged at the extraction and therefore could not be studied in the histological series. Specimen IX, to which the reconstruction model, Fig. 91, corresponds, was cut from the mesial approximal surface, in a bucco-lingual direction, toward the distal approximal surface. The specimen is fixed to the base on this surface for the same reasons as stated for model, Fig. 90. Photographic reproduction of the model and observation of the microscopic slides followed, therefore, in the same direction.

With the third model the facts are different. The photographic reproduction of this tooth was made from distal and mesial, Fig. 92, while the microscopic slides were always observed from the distal, for the tooth, Specimen XIV, was cut from the distal approximal surface, in a bucco-lingual direction, toward the mesial approximal surface, which remained undamaged at the extraction. Consequently, in the second half of the series, cut from the center toward the mesial approximal surface, the microscopic pictures, in relation to the photograph reproduction of the model from mesial, must appear as mirror-images (reversed).

Section a, in Fig. 92, I, corresponds to the histologic specimens, Fig. 79 and Fig. 80. This shows the three terminations of the great resorption, which were just cut in this section. Section b, Fig. 92, I, corresponds to the great resorption in the microscopic slides, Figs. 81 and 82.

Section c, Fig. 92, I, corresponds to the microscopic slide, Fig. 83. The section goes through the isthmus between the two parts of the great resorption, a, Fig. 83, and meets the small apical resorption on the buccal root, b^1, Fig. 83, that was produced by the backward movement (double arrow).

Section d, Fig. 92, II, corresponds to microscopic slide, Fig. 84. The model is looked at from mesial, the microscopic slide from distal. Therefore it is like a mirror-image. 1, Fig. 92, II, corresponds to a, Fig. 84. 2, Fig. 92, II, corresponds to a^1, Fig. 84; 3, Fig. 92, II, corresponds to b^1, Fig. 84, which was created during the backward movement.

Section e, Fig. 92, II, corresponds to Fig. 85, which microscopic slide is already near the end of the series. 1, Fig. 92, II, corresponds to a, Fig. 85; 6, Fig. 92, II, corresponds to b^1, Fig. 85; 5, Fig. 92, II, corresponds to a^1, Fig. 85. 6 and 5 are to be attributed, probably, to a deviation of the force to the mesial.

The two visible small resorptions between 2 and 5, (Fig. 92, II), are not shown as microscopic pictures and may have been produced by the primary movement or by a deviation of the force to the mesial.

Section f, Fig. 92, III, corresponds to Fig. 81. The views of both the model and the microscopic slide are from the distal and therefore there is harmony in the sides. 1, Fig. 92, III, corresponds to b, Fig. 81, and was caused by a backward movement (double arrow). 2, Fig. 92, III, corresponds to a^1, Fig. 81. 3, Fig. 92, III, corresponds to bi, Fig. 81.

The three visible small resorptions on the distal side, Fig. 92, III, were caused by a deviation of the force to the distal.

4, Fig. 92, III, also visible at 4, Fig. 92, I, was caused by the primary movement (single arrow), and corresponds to a^1, Fig. 83.

Summary

The description of single details occurring in the course of orthodontic movements in man does not by any means exhaust the possible variety of changes that can and must take place as a result of very different local, external and above all, constitutional influences. All of these possibilities or influences must be taken into consideration in further investigation of a large amount of material. Much is still left to study, to verify or to refuse. This means a long and difficult way and is explained already by the fact that, where life is active, one cannot always expect the same results even in apparently the same procedures. Rather must we agree with A. Keith* that "as long as man remains an inquiring animal, there can never be a complete unanimity in our fundamental beliefs."

The fact that orthodontic procedure is *always* equivalent to a trauma was hitherto never enunciated by any experimentally working author. Now any traumatic damage means a disturbance of normal metabolism, for the crushed tissues, the necroses and hemorrhages, which, always present, show only graded differences, must, as dead tissues, always be eliminated. This can only be accomplished under the phenomena of inflammation.

This inflammation is the morphologic reason for the clinical picture of the sensitiveness of orthodontically moved teeth, which clinical picture frequently may be intensified to a real soreness—even to a periodontitis.

