VOL. V NO. 3

The Angle Orthodontist

A magazine established by the co-workers of Edward H. Angle, in his memory . . . .

Biologic Orthodontic Therapy and Reality

A Theoretical and Practical Treatise

PROF. DR. ALBIN OPPENHEIM
Vienna, Austria

(*Dedicated to my Friend and Teacher,* EDWARD HARTLEY ANGLE)

Preface

The scanty reports now existing in the literature, dealing with the changes in human tissues under orthodontic influence, have been the cause for further research by the author on a wider basis. This research proved the irrefutable fact that there is no biologic orthodontic therapy. The possibility that biologic treatment could only be effected through the use of the lingual arch appliance, which has been claimed as a fact, has been found to be a fallacy. Based on the statistics of Ketcham, it was, as we will see, built upon false premises. The results of histological researches in human material which we had at our diposal up to now, were not sufficiently convincing to stand as a basis for binding conclusions.

The conviction of the author that there are no general rules and figures, either for the active time of treatment or for the retention period, based until now on practical experience, received scientific confirmation by the deductions derived from this human material. This shows that there can only be individual judgment in treatment. Painlessness and firmness of the teeth are the sole criteria for judging that no severe damages are being effected. The clinical evidence of tissue damage is expressed in pain and in loosening of the teeth.

In their reaction to outer influences, the tissues of the paradontium must stand a certain degree of alteration without showing pronounced clinical symptoms. If this were not true it would not be possible to explain how the pathological pictures that are found as a result of the influence of even the "weakness" of forces, could be evolved without clinical symptoms.

In spite of the fact that orthodontic treatment has often proved to be a successful disciplinarian in the hands of the author, yet a more pessimistic attitude, in general, is now prevailing against this specialty. Because of this fact the author has tried to establish confidence in the success of treatment by stating some methods which have proved reliable within the last years and by opposing those methods which have not been successful after years of testing. The author is by no means a reactionary who actively resists every innovation or reform. On the contrary, he was and will always be approachable to such suggestions and will examine them in a conscientious way. However, the deductions evolved from this human material have fully supported his disapproval of the lingual arch appliance, a conclusion that seemed justified a long time ago because of his experiences when using this device in practice.

The author is well aware of the fact that he will meet with opposition, but the opponents will only find recognition if their arguments are not based upon mere words but rather on strict proofs, which hitherto, for the most part, has not been the case. The author is striving "to break a lance" for an "old-fashioned" orthodontic therapy,—one with which it is possible not only to report relatively good successes but also to actually demonstrate them.

It is beyond the power of a single individual, basing his deductions on the present amount of material, to fully corroborate, on a sufficiently broad practical basis, the value of the several suggested new methods of therapy. These methods can become authoritative only by added experience. Hence the problem demands the attention of many specialists interested in our particular methods. Therefore I invite the co-operation of all colleagues in our profession and, above all, general practitioners of dentistry because the latter group will see these treated cases in future years.

Which methods will finally succeed depends upon the reports of true facts, the result of observations over many years, especially by general practitioners, who have the opportunity to observe the cases which we have once treated.

This work should only direct general attention to the fact that certain unavoidable damages are bound to occur by our operations. Our foremost task is to heal. If we succeed in doing this, it is of no great importance by what means or in what way we attain our results. *Truth, however, must find the way clear.*

I wish to express my thanks to Assistant Dr. A. Biro for his valuable clinical co-operation; to Drs. Sternschuss, Molnar, Petrik, Schönbaum, for some specimens and models; and to Dr. O. Novotny, Assistant of the I Anatomical Institute in Vienna, for the valuable advice and active help received in making the reproduction-models.

Vienna, July 1935 ALBIN OPPENHEIM

Theoretical Section

Changes in the tissues effected by orthodontic measures conducted in the form of experiments on animals, have already been reported several times. From the results of these experiments conclusions were applied to human beings without any restrictions being placed upon procedures in practice. Human material has also been the object of investigation by different authors and their deductions proved similar or even identical, in many respects, to the results of experiments on animals. It was generally accepted that inferences from animals to human beings were permissible. To determine whether or not this can be sustained in the future is the purpose of this essay. Another object of my recently completed investigations was to follow the general challenge put forth by me in one of my works,[10] viz., "that it is one of the next tasks of orthodontic investigation to prove whether or not the lingual arch is really the only existing biologically working orthodontic appliance."

It goes without saying that we cannot apply the same methods in obtaining the material from man as are used in gaining it from animals. To procure the material in question we proceeded with the utmost care yet very often large portions of the root and the apex are not covered with or imbedded in the surrounding bone.

Some slides procured in this work are not entirely satisfactory, yet they will be published, for, even though they do not show every detail, still they reflect the aim of the project. The details of these pictures may be followed distinctly in the microscope but they have lost some clearness in the photography and reproduction.

The material now at our disposal opens the discussion of many pending questions, for it permits a clearer insight into the real tissue reactions, far more so than the experiments made upon animals. This new material could not help influencing the author's attitude toward some questions of principle as well as the interpretation of several previous statements.

The existent anatomical similarity in monkeys and man has not fulfilled the expectation of duplicate results under similar external conditions, now that a greater amount of material has been examined. Even if, on the whole, a congruity in the reaction of the bone was found, there still were ascertained so divergent findings in quite essential points, that it is henceforth impossible to make strict conclusions from monkeys—not to mention other animals—to man. A great deal that proved correct for animals will continue to be right, but cannot be maintained in transference to man, because the human tissues, as we will see, in their reaction to outer influences hold an exclusive position. Some changes in animals, always constant and considered as characteristic, are not found at all in man or only in a very moderate degree. Some characteristic reactions which in man were always found under certain conditions, have never been observed up to now in animals.

Therefore the directions for treatment, formerly given, must receive a corresponding analysis, though it has not been possible up to now to make such a study complete. However, anticipating the conclusions, the chief postulation still remains valid, viz., that *only the weakest elastic forces intermittently applied and interrupted by longer or shorter intervals of rest, are now permissible in practice.*

A full understanding of the many changes in the teeth can only be gained by the examination of the whole consecutive series of slides. But these cannot be published in their entirety. On the other hand, one cannot obtain from single slides of sections centrally located, a proper understanding of the structural changes which occur on the entire surface of the root and in the surrounding bone. As the reactions to our measures, even from supposedly centrally directed force, though only slightly deviated, do not appear alone centrally, but also in corresponding lateral parts of the root, central slides are not the only important ones. Such central slides, which go through the middle of the tooth and pulp, and which are generally considered authoritative, often do not show the severe changes which occur at the periphery and vice versa.

Therefore, without special consideration of the position of the cut, Schmittlinie, the most striking changes must be shown from several slides which illustrate, kaleidoscopically, the results of our proceedings.

On all of the teeth which were examined, the orthodontic treatment, preceding the extraction, was conducted in the usual way, so that actually such changes were brought about as really are attained by the orthodontic treatment of otherwise healthy patients from ten to sixteen years of age.

In my treatise, "Ueber Wurzelresorption bei Orthodontischen Massnahmen,"[10] I opposed the procedure outlined in *Ketcham's* proposition, which directs that "the teeth before they are extracted may be moved with orthodontic appliances and . . . removed if possible with some of the surrounding bone . . . and should be sent to Dr. J. A. Marshall. This method costs less than monkeys." (I.J.Orth. April, 1929, p. 328.) I opposed this method because stress was placed on the economy of such a procedure. My methods, which correspond entirely *Ketcham's* proposition, were justified by quite different motives. The patients were—and this I want strictly to point out—not used as rabbits for experimental purposes. I was governed by an endeavor to ascertain the changes brought about under certain definite conditions, so that the indications for the extractions were guided chiefly by three motives:—

(1) To re-examine the work of other authors who have experimented with extraction, and who have reported favorable results in literature and always praised this method although having no experience whatever in this kind of therapy.

(2) Because of the viewpoints of A. Bichlmayer* and E. Herbst** according to which authors the removal of bone in the direction of movement brings several advantages over the simple extraction.

(3) Chiefly because various extraneous factors became imperative (economical conditions, professional duties, living far remote) and urgently demanded a simplifying of procedures so that there could be a corresponding reduction of fees by taking up less of the orthodontist's time.