The primary traumatic lesion of the periodontium has, without exception, its effect in bone and cementum. These three tissues constitute an inseparable unit from which, in further consequence, the pulp, also, cannot

*Quoted after A. F. Jackson, I. J. Orth. 1934, p. 477.

be eliminated. As already mentioned in the beginning, we cannot, as far as conciseness and intactness are concerned, apply the same standard in obtaining the material from man as governs that derived from animals, whereby whole parts of the jaw may be preserved for further studies. Marschall's[37] claim that, for correct judgment of the conditions on the side of pressure, the side of traction must also be present in the slide or vice versa, or that, for the same reason, both adjoining teeth must be present, is not even necessary in specimens of animals, and does not come into consideration at all with human material, for reasons quite easily understood. The neighboring teeth would perhaps be necessary, if it was the task of a special investigation to ascertain the degree of co-movement of these teeth and the changes brought about thereby. We had, therefore, only single teeth at our disposal, and, also, as far as it was possible, with the utmost consideration of the patient, the surrounding bone.

Now we will first summarize, clearly arranged, the morphologic findings of the investigation at hand.

Bone

The bone in man reacts to increased pressure the same as the bone of animals, with resorption. Thereby room is created for the movement of the tooth. This resorption of bone, performed by the activity of the osteoclasts, is always, without any exception, the most advanced at the alveolar margin and gradually causes an irregular diminution in height in proportion to the degree of intensity of the force and the duration of its action. The alveolar border does not disappear in a circular regularity but preserves, here and there, its original height. This depends on the change in the direction of the force.

The morphologic indication of the actual lowering of the alveolar border is shown by the fact that it does not reach the upper or lower border of the cementumresorption which has arisen on the corresponding tooth surface, but terminates within, above or below this cementumresorption, depending upon whether we have to deal with an upper or lower tooth.

According to the length of time that has elapsed between the last renewal of force and the extraction, we find in the bone and especially in the alveolar border, the same as in all other tissues, signs of a more or less advanced regeneration, also. The osteoclasts have disappeared and the lacunae are filled up and smoothed off by the deposition of osteoid bone through the activity of osteoblasts.

The same as in the specimens derived from animals, we find, also, in the human specimens that *the alveolar border*, in tilting as in bodily movement, *is always the seat of greatest destruction.* The statement made in our special literature that the alveolar border possesses a natural protection against resorption during tilting movements because of the peculiar form of the alveolus and the root (A. M. Schwarz, *Dental Items*, Feb., 1930), does not prove to be correct.

The observation, first made by the author on monkeys, that as a protective measure of nature against the thinning of the alveolar wall from the inside, bone is deposited on the outer wall (osteophyt), had been verified on dogs by Gottlieb-Orban[12]. This protective measure has developed in man only in a very slight degree, frequently only in the form of a single row of osteoblasts and often not at all. A real formation of osteophyts in the material at hand was found only in Specimen V, (Fig. 19), wherein the weakest intermittent forces were applied. Furthermore, in this case, the amount of periostal deposition does not correspond, approximately, to the resorption brought about by the activity of the periodontal tissue.

Let us remember the ground sections of Loos (I. J. Orth. 1934, p. 1073) and we will see that on the labial side, against which the teeth are moved, is found only a paper-thin wall of bone, which, toward the alveolar border, becomes razor-edged. Therefore it is not astonishing that this thin bony margin disappears under every influence that surpasses biologic force, and this occurs more quickly and surely if no osteophyts are formed. But such an eventuality must always be taken into account and our procedures governed accordingly.

The *formation of bone* during the periods of rest or after the completion of orthodontic treatment for the purpose of reducing the width of the periodontal space and to thereby stabilize the tooth, does not take place only in the form of a thin, more lightly colored layer of osteoid, but, where there is need for a considerable reduction of the periodontal width and where such a procedure would take too much time, the bone, in its entirety, is protruded in a convex-shaped form into the periodontal space, (obl, Fig. 13 and 15 or ost, Fig. 25). In places where the resorptions are not very extended but very deep, nature tries to attain, as quickly as possible, the same result by driving forward, into the hole, a bony spicule, (Fig. 46), into which the periodontal fibres are quickly inserted.