The operation itself, viz., the removal of the tooth with the surrounding bone, is not highly pretentious, either to the physician or to the patient, and it is, in any case, much less harmful than the gingivotomy and septotomy, proposed by Skogsberg[31] as the method of securing the best results,*** and performed on several teeth, after the orthodontic intervention, which are in close relationship to one another. Endangering the root, often unavoidable by such methods, is not to be feared in our procedure, for, in order to spare the neighboring teeth, the bone was always dissected away with fine fissure burs kept in close contact with the tooth that had to be removed. In this way the proximal surfaces of the extracted teeth often were injured and even partly removed, so that they are frequently not present in the slides.

As the extraction of single teeth was decided on, they were orthodontically moved in different ways before their removal and with different appliances, in order not to miss an opportunity to study the changes occurring in man.

*(letter Nov. 6, 1933) Supplement to the publication of this author in Z.F.Z. Orthopädie 1930, p. 117, and 1931, p. 59: "On the teeth treated chirurgically I have never observed a resorption of the root end as you describe (cut off as with a razor), in my opinion for the reason that the movement of the tooth to its future location is facilitated by this osteotomy . . . In upper protrusion I had best success with palatal excision of bone."

**Fortschr. d. Zhkd. 1933, p. 835: . . . (to make easy the procedure) "It would be advisable to make a groove in the bone, by which as much bone is removed as seems necessary to accommodate the root (of the tooth) . . . to perform the regulation without such a surgical procedure, would be so far protracted, that it could, under certain circumstances, be called a failure."

***In one case, 19 septotomies were performed (I J.Orth. 1932, p. 1051, Case 8).

Nearly all cases in which the extraction was performed were cases in which, by the forward movement of the buccal teeth, the space between *2/2* and *5/5* was reduced or entirely closed, the canine being in a high labial position. In order to equalize the circumference of the jaws, in some cases single teeth were also extracted in the lower jaw.

The teeth which were examined were moved by different appliances,— by the ordinary Angle expansion arch of a very elastic gold-platinum alloy, 0.80 mm. thick; by a straight spring soldered to the expansion arch; by a spring on a lingual arch, not secured in its position; by a closed loop spring. Some teeth were allowed to relapse more or less to their original positions; others, again, were rigidly retained for a certain time in their newly gained positions and, after the removal of the retaining appliance, left alone for several weeks or months. Four teeth, still lacking space, were extracted and examined after being treated two years. Two of these were treated with the lingual arch appliance and the other two with the expansion arch.

I state in express terms that I was not able, in spite of several trials, to test the method used by *Mershon* personally and recommended as alone correct, viz., to leave the spring, once adjusted, in an unaltered condition for months, so that it may act only as a stimulation for growth.* This was due to the fact that I was not successful in having a spring remain unbent or unbroken for such a long interval; the spring slipped off from its original place, became deeply embedded into the gum, impinging somewhere against the root, consequently it had to be rebent, or, if broken, renewed and readjusted.

The findings at hand are brought about by springs which, being readjusted at shorter intervals, certainly show more severe tissue reactions than there would have been if I could have used the original *Mershon* method. Therefore the slides, in the majority of instances, would have probably shown stages of reparation, for the spring, lying unaltered for so long a time, represents a retaining appliance for the active movement which is performed in a relatively short time even when using the *Mershon* method. This concedes also the following statement of *Mershon*: "It is more than likely that we bring about the change in the position of the teeth far more rapidly than the changes take place in the correlated tissues."

The rate of movement of the teeth obtained for investigation was conformable to the method generally used by the author. For reasons, explained already in I.J.Orth., 1934, p. 251-252, I desisted principally from a certain dosage of the forces used, which in certain limits are believed to bring about biological effects because I was convinced, first of all, that there do not and

*Mershon: I.J.Orth. 1926, p. 1011: "It is seldom that I make a readjustment on the springs oftener than every three to five months."
D. Cosmos 1920, p. 703: "Adjustments in the lingual arch, unless for some special condition or reason, should not be more frequent than one every four to eight weeks."

cannot exist fixed numbers or rules where life is operative.* This conviction was affirmed by the results of this investigation, which proved the undeniable fact that *with the appliances at our disposal today it is impossible, in practice, to apply forces that will produce biologic reactions under any conditions.*

In these cases, treated with the plain archwire and ligatures, the indication for the right measure of force, in order to produce the most biological results was, according to my belief, the constant firmness and painlessness of the teeth.

To re-examine another criterion for the correct movement, in order to obtain biologic results, I strictly followed, wherever possible, the rule, reprinted often in the literature of the last years, that proper movement means 1 mm. per month.

Yet, in spite of the fact that the teeth remained constantly firm and painless and the movement did not exceed 1 mm. per month, it was impossible to obtain a biologic reaction. I was not able to ascertain in the literature by whom and by what kind of research methods and measurements it was ascertained that 1 mm. per month resulted in biologic reactions in growth and development.

The statement made within the last years that the imperative demand upon any orthodontic appliance is biologic efficacy, can no longer be maintained. *No possibility of biologic treatment exists.* The assumption, generally accepted as true, that damage "may be avoided by slight pressure of the spring," (Winkler,[11] p. 141), is just as clearly disproved, by the material at hand, as the deduction "that slight intermittent forces are able to produce a biologic reaction." (Oppenheim.)

All of our procedures produce pathologic changes which nature tries to attenuate by appropriate preventive measures. Yet, notwithstanding this, all our work is a violence to nature. We must try to do only the least amount of damage for we cannot, by any means, evade or avoid some damage.

As all forces at our disposal represent an innumerable multiple of the natural growth forces, it is inevitable that both in the use of intermittent and still more in the use of continuous forces, the periodontal membrane, on the

*Also Rogers[12] confirms this for his method of treatment (p. 41): " . . . we must accept the fact that no two individuals react in a parallel manner to stimuli from like sources." A similar statement has been made recently by R. Grude[10] (p. 151): "it is incredible to obtain in each individual a similar reaction in the tissues of the periodontal membrane, even if it would be possible to measure the applied force and to dose it under the "biologic limit" of 20 gr. in the beginning."

side of pressure, is finally compressed in quite a pathologic manner so that the tooth is actually leaning against the bone. This fact was not noted by the author when studying the specimens derived from animal material, when using light, intermittent forces, but is clearly evident in the findings obtained from human material. Therefore, I cannot any longer uphold the statement made in the "Crisis of Orthodontia," which was written before I had the knowledge obtained from the deductions in man, to the effect that, "for the orthodontist using light forces there can only exist a *side* of pressure but no *point* of pressure." (Z. Stom. 1933, p. 525.) This cannot be maintained any longer, as no biologic forces are at our disposal by virtue of which the bone resorption keeps pace with the movement of the tooth.

It goes without saying that this also alters the deductions of the author relative to the location of the tilting axis in tooth movement, viz., whether the tooth represents a lever of the first class or whether it is a double-armed lever with the crown moving in one direction and the root apex in the opposite direction. This question will be largely discussed in the summary.

When I have spoken in the past of an "orthodontic trauma" and of the fact "that the active influence of appliances creates only relatively biologic changes"; where I have quoted Ottolengui (I.J.Orth. 1927, p. 119) to the effect that "somewhere between the rapid and the slow movement of teeth exists the line of demarcation between trauma and treatment," all this must now be contradicted for *we are in no way able to imitate nature or to create biologic reactions.*

The assumption, made by Hellmann,[38] p. 595, years ago, without having an insight into the histologic changes in man, can be valued as a fact today, viz., "Physiologic treatment can under no circumstances be construed to mean any sort of mechanical procedure, regardless of what type of orthodontic appliances is used, and how well it is manipulated and controlled."

The knowledge gained by the material at hand also points to the fact that, by the microscopic pictures, we cannot conclude what kind of force was used. Both intermittent and continuous forces create pathologic changes. In the use of the latter, however, the damage, as we will see, is generally more severe and, because of the tooth "jiggling," is located both on the buccal and on the lingual sides, while in the use of the expansion arch and ligatures, these lesions are found mainly on the side toward which the tooth is moving, viz., on the side of primary pressure.

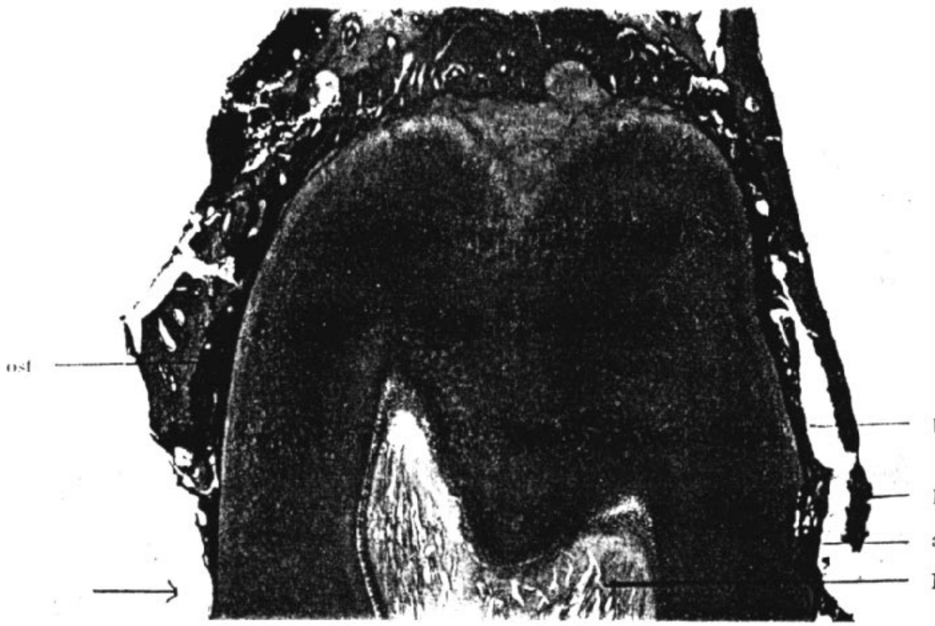
It is impossible to show the whole extensive material within the bounds of a magazine, yet in order to be convincing and conclusive it cannot be restricted too far. Therefore, only a few cases may be reviewed in detail and then, when findings are similar, only the existing congruities or discrepancies will be reported.

Hitherto, orthodontically moved teeth of man were examined by Grubrich,[3] W. Gubler,[4] B. L. Herzberg,[5] and Tokutaro Kogure.[6] Nearly all the slides of these authors show only the changes on the teeth themselves, as they were removed without the surrounding bone. Herzberg's slide is the first of human material that does not exhibit this deficiency. As far as concerns the reaction of the bone, this author verified, on the whole, the results of my investigations on monkeys, but he failed to mention and to describe the cementum resorptions at the points of pressure as seen in his slides, probably, also, for the reason that they did not show the bone. This may be inferred from studying Fig. 3 in Herzberg's publication.

Reports of Specimens Obtained from the Experiments

Specimen 1 (4): A girl of fifteen. The appliance used was the expansion arch (Angle), 0.8 mm. thick, made of highly elastic, gold-platinum alloy. The extent of movement was 1 mm. of parallel expansion from canine to molar. The archwire stood away from the tooth 1 mm. The ligature strands ran parallel and were tied to two staples on the archwire in order to prevent a lateral tilting. Movement was begun November 24, 1931. The tooth was ligated into contact with the archwire. The force was renewed after fourteen, thirty-five and three days. There was a lapse of three days between the last application of force and the extraction of the tooth (January 15, 1932). The distance between *4/4*, at the end of treatment, was about 2 mm. greater than at the beginning. *The whole time under treatment was fifty-two days,—seven and one-half weeks of intermittent elastic force.*

On account of the last renewal of force three days before the extraction, the pictures show the active stage of the tissue changes. Fig. 1 does not represent a central slide but is one that most distinctly shows the changes that were brought about. The buccal movement was effected in the direction of the arrow. It cannot be absolutely ascertained whether the alveolar crest, which corresponds about to the center of the cementum resorption (a, Fig. 1) was injured during the extraction or has disappeared intravital. The lower half of the buccal alveolar wall has been artificially removed from the tooth and from the periodontal space. The inner side of this bone, (Fig. 2, a higher magnification of "a" in Fig. 1, taken from a neighboring slide), shows distinct signs of resorption and osteoclasts, though not numerous, are to be found in some of the lacunae, (Ocl., Fig. 2). There is nothing to be seen of a deposition of osteoid in spite of the long period of treatment, which justifies the assumption that the ligature, which remained constantly intact, transmitted the force of the archwire to the tooth and bone almost up to the moment of the renewal of the force. The *periosteum*, (Pr., Fig. 2), is intact. There is, however, no sign of those periosteal deposits, which, in dog and monkey, are nearly always an attendant phenomenon of the attenuation of the alveolar wall from the pressure and which are formed in order to create

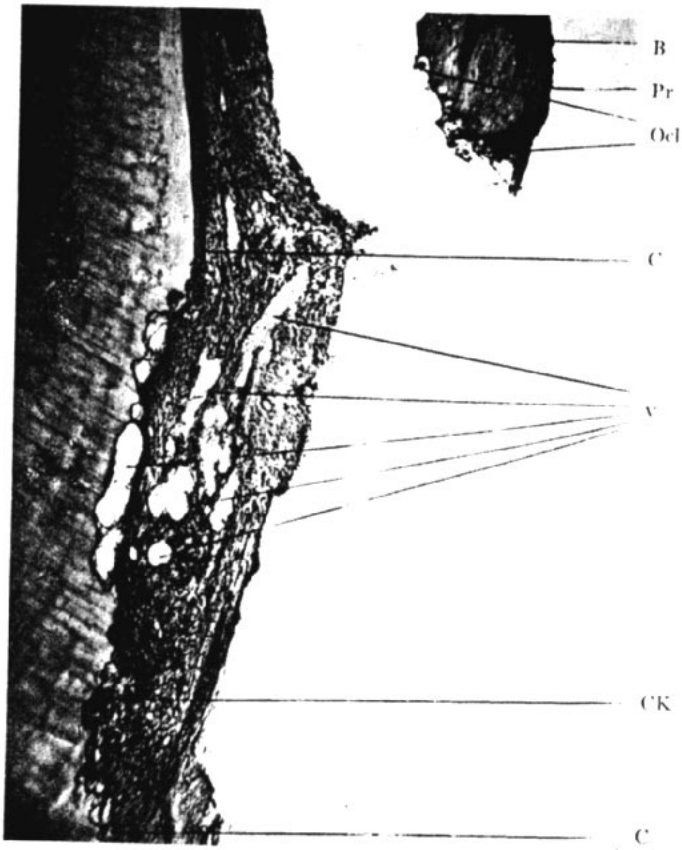


Specimen I (Figs. 1 to 3) Figure 1
Magnification 11; direction of movement is indicated by the arrow. B, bone; Ps, periodontal space; ost, osteoidformation; P, pulp; a, cementumresorption.

a protective balance (Osteophyts). If the reduction in the height of the buccal alveolar wall was not produced artificially then the alveolar border was resorbed by the pressure, for it must have originally reached at least to the gingival border of the cementum resorption, if not still further, in order to make possible the appearance of the cementum resorption at the area where it is seen.

A deviation of the apex cannot be ascertained in the microscope and in the whole series we find no reduction of the periodontal space on the corresponding lingual side of the apex,- no point of pressure, and there is no resorption of the cementum.

The conclusion evolved from this material, which in no case showed an exception, is that we find an injury of the cementum as an expression of the fact that the pressure within the periodontal space has surpassed the physiological limit. A contact between bone and tooth must not exist for this creates necrosis of the bone. The verification of a cementum resorption in the region of the apex is sufficient proof that a deviation has taken place here



Specimen I (Figs. 1 to 3) Figure 2
Resorption "a" of Fig. 1; magnification 65. B, bone; Ocl, osteoclasts; Pr, periosteum; C, cementum; CK, cementoclasts; v, vessels.

in a direction opposite to the movement of the crown, just as much as each cementum resorption at the alveolar border or in the intra-radicular septum, with a reduction of the periodontal space, is the sign that the pressure has surpassed the physiological limit.