On the traction side, similar as in animals, we find, in order to reduce the width of the periodontal space, the formation of osteoid, following the traction of the periodontal fibres. This bone formation was described in monkeys as well as in dogs in the form of long stretched spicules, (Am. Orth. 1912, Fig. 6, p. 114; I. Journ. Orth. 1930, Fig. 6, p. 540 and Fig. 20,

p. 549), and in dogs also in the form of an even apposition of osteoid, (I. Journ. Orth. 1930, Figs. 13 and 17). We find both forms also in man. Thus we see in Specimen I, Fig. 1, Specimen II, Fig. 6, and in Specimen V, Fig. 20, in the use of gentle intermittent forces, the apposition of osteoid in the form of an evenly thick layer, which corresponds approximately to the extent of the performed movement. In the same manner this osteoid was built during the relapse movement, (Specimen VI, ost, Figs. 25 and 27; and Specimen IX, ost, Figs. 40 and 42).

In Specimen VII, Fig. 32, under the influence of continuous force, the osteoid on the traction side was built in the form of irregular spines, but in the intraradicular septum, which is not under the direct influence of the force, the osteoid was deposited again in an even thickness, (Specimen VII, Fig. 34).

In four specimens (III, IV, VIII and X) it is impossible to ascertain the relative formation, as the bone on the traction side is missing.

Therefore we have at our disposal only one case in which, under the influence of continuous force, the osteoid was built in spine-like shape. On the other hand, we have at our disposal three cases in which intermittent force was applied, (I, II, V), two cases of relapse movement, (self movement) (VI and IX), and one case of indirect force transmittance, (VII, intraradicular septum), which show the formation of osteoid in an *evenly thick layer*. Naturally it would go too far to draw conclusions from one case, but still the supposition is justified that in the use of gentle force, or during the movement of teeth by their own forces as when relapsing, or as a result from indirect force transmittance, the osteoid, following such slight traction, is formed in an *evenly thick layer*. On the other hand, in the use of strong forces, the periodontal fibres here and there loose their insertion in the bone or tooth, and hence cannot transmit an even traction to the bone for this is only possible when the insertion remains intact. In this way spine-like projections of osteoid are formed instead of evenly thick layers.

In the case of Herzberg[5] the osteoid, according to his Fig. 3, was built in the form of spines, which also justifies the assumption for this case that the continuous forces of the rubber ligatures were too strong to permit the formation of an even apposition of osteoid, for which assumption his control picture, Fig. 4, wherein the deposition of the osteoid was affected in an even, surface-like manner, also speaks.

In animals, also, we could ascertain two different kinds of osteoid formation. In monkeys and dogs, with the use of gentle, intermittent forces, the osteoid was formed in the shape of long-stretched spicules, but in dogs there was also an evenly thick apposition. On account of the existing differences in the reaction of the tissues in man and monkeys, comparisons may not be sound and still less so when making a comparison between dog and man. This is because of the quite different functional conditions under which the structural formation of the jawbone takes place (in man it is under the influence of a hinge joint, while in dogs it is under the influence of a ginglymus joint). Hence the bony changes brought about artificially cannot be identically under the influence of the same forces. If the traction is slow and especially intermittent, one does not find, as *Häupl* and *Adami* and *McCrae** could verify my statement,** a stretching of the fibres (this of course is impossible for they do not contain elastic fibres), but a thickening. In this manner they increase their capacity for resistance and sustain a further and sometimes, also, a greater load of tension.

These fibres of the connective tissue are, according to *Noyes,* "formed in response to mechanical conditions and stimuli . . . and not as having been designed to sustain the forces but as being the result of the forces to be sustained and therefore beautifully adapted to them," (quot. I. J. Orth. 1933, p. 575).

On account of the permanently existing physiologic self-motion of the teeth towards the mesial (Stein-Weinmann[21]), we never find real osteoid on the inner side of the distal alveolar wall, viz., on the side of traction, but on account of the very slow and, therefore, biologic character of movement, bundle-bone (Bündelknochen) is directly built there. Its thickness, which represents the extent of movement performed *within recent time,* (for the bundle bone is gradually substituted by lamellar bone from the distal), amounts to 1.5 mm. The formation of this kind of bone is naturally impossible with any kind of artificial movement, for this is too quickly performed and, up till now, it was not observed. In all specimens hitherto examined after orthodontic movement, if this movement had ever been performed biologically, bundle bone ought to have been formed on the traction side; *the absence of this formation is proof enough for the unbiology of our procedure.*

But by no means may we expect to find the same bone reaction even under quite similar outer conditions. "The manner of bone reaction is and remains the great unknown with which the orthodontist has to deal," (*Korkhaus* in Scheff Handbuch,[72] p. 584).