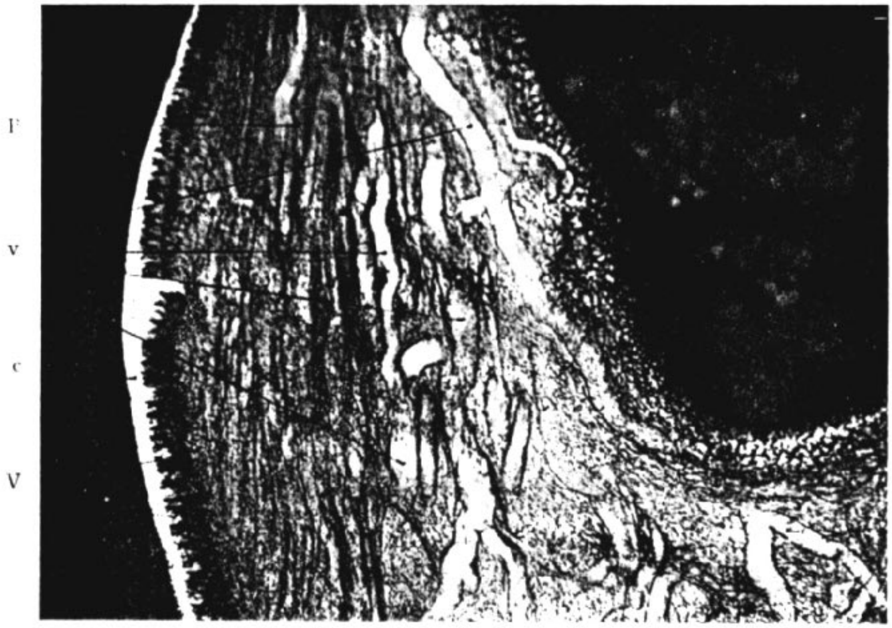
The cementum resorption at the buccal alveolar border, (Fig. 2), is the only one on the whole surface of the cementum in this specimen. The actual length of this resorption is 1.3 mm.* Its borders are very irregular and in the lacunae are found, here and there, cementoclasts, (C K, Fig. 2). There is no indication of an incipient process of reparation or of the formation of secondary cementum. The fact that there are no cementum resorptions on the two sides of traction (lingual alveolar border and labial apex region) is to be especially noted and will be discussed, comprehensively, later on.

Moreover, in this specimen there is another condition of special biologic interest which, up to now, has not been observed in animal specimens. Corresponding to the cementum resorption, the periodontal membrane shows such an abundance of large vessels and capillaries that it suggest clearly an *angioma-like appearance*, (v, Fig. 2, from a neighboring section, where the lowest portion of the bone specule is missing). Further apically, also, on the pressure side, almost as far as the root end, the capillaries are enlarged and increased in number. This may be considered as a protective measure of nature's, a sort of cushion, which, interposed between tooth and alveolar wall, tries to protect these structures from the increased pressure or at least to lessen it. *This buffer-formation, consisting of angioma-like increased capillaries and enlarged vessels, is to be found in all cases in which the force was applied intermittently and did not surpass a certain limit.* If this limit is exceeded, the readiness and capability of the periodontium for reaction is suppressed. I can only repeat what I have already said ((I.J.Orth. 1934, p. 140) on the occasion of the controversy about intermittent and continuous forces: "With the use of gentle intermittent forces, the periodontal membrane recovers comparatively quickly, because of the rapidly re-established blood supply, from the application of a pressure which extended over a short period of time, even if the force was occasionally somewhat stronger. It soon regains its ability to react biologically."

This biological reaction of the periodontal membrane, the formation of the angioma-like tissue, is in no case evident where a suppression of the vitality of the cells of the periodontal membrane,—necrosis, occurred. Thus it appeared in no case in which crushing of the periodontal membrane and leaning of the tooth against the alveolar wall took place, or in no case in which strong intermittent or continuous forces were applied. It cannot occur in these cases, as the premise for such a formation is lacking,—a vital periodontal membrane, not deprived of its biological capability of reaction.

*All measurements were performed with the Abbe-Designing appliance (Zeiss).

Besides acting as a protective measure against too great pressure, this angioma-like formation probably fulfills another purpose which is of advantage to our proceeding,—the favoring and encouragement of the resorption by virtue of the capillaries lying in direct contact with the bone. One often gets the impression that the endothelial cells of the capillaries lie very close to the lacunae already existing, thus producing these lacunae by exercising



Specimen I (Figs. 1 to 3) Figure 3
Magnification 80; P, pulp; v, vessels; V, vacuoles.

osteoclastic and—depending on their position—cementoclastic functions, working in the sense of relieving the pressure by gaining space. Osteoclasts do not develop during this process.

In the formation of the angioma we nearly always find the normal course of the periodontal fibers preserved, with the exception of these narrow limited areas which lie within the sphere of the resorptions, where this is not possible because the fibers have lost their source of insertion.

The apposition of bone on the lingual side of traction, following the traction, took place in the form of an even layer of osteoid, (ost, Fig. 1).

The pulp, (Fig. 3), reveals stasis, with all the accompanying symptoms. The capillaries, exceedingly multiplied and filled to a stretching point, dominate the range of vision. The odontoblastic layer is either entirely obliterated or we find scattered rows of odontoblasts, the result of the formation of numerous embedded vacuoles, (V., Fig. 3), which finally unite in larger cyst-like formations, (Cy, Fig. 71). The separation of the whole odontoblastic row on the left, at "c," Fig. 3, is artificial. The stroma is degenerated

Specimen II (Figs. 4 to 6) Figure 4
Magnification 10; direction of movement is indicated by the arrow; B, bone; Ps, periodontal space; P, pulp; t, areas of traction; a, b, c, cementumresorptions.

in a fibrillary way and the embryonal character of the pulp cells has been completely lost. Diapedesis and hemorrhages are to be observed in numerous places.

All orthodontically influenced teeth show stasis with more or less advanced degeneration of the pulp and only graded differences are to be observed.

Specimen II (4): Girl of fifteen. Appliances used: Expansion arch (Angle); 0.8 mm. thick. Extent of movement: 1 mm. of parallel expansion from canine to molar. Treatment was begun November 24, 1931, using common wire ligatures. The tooth was ligated to contact with the archwire which stood off 1 mm. Every fortnight the ligature was changed. Three days before the extraction, (January 15, 1932), the last change of the ligature was made. The distance between *4/4* at the end of the treatment was 2 mm. greater than at the beginning. *The whole time of treatment was fifty-two days,—seven and one-half weeks of intermittent elastic force.*

Hence, also as in Specimen 1, we find the active stage of reaction as a result of the renewal of force three days before the extraction. The slide which shows the changes best was chosen for the reproduction, (Fig. 4). The movement was effected in the direction of the arrow.

The alveolar crest does not reach the lower border of the cementum resorption, (a, Fig. 4), and unquestionably this disappeared intravital under the effect of the force. Proof of this is the presence of the fibers of ligamentous connective tissue which lead from the periosteal outer surface of the bone, (bi, Fig. 5), to the cementum below the resorption. Fig. 5 is a higher magnification of the resorption "a" of Fig. 4. On the surface of the bone which faces the tooth, osteoclasts are visible, (Ocl., Fig. 5), which, during a longer period of treatment, would have further resorbed the alveolar crest.

There is scarcely anything to be seen of an *osteophytic* protective formation at the outer side of the bone,—just scanty osteoblasts scattered here and there, (obl., Fig. 5). On the inner side of the bone we find (on account of the intermittent movement) only now and then a trace of osteoid, (ost., Fig. 5).

In addition to this great area of resorption, which has a real length of 1.25 mm., we also have two smaller ones, situated more apically, (b, c, Fig. 4). Their magnified reproduction is omitted. *At the bottom of all three cementum resorptions* there are signs of destruction,—dispersed cementoclasts, (cK, Fig. 5). Yet there are also depositions of secondary cementum of a recent date, in a uniform row of cementoblasts, (s C, Fig. 5), and this formation of secondary cementum stands in contrast to Specimen 1 where, in spite of the same period of treatment, it was not seen because the commonly applied ligature loosens more quickly so that the tooth can recover more rapidly from the active force. In the two more apically situated smaller resorptions of recent date, hemorrhages are to be observed but the normal course of the fibers of the suspensory apparatus is, on the whole, as little injured as in the great resorption, Ps, Fig. 5).

Specimen II (Figs. 4 to 6) Figure 5
Cementumresorption "a" of Fig. 4; magnification 85. B, bone; Ps, periodontal space; C, cementum; sC, secondary cementum; D, dentin; cK, cementoclasts; obl, osteoblasts; ost, osteoid; Ocl. osteoclasts; v, vessels; bi. fibres of connective tissue between bone and cementum.

On the lingual side at the apical section of the root, lying diagonally opposite to the three resorptions, there is no cementum resorption in the whole series,—that is, *no tilting of the apex is to be observed by the microscope*, for, whenever this happens, the root is marked, without an exception, by a corresponding injury to the cementum. All other parts of the cementum surface are perfectly intact, just as is seen in Specimen I, within the spheres of tractions at the alveolar margin and on the apex, (t, Fig. 4). Here we also find, as in Specimen 1, the formation of the angioma-like cushion in the region of pressure, (v, Fig. 5).

Specimen II (Figs. 4 to 6) Figure 6
Point x of Fig. 4; magnification 85; direction of movement is indicated by the arrow; oB, old bone; nB, new bone; f, demarcation line between old and new bone; Ps, periodontal space; C, cementum; D, dentin.

The periodontal space on the side of traction, lingually, shows severe traumatic damages, which occurred during the extraction. A comparative measurement of the periodontal breadths on the side of pressure and traction, consequently, would not afford a reliable result.

On the lingual side of traction, the formation of osteoid bone occurred in a smooth and even deposition, (Fig. 6). The demarcation line between the old and newly formed bone is distinctly to be seen, (f, Fig. 6). The width of the latter approximately represents the extent of the movement. It

Specimen III (Figs. 7 to 10) Figure 7
Magnification 11; direction of movement is indicated by the arrow; B, bone; ac, alveolar crest; Ps, periodontal space; P, pulp; a, cr, cementumresorptions; Cc, cementum thickened by traction; t, sphere of traction; Dt, one free and four wallstanding denticles.

shows no signs of functional transformation and does not yet contain Haversian systems.

The *pulp* shows, as in Specimen 1, in addition to an enormous increase and expansion of the vessels, as well as a strong thickening of their walls, especially a picture of reticular atrophy with destruction and dissolution of the odontoblastic layer in some parts.

The object of this movement was to ascertain if there had been a lateral tilting of the tooth, caused, perhaps, by the ligature-legs lying at different

Specimen III (Figs. 7 to 10) Figure 8
Cementumresorption "a" of Fig. 7; magnification 85; B, bone; ac, alveolar crest; Ps, periodontal space; C, cementum; sC, secondary cementum; obl, osteoblasts; bi, fibres of connective tissue between bone and cementum.

levels, determined by the thickness of the archwire. As the approximal surfaces were injured at the removal of the tooth, in order to spare the adjoining teeth, no deduction in respect to a lateral tilting was possible.

Specimen III (4): Girl of fifteen. Appliance used: Angle expansion arch (0.8 mm.), highly elastic, platinum-gold alloy. It was adjusted to stand off passively 2 mm. from the tooth. Treatment was begun November 17, 1931. By means of an ordinary wire ligature, the archwire was repeatedly drawn ½ mm. nearer to the tooth at intervals of a fortnight. The last change of ligature took place seven days before the extraction which was performed on February 3, 1932. The position of the ligature was secured by a band and spur. The total extent of the tooth movement was 2½-3 mm. *The duration of treatment was seventy-eight days,—eleven weeks of intermittent, elastic force.*

As a result of the character of the whole treatment and because of the time interval of seven days between the last change of ligature to the time of extraction, we notice a sub-active stage of reaction. The movement took place in the direction of the arrow, (Fig. 7). The alveolar crest, (ac, Fig. 7 and also Fig. 8 in high magnification), reaches just to the upper border of the deep cementum resorption. The strong fibers of ligamentous connective tissue, which run from the outer surface of the most gingivally visible bone-specule to the cementum, (bi, Fig. 8), is a sure proof that the disappearance of the alveolar crest has been brought about intravital as a consequence of the resorbing effect of the pressure. As the appliance was working twenty-six days longer than in Cases I and II, the atrophy had progressed accordingly. The alveolar crest must have formerly extended farther occlusally on the root and by the renewal of force, i.e., by a continuation of the tooth movement, the resorption naturally would have made further progress. At the time of extraction, the surface of the present alveolar crest facing the tooth and the whole inner side of the labial alveolar wall, almost to the middle of the root, offers a picture of sub-active resorbing processes, (Fig. 9 and the continuation of Fig. 8, apically. The upper border of the resorption, a, Fig. 8, is still just to be seen). In the lacunae, on the borderline of bone facing the periodontal space, single osteoclasts are still visible in spite of a rest period of seven days, (ocl., Fig. 9), but no deposition of osteoid is to be seen. On the surface of that part of the bone farthest away from the tooth, we find, in some places, the beginning of a periostal bone-deposition (osteophyt). These surfaces are beset with a layer of osteoblasts arranged in an epithelial-like manner, (obl., Figs. 8 and 9).

After a treatment of eleven weeks we find already, in contrast to Specimens I and II (7½ weeks) a microscopical deviation of the apex that is distinctly noticeable with the corresponding modifications,—the traction sphere, bucally, at the apex, (t, Fig. 7), and extended cementum resorptions within the lingual pressure sphere at the apex. (Cr, Fig. 7.)

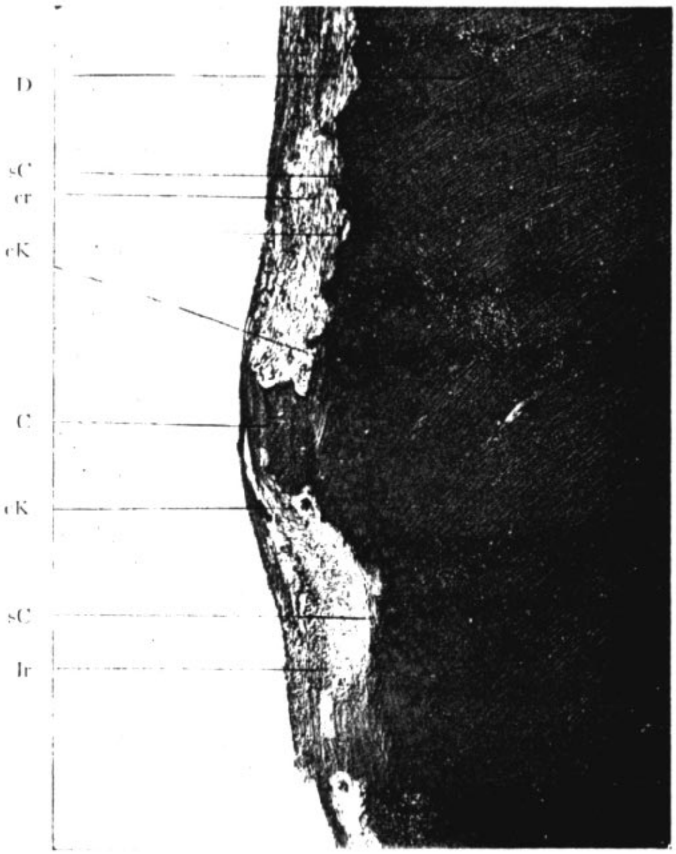
The changes on the *lingual side* of the tooth cannot be shown, as those parts are missing in the specimen. In the apical traction sphere, the bone-spicules are arranged radially following the lines of traction, (t, Fig. 7).

The cementum has already undergone severe injuries. On the labial

Specimen III (Figs. 7 to 10) Figure 9
Periodontal space above the cementumresorption "a" in Fig. 8; magnification 80; "a" corresponds to the cementumresorption "a" of Fig. 8; b, second cementumresorption; B, bone; Ps, periodontal space; C, cementum; D, dentin; ocl, osteoclasts; obl, osteoblasts; v, vessels; v', spongelike conglomerated vessels.

side of pressure, at the level of the original alveolar crest, we find a resorption reaching deeply into the dentin, (a, Fig. 7, and in higher magnification, Fig. 8), and in the course of the series, several more resorptions, located more apically, are found. These do not reach as deeply into the dentin. One of these we find in Fig. 9 and in this slide we also see the upper border of resorption "a" from Fig. 8.

As the alveolar crest had disappeared so that no more force was acting on the corresponding side of the tooth, (a, Fig. 8), we consequently find the



Specimen III (Figs. 7 to 10) Figure 10
Point "cr" of Fig. 7; magnification 85; Cr, cementumresorptions; cK, cementoclasts; sC, secondary cementum; C, isle of intact cementum; D, dentin.

cementum resorption of that sphere already in a state of repair. Layers of secondary cementum of various degrees of thickness are found everywhere, (s C, Fig. 8), objectively to compensate for the defect of narrowing the periodontal space and also to offer a new base for the insertion of the periodontal fibers.