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*Quoted according to Box.[8]
**Am. Orthod. 1912, p. 131: "We find that the individual fibrilli gain in strength and number upon the stimulation of these fibres."

Cementum

The osteoid, formed on the side of pressure during the periods of rest, is considered by the *Gottlieb-School* as dangerous for the cementum, on account of its apparently greater resistance against resorption and, therefore, the intermittent form of tooth movement is discarded in favor of the continuous. With regard to these contentions, as not being right, I defined my position several times in the "Crisis of Orthodontia"; also in the I. J. Orth., 1934, p. 139-141. My arguments, there expressed, find their verification in the human specimens. As long as the physiologic conditions of pressure in the periodontal space are not exceeded in a pathologic way, so that by the diminishing of the vitality of the periodontal tissues the life processes in the cementum are altered, the cementum is not endangered by osteoid. During the relapse movement of the teeth to their original position (therefore without interference of any appliances), this movement is performed against osteoid, built during the primary movement and this osteoid was resorbed partly in its entirety, (Fig. 24), and partly in sections, (ost, Fig. 41), without showing the slightest damage to the cementum.

The conditions, are, as we have seen, entirely changed if appliances are used for movement, whereby the physiologic pressure conditions are inevitably *always* exceeded. Thereby it is proved that the cementum does not need the increased resistance of osteoid bone, in order to be changed by resorption. The resistance of the normal bone is sufficient to bring about (if the pressure is increased) resorptions even in the young cementum which is considered as specially resistant. We find in Fig. 88 the best proof for this and also a confirmation of my assumption that the human cementum is a very vulnerable tissue.

But there is no doubt that in the problem of cementum resorption, the constitution also plays an important part, (see remarks to Cases IV and X, p. 256, *Angle Orthodontist,* Vol. V, No. 4). The increased resistance of the cementum against resorption, in comparison to bone, is surely established in *biologic tooth movement,* as performed by nature. From this is explained: (1) The ever present intact cementum surface found in normal development notwithstanding the great change in the position of the teeth; (2) The intact cementum surfaces associated with the mesial movement of teeth constantly taking place throughout life (Stein-Weinmann[21]) and ascertained by histologic investigation; (3) the fact that the cementum remained uninjured during the self-movement of the teeth into their original position and that only the osteoid became resorbed, notwithstanding that this movement was directed against osteoid bone, (Fig. 24 and Fig. 41).

But such a biologic tooth movement can by no means be performed with the use of appliances. *There does not exist an artificial biologic tooth movement.* Consequently, the appearance of cementum resorptions in *all* spheres of increased pressure, created by our procedures, is an inevitable phenomenon. I can only repeat what was already said in the "Crisis of Orthodontia" (1. Journ. Orthod. 1934, p. 141): "However, the intermittency or the continuity of the force has nothing whatever to do with it (with the cementum resorption by the osteoid formed in the intervals). In both the methods it is the degree of force alone that is responsible for the cementum resorption, if the permissible compression of the periodontal membrane is exceeded."

The dispersed appearance of cementum resorptions on the root surface depends, as already mentioned, upon the change of the direction of force. The depth and the extension of the resorptions depend on the greatness of the force and the time of its action or on the possibility and frequency of the change of the force direction.*

Under the action of strong forces, to which, in contrast to the snail-like mode of the biologic self-movement the continuous working forces appertain, whole parts of the root, as we have seen, may be resorbed away (a^1, Fig. 50; a-b, Fig. 63), and the root wall penetrated, (Fig. 58).

As is the case in all other tissues, we cannot expect or hope for the same reaction in the cementum even under quite analogous outer conditions and it would be wrong, in order to obtain the most favorable effect, to give stereotyped rules for practice. We must always take into account the difference in the tissues in respect to readiness for reaction, the difference in the constitution of the individual and the chances in practice (which are dependent on outer moments and often make impossible not only an undisturbed event of the hoped-for tissue reaction but even an undisturbed course throughout the entire period of treatment). Therefore, we must *treat each case individually.* We are forced to depend upon the only reliable and dependable signs that are available to the practitioner, viz., that *the criterion for the best obtainable reactions, approaching nearest the biologic conditions, lies only in the firmness and insensibility of the moved teeth, as is the case during the self-movement of the teeth.*