The depth of this resorption is .30 mm. The thickness of the root wall from cementum to the pulp chamber at this spot is 1.75 mm. Therefore, after a treatment of eleven weeks, one-fifth of the thickness of the root wall was already penetrated by resorption.

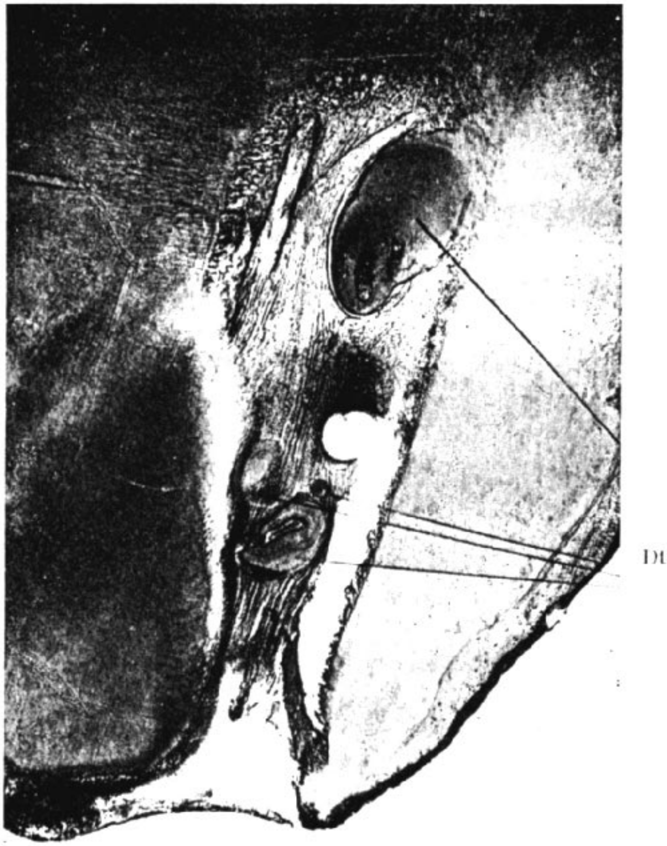


Figure 11
Formation of denticles in the root pulp from a case not published here, in the use of strong forces. Dt, denticles.

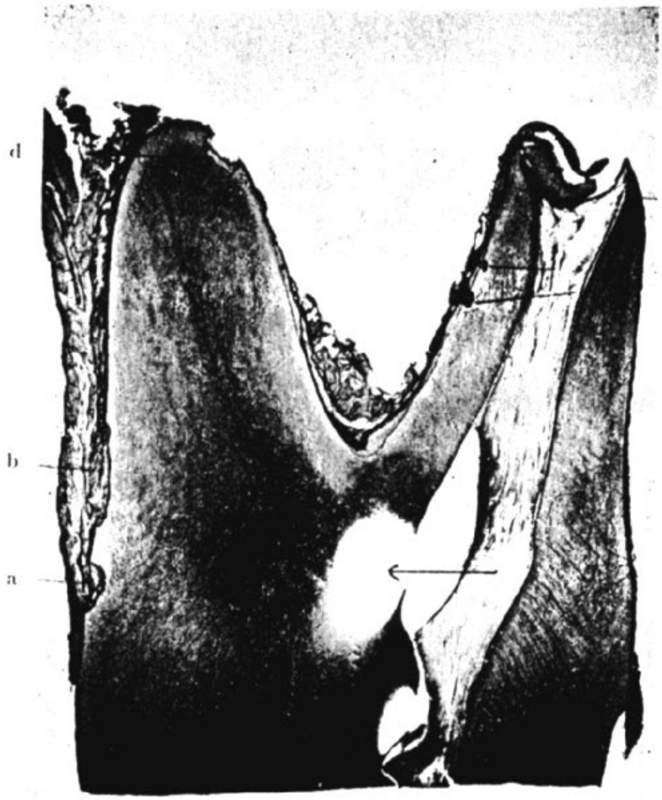
The resorptions at the apical end of the root, (c r., Fig. 7 and also in higher magnification in Fig. 10), have already penetrated the whole thickness of the cementum and also reached into the dentin. There are, in addition to sporadic cementoclasts, (cK, Fig. 10), depositions of secondary cementum, the distinct marks of repair, sC., Fig. 10), but not developed to the same extent as in the cementum resorption at the buccal alveolar crest, (Fig. 8), where the pressure could not work any more because of the absence of the bone. Between the two deep resorptions a cementum-isle has been left, (C, Fig. 10). The cementum on the labial side shows in the lower half, (sphere of pressure), besides the already discussed areas, (a, b, Fig. 9), some single resorptions of the cementum which do not reach into the dentin. On the other hand, the cementum has considerably and irregularly thickened in the upper half, (Cc, Fig. 7), which probably can be attributed to the effect of traction of the periodontal fibers. In the apical sphere of traction there is no cementum resorption. Nothing can be mentioned about the cementum on the corresponding side of traction at the alveolar crest for that part of the specimen is missing. Furthermore, nothing of an *angioma-like protective formation* in the periodontal space is noticeable in Fig. 8, for, owing to the non-existence of the bone, there was also no pressure. But from the upper border of the resorption, "a" in Fig. 9, to about the middle of the root, the angioma formation is still distinctly visible in the neighboring slides, (v and v', Fig. 9). In the upper part of this picture, at v', we find a conglomeration of small vessels.

In the *crown portion of the pulp* there is the usual picture of stasis with increased and expanded vessels and progressing destruction of the odontoblastic layer. In the pulp within the root we notice the same picture of quite large vessels, vacuol-formation in the odontoblastic layer, their entire dissolution in some places, and the formation of four wall-standing and one free denticle. (Dt, Fig. 7.)

Fig. 11 shows the root-pulp of a case where, at the beginning, the movement was effected by strong, intermittent forces and was continued by continually working forces. As such a movement is practically out of the question, the publication of this case was dismissed. However, in addition to the cementum resorptions in the sphere of pressure, it showed a disappearance of the alveolar crest. Only the picture of the pulp is interesting, as, quite apart from the typical stasis, denticles in the root-pulp, (Dt, Fig. 11, as in Specimen III), were produced.

Specimen IV (4): Girl of thirteen. Appliance used: Angle expansion arch, 0.80 mm. thick, highly elastic, platinum-gold alloy. When passive, the archwire stood away from the tooth 1½ mm. Treatment was started November 24, 1931. Traction with an ordinary ligature was renewed at irregular intervals, viz., after seven, fourteen, twenty-eight and finally sixteen days. Before the last renewal of the ligature the archwire was bent buccally for a distance of 1 mm. from the tooth. The last force-application was made nineteen days before the extraction. (February 16, 1932). The total extent of the movement was 2½ mm. *The whole time of treatment was eighty-four days,—twelve weeks of intermittent elastic force.*

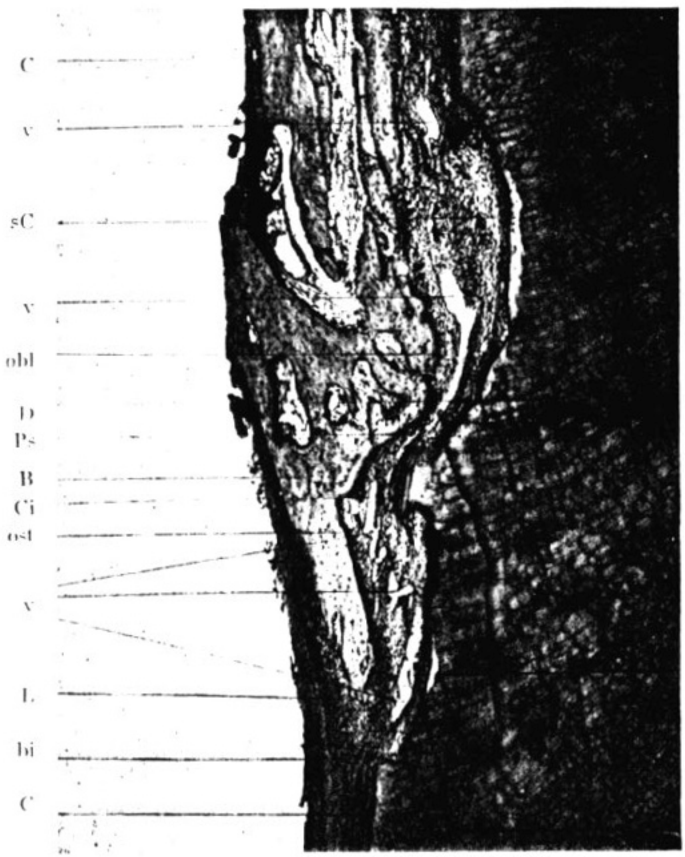
Because of the lapse of an interval of nineteen days between the last renewal of the ligature and the extraction of the tooth we are now almost



Specimen IV (Figs. 12 to 16) Figure 12
Magnification 9; direction of movement is indicated by the arrow; a, b, d, e, f, cementum-resorptions at the points of pressure.

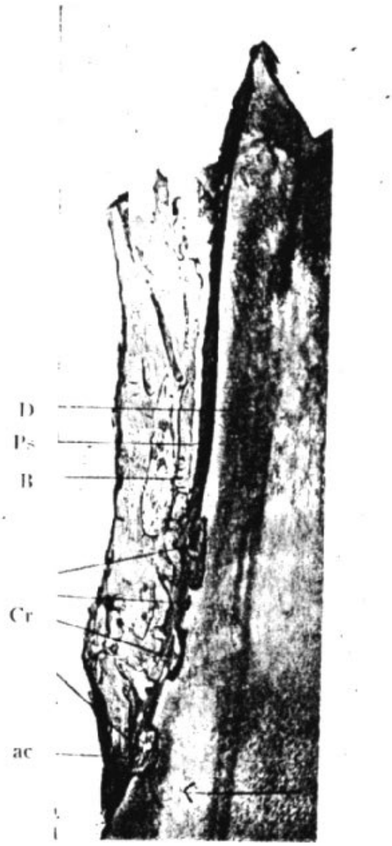
completely in the stage of repair. Both upon the bone and in all cementum resorptions we find apposition of osteoid and secondary cementum, respectively.

The movement followed the direction of the arrow, (Fig. 12). *The disappearance of the alveolar crest,* certainly brought about intravital, is noticeable in Figs. 12, 13, 14 and 15. The vital process is proved by the connective tissue fibers that are still intact between the cementum and the lowest spicule on the labial side of the alveolar process, (bi, Fig. 13), and also by the lacunary borderline at the lowest (most apical) part, (L. Fig. 13), a sign of preceding resorption. However, this disappearance of the alveolar crest (also seen in all the other examined teeth) cannot be found without interruption or with regularity in the whole series, for in some places the alveolar crest surmounts the apical border of the cementum resorption. At any rate this depends upon a change in the direction of force. This dis-



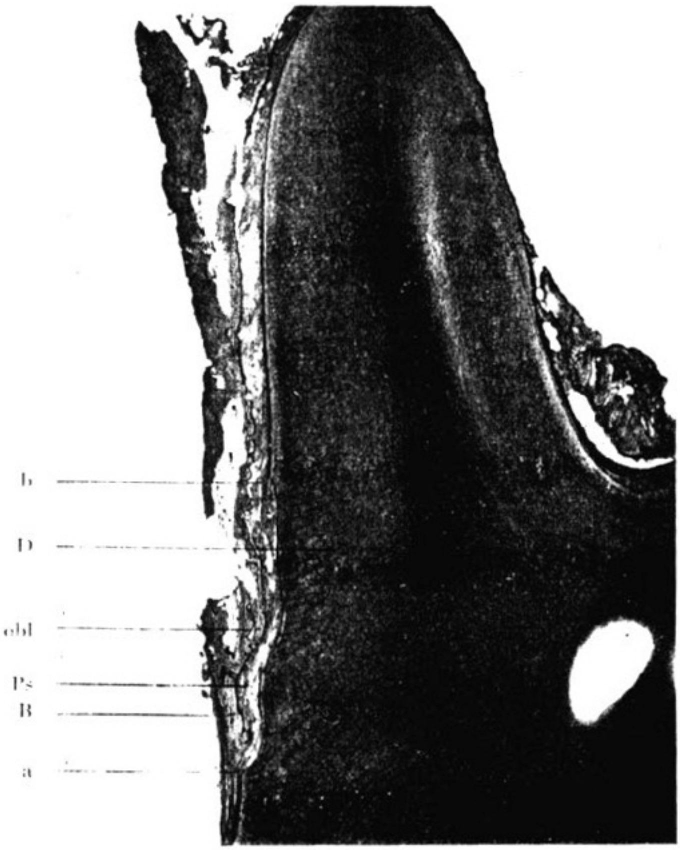
Specimen IV (Figs. 12 to 16) Figure 13
Points a, b of Fig 12 from a neighboring slide; direction of movement is indicated by the arrow, magnification 44; B, bone; Ps, periodontal space; C, cementum; Ci, isle of cementum between the two resorptions; sC, secondary cementum; L, alveolar crest, bordered by lacunae; ost, osteoid; obl, osteoblasts; v, vessels; D, dentin; bi, fibres of connective tissue between bone and tooth.

appearance of the alveolar border has not taken such a deleterious form although the treatment lasted one week longer than in Specimen III. This is probably accounted for by the weaker forces used, (distance of the archwire was 1½ mm. instead of 2 mm. as in Specimen III), and by the longer intervals of treatment and corresponding intervals of rest.



Specimen IV (Figs. 12 to 16) Figure 14
Magnification 14; direction of movement is indicated by the arrow; ac, alveolar crest; B, bone; Ps, periodontal space; D, dentin; Cr. four cementumresorptions.

The periodontal surface of the labial alveolar wall, in the whole original area of pressure, is in a stage of repair. Small seams of osteoid in flat apposition, (ost., Fig. 13), are beset with dense rows of osteoblasts, (obl., Fig. 13.) The whole side of the bone, opposite the deep resorption at the alveolar crest, is vaulted convexly and hump-like toward the cementum resorptions, (obl., Fig. 13 and especially in obl., Fig. 15, where it is distinctly seen), in order to restore, as quickly as possible, the normal periodontal width.



Specimen IV (Figs. 12 to 16) Figure 15
Magnification 14; direction of movement is indicated by the arrow; out of the four cementumresorptions in Fig. 14, has developed by union, one large one, reaching from "a" to "b"; B, bone; Ps, periodontal space; D, dentin; obl, bone vaulted convex and humplike towards the cementumresorption.

We observe this process occurring, almost without exception, at all *plane-like, extended resorptions,* without regard to their depth. We shall, later on, see the peculiar way in which this repair is achieved for the purpose of reducing the periodontal space and for the restoration of the original firmness of the tooth at deep resorptions with narrow entrances.

No periosteal apposition (osteophyt) has taken place as a compensatory measure of nature against the thinning of the alveolar wall. We find, now

Specimen IV (Figs. 12 to 16) Figure 16
P, pulp; D, dentin; od, odontoblastic layer; h, hemorrhage; v, vessels.

and then, only a simple layer of osteoblasts, which started to form with the beginning of the rest period.

As a result of the twelve weeks of treatment we note, already, in this case also, a tilting of the apex with the unavoidable sequence of resorption of the cementum at the location of increased pressure.

If a tooth with two roots tilts, there are always four points of pressure and traction, as registered in the sketch, Fig. 17, pressure by + and traction by —. The arrow indicates the direction of the movement. If the movement follows the reverse direction the signs of pressure and traction change, as a matter of course.