The difference in the cementum reaction in similar movements is demonstrated by Specimens VII and XIII, where we find a reaction just opposite to the expected one. Judging from the microscopic findings we could

*In the use of the expansion arch (guidance by the ligature) the resorption in Specimen XIII has a width of 0.7 mm., while this width in Specimen XII (lingual arch) amounts to 1.7 mm.

assume in Specimen VII, (Fig. 33), as well as in Specimen XIII, (Fig. 78), that identically the same movement of the teeth took place. Yet, in the first case, the continuous force of a spring was used while in the latter case the intermittent force of the expansion arch was applied. Contrary to the findings, in all other specimens, the cementum in the use of the continuous force, (Fig. 33), remained uninjured and only the bone along the whole inside of the alveolar wall became resorbed under the influence of pressure. In the other specimen (Fig. 78), though much gentler forces were used, great portions of the cementum were resorbed. In respect to the bone conditions in this specimen nothing can be said, because the bone is lacking.

Gottlieb-Orban,[12] basing their investigations on dogs, came to the conclusion (p. 203) "That young teeth exhibit a great resistance towards resorption" notwithstanding the efforts of the animals to get rid of the inconvenience of caps upon their teeth, whereby thousands upon thousands of force actions were executed upon these capped teeth every day. Still believing that it was right and justifiable to transpose to man the results of the investigations on animals, and relying on the specimens from monkeys, where the cementum resorptions, even in the use of strong forces, did not penetrate into the dentin, (I. Journ. Orth. 1933, p. 1210, Fig. 11 and I. Journ. Orth. 1934, p. 23. Fig. 20), I supposed analogically also for man that the damages on the root substance would not be very severe. Consequently, I said (Z. Stom. 1933, p. 472): "how much less then will be the possibility of creating cementumresorptions, if our orthodontic forces, as is really the case in man, are so seldom renewed."

The whole controversy in this matter in the "Crisis of Orthodontia," (Int. Journ. Orth. 1934, p. 138-140), based upon the results of experiments on animals, as well as the conclusions of other authors, also founded on the same basis, cannot be considered as correct today. Especially is this true of the statement of *Gottlieb-Orban* that only the greater resistance of the cementum in comparison to bone makes orthodontic tooth movement at all possible.

Contrasted with this opinion is the statement of *Bauer,*[74] confirmed by *Häupl,*[17] p. 488 and verified *on human material,* "that there does not exist a fundamental difference between bone and cementum in their mode of action in apposition and resorption."

All authors who up to now have examined human material have ascertained the presence of cementum resorptions, ***although the universality of this appearance had not been recognized or emphasized.*** Kogure,[9] for instance, states, (p. 251), "that on the root surface of orthodontically moved teeth . . . in the most instances were found lacunae of resorption." Grubrich[3]

(p. 160), "could ascertain lacunae of resorption in all the five treated cases"; *Gubler*[4] (p. 1092), "found, besides the root resorptions (at the apex), also resorptions on the root surface, which penetrated into the dentin." In one case, (in his Fig. 65), where resorptions were found buccally and lingually on the neck of the tooth, produced by its buccal and lingual tipping, this author comes to the conclusion (p. 1050), "that from the localization of the resorptions we are able to determine indubitably the direction of the force."

Also in the specimens of *Herzberg*[5] we find cementum resorption on the two points of pressure, brought about by the tilting movement. Fischer,[2] also, shows a case, orthodontically treated years ago, in which the signs of an old cementum resorption are to be seen, (Fig. 8, p. 29 of his book).

According to the opinion of several authors, there must not be attributed only a local importance to the cementum resorptions. Notwithstanding the complete filling in of the resorption with secondary cementum, *Euler-Mayer*[13] utterly doubts that a real restitutio ad integrum ever takes place. They say on p. 272: "the apposition first takes place by a second-rate cementum which is followed by an even lamellar apposition with the result that an interruption of the smooth root surface does not exist any more; in so far—but only in so far—exists a restitutio ad integrum."

According to Fischer[2] every injury of the intact cementum covering represents a remote irritation (p. 159) "which in the scope of the resorption of the dentin results in a distinct disturbance of the odontoblastic layer." This author demonstrates, (p. 138, Fig. 20), a case, reproduced in Fig. 93 of this work, which is described as follows: "intact canine, with minimum resorption within the scope of the lig. circulare; thirteen years old, removed on account of crowding. *In the scope of the resorption the odontablasts on the dentin are atrophied;* stasis of capillaries." If now already "the first damages of cementum and dentin of the root show distinct symptoms of reaction of the pulp" (Fischer, p. 143) how must the picture be if we have to deal with quite extended and deep resorptions labially, lingually and, with the deviation of force, also on the approximal root surfaces, or in cases where, as we have seen, the whole intra-radicular dentin was exposed, (Fig. 54).

From the material at hand it must be admitted that, on account of the general severe disturbances, a local reaction of the pulp by a cementum resorption that had penetrated into the dentin, could not be verified.

Based upon their investigations on dogs, *Gottlieb-Orban*[12] gained the conviction (p. 221) "that each resorption on the tooth must be regarded as an endangerment for the tooth" and that (p. 224) "tooth resorptions are, on the whole, incalculable."

These statements are fully verified by Fig. 70 of this work.

The cementum resorptions which only result from unusual pressure of the tooth against bone show, without exception, a great healing tendency, for, as soon as the cause is eliminated through the discontinuity of the force or the disappearance of bone, we see at once the picture of regeneration, the formation of secondary cementum. However, the traces of these lesions remain throughout life.

A concretion between cementum and bone, even where great cementum wounds were present, could not be ascertained, notwithstanding the fact that such concretions were reported by several authors in cases with much less cementum lesions of *traumatic* origin. (*Euler-Mayer,*[13] *Bauer,*[15] *Kronfeld,,*[18] *Köhler*[20] as.s.f.). In these cases, it must be admitted, we must take into consideration that the local damage caused by a severe, sudden trauma is quite limited and that, on account of the remaining complete vitality of the nearer and remote periodontal tissues, a quite intensive, even rapid restoration is established, producing sometimes hypercementosis. This may result in a quick apposition and union between bone and cementum.

In our cases, however, the periodontal tissue is severely damaged to a large extent and the regeneration, which is solely dependent (as far as rapidity and bulk of formation are considered) on the existing vitality of the periodontium, begins at a slow rate and occurs in an amount that is not sufficient for a concretion.

The periodontium, always traumatically changed by our procedures, eliminates the necrotic tissue by inflammation, as already mentioned. "With a periodontium inflammatorily changed and weakened in such a manner, the reparation is retarded on account of the thereby changed function, so that it may take place only in a deficient way" (*Bauer,*[15] p. 787).

Also the author[19] once has reported on the concretion of cementum and bone. According to these deductions "the eruption of the teeth does not take place continuously, but phases of eruption alternate with those of rest. During the latter stage, the resorbed parts of the root of the deciduous tooth and of the bone are repaired. During the phases of eruption concretions often take place between bone and cementum. The germ of the permanent tooth is the stimulus and this phase ends in a concretion if (not, as I said on that occasion, the tissues present are especially capable of reaction) the periodontium, on account of the vitality still remaining, is able to produce bone and secondary cementum."

Concretions of bone and cementum on roots remaining in the jaw, were also reported by *Gottlieb*[16] whereby the concretion took place in a state of absolute rest. The vitality of the periodontal membrane was also made responsible for this union. In such cases the periodontal membrane has not been modified, as in other places, into granulation tissue that expulses the root, but "has changed in the opposite direction, viz., has changed into cementoid. These procedures, which must be considered as protective measures, can go so far that here and there a union between tooth and bone takes place" (p. 11).

The cementum hypertrophy, also sometimes found in our cases, (Ex., Fig. 43), (which generally is provoked by some physiologic or pathologic stimulus from the neighborhood), is a functionally conditioned protective and reparative measure of nature's whose purpose is to reduce the periodontal width and is by no means a pathological condition.

It is a generally acknowledged fact that defects on the root surface (brought about by any reason) finally heal by apposition of secondary cementum. While some authors (*Euler-Mayer*[13]) report a complete filling up until there is an entire smoothing of the defects, which we could also ascertain in our specimen, (Fig. 43), there remains, according to others, a more or less deep impression, (*Kronfeld,*[18] Figs. 178-180). But, while, according to most of the authors, "the damaged root surface is restored to its normal functional properties," (*Kronfeld,*[18] p. 215), *Euler-Mayer*[13] admit only the anatomical fact but doubt the biologic equivalence of the apposed secondary cementum. (See page 34.)