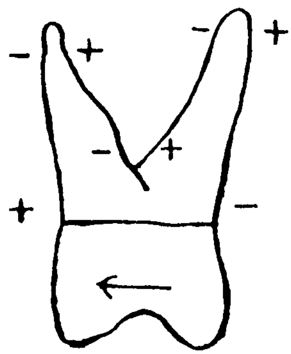
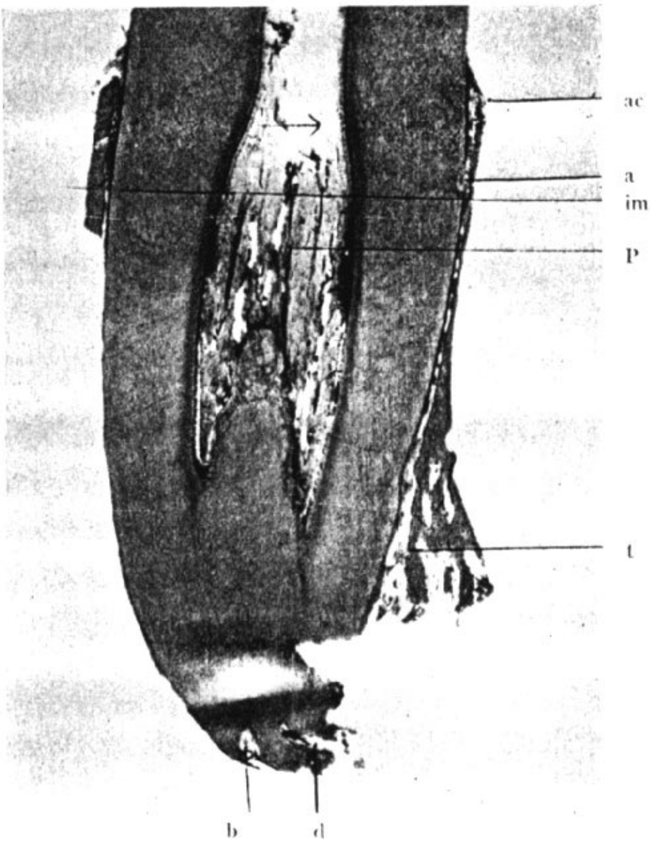


Figure 17
In a tooth with two roots there develops, during the tilting movement, indicated by the arrow, 4 points of pressure (+), and 4 points of traction, (—).

Corresponding to the sketch in Fig. 17 there are, consequently, four points of pressure in our specimen. One is at the labial alveolar crest, Fig. 12 "a" and "b," a second is at "d," a third at "e," and a fourth at "f."

In reviewing one series we do not see all the findings joined in all sections. That fact holds good, of course, for the cementum resorptions. They suddenly disappear from the horizon and reappear again in other places. This variation in the pictures is explained by the presence of isles of intact cementum between the individual resorptions, as we will see, plastically, in the reproduction models that I have made. The form and extension of the resorptions vary almost from slide to slide. From the two resorptions, (a and b, in Fig. 12), there apparently appears to be four, (cr, Fig. 14), in the course of the series, and these, in turn, become confluent in a great wounded surface of the cementum as shown in Fig. 15 a-b. The resorptions "a" and "b," shown in Fig. 12, are reproduced in magnification in Fig. 13, which is taken from a neighboring slide. Here we note the remaining cementum-isle, (Ci, Fig. 13), which may be compared wtth Fig. 12. The proportions of the two resorptions in their relation to each other have again changed. In the cementum resorptions shown in Fig. 13, the lower one measures 0.8 mm. and the upper one 1.7 mm. The cementum-isle between the two measures 0.30 mm. The whole resorption area, therefore, is 2.8 mm.

It is reduced to 2.6 mm. in Fig. 14, but again measures 2.9 in Fig. 15. With a total length of the root registering 9.4 mm., the resorption consequently covers about 1/3 of the root.

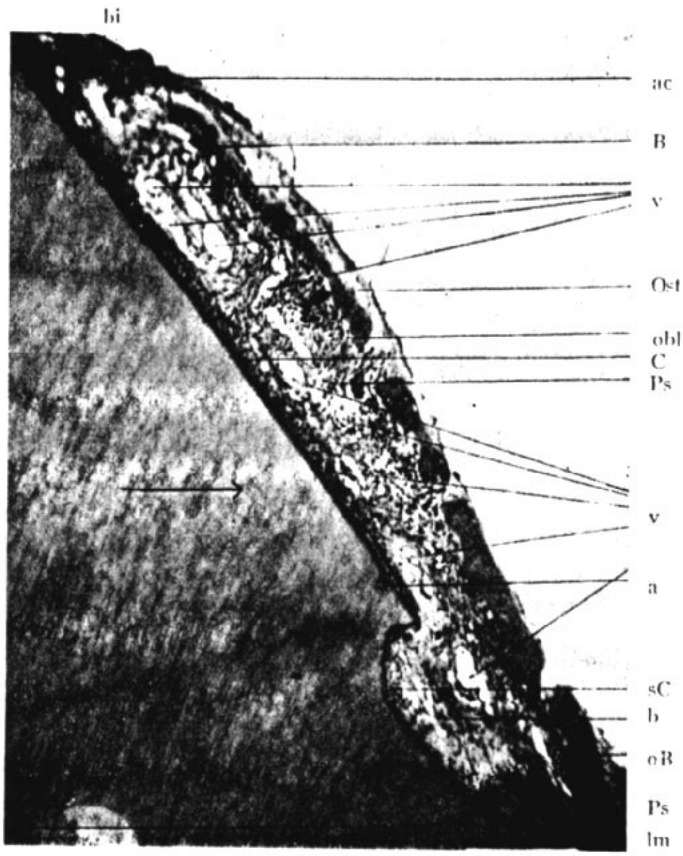


Specimen V (Figs. 18 to 22) Figure 18
Magnification 7; direction of movement is indicated by the arrow; ac, alveolar crest; t, sphere of traction; P, pulp; b, d, divided foramen apicale; a, cementumresorption; lm, line of measure.

The publication of a magnified reproduction of the intraradicularly situated resorptions "d" and "e," Fig. 12, is omitted. These also show the marks of advanced repair, with secondary cementum, similar to the resorptions in Fig. 13 (sC).

In that specimen, too, there are no cementum resorptions at the alveolar crest in the area of traction.

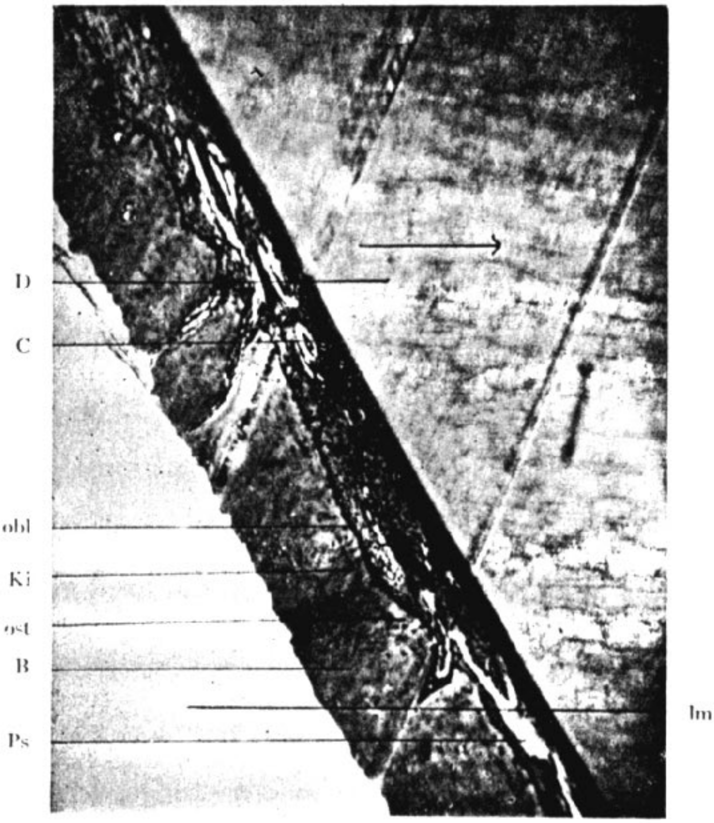
The *periodontal space* on the pressure side shows every indication of a return to normal. Its width and the course of the fibers are in some parts already normal. The numerous, great vessels which still exist, (v, Fig. 13),



Specimen V (Figs. 18 to 22) Figure 19
Direction of movement is indicated by the arrow; point "a" of Fig. 18; magnification 60; oB, old bone; ost, osteophyt; obl, osteoblasts; ac, alveolar crest; Ps, periodontal space; C, cementum; a, small, b, large cementumresorption; sC secondary cementum; v. vessels; bi, fibres of connective tissue between bone and tooth; lm, line of measure.

on the pressure side are probably to be considered as evidence of the *angioma-like buffer-formation* that was present during the active movement. Nothing can be said about the state of the periodontium and bone on the lingual traction side. These tissues are missing in the specimen. For the same reason it is not possible to state whether or not, at the other three points of pressure, a formation of the "angioma" had developed