In all cementum resorptions there could be ascertained, also, in the material at hand that, with the discontinuation of force, the reparative action of the cementoblasts sets in at once. However, in reference to the rapidity and the bulk of formation of secondary cementum, there could not be ascertained a uniform procedure. This is individually quite different and certainly depends, in addition to the vitality of the periodontium that exists after traumatic lesions (Bauer,[15] p. 787),* to a high degree, upon constitutional moments. Therefore it is also impossible, by referring to the process of formation of secondary cementum, to state definite periods for the reparatory processes in general or for the length of the period of retention, which, naturally, would have been of the highest interest and value.

Comparison of the secondary cementum that has formed in different cases during a certain period offers no help whatever in making any definite statement as to extent of the apposition that can be hoped for in a given period of time. While in Specimen II, Fig. 5, indications of secondary cementum could already be ascertained three days after the last application of force and in Specimen III, Fig. 8, secondary cementum became very distinct in appearance after seven days, yet in Specimen IV, Fig. 13, after

* See quotation of Bauer, p. 35.

nineteen days, it has scarcely developed stronger than that in Specimen III, (after seven days). And in Specimen V, Fig. 19, where the weakest of forces were used, with intervals of fourteen days between applications, the apposition is smaller than in Specimen III, Fig. 8, in which an interval of but seven days after the last application of force gave a chance for the reparation process.

In Specimen VI, Fig. 25, where seven weeks were allowed for the tooth to return to the original position, we find a far advanced apposition of secondary cementum indeed, but no filling up of defects whatever; and in Specimen IX, Figs. 40 and 41, where, for about seven and a half months no new force had been applied, the secondary cementum apposition in the resorptions located on the alveolar crest had progressed scarcely more than in Specimen IV, Fig. 13, (nineteen days) whereas the large resorption at the apex, Fig. 43, has repaired perfectly and is at the same level with the original root surface, and even had accomplished a hypercementosed apposition. (Ex and s Ce, Fig. 43.)

We have no help to ascertain, in vivo, the existing degree of apposition of secondary cementum, for it cannot be accurately determined, even with X-rays, not even if the loss of substance, like with *Rehak*,[67] is lying on the approximal surfaces of the teeth. (On the buccal and lingual surfaces the resorptions are not at all ascertainable by X-rays.)

Consequently, we find, individually, quite different stages of repair on the cementum, not corresponding to the unequal intervals of time. So it is also true, in this problem, that *every case must be judged individually,* just the same as there cannot be universally valid rules and formula for active treatment, as to the amount of force, and no generally valid rate of movement such as 1 mm. per month, which has been pointed out as biologic and demanded for the active movement, (*A. M. Schwarz*). The same generally valid assumptions for the reparatoric processes cannot exist.

It was not possible, for the purpose of comparison, to follow the rebuilding processes in the bone in a similar manner as in the cementum, because the essential places for judgment often were not present in the specimens—a deficiency, as was mentioned introductorily, cannot be avoided on human material.

The statement of *Marshall*[37] that the temporal course of certain vital processes in monkeys corresponds to a period in man that is five times as long and concerning which I said (Int. Journ. Orth. 1934, p. 639), "that if by examination it will prove correct, it would be the solution of the temporal retention problem," has meanwhile been revised* by myself with a negative result.

So, for the present, we have no other alternative than vague and undefined statements. We do not possess a sound foundation upon which to build our measures and decisions. Consequently, what I have said concerning the retention period also must still be maintained (Int. Journ. Orth. 1934, p. 639): "the time of retention is just as individually different as the time of active movement and as the forces necessary for individual cases; the age, constitution, race, type of anomaly, time of active treatment, kind of appliances used, will have to be considered."

(*To be continued*)

* Based on the existing literature which was rendered accessible to me by *S. Fickerman*, Oxford, one of the most prominent living authorities in the scientific study of monkeys (and to whom, on this occasion, I extend thanks for his courtesy). I could ascertain, that none of the most characteristic manifestations of life (average duration of life, puberty, duration of pregnancy) do not even show approximately the same relationship between monkey and man. It is, therefore, astonishing that this strict relationship of 5 should exist alone for the teeth and jaws. Therefore, Marshall alone is responsible for the correctness of his statements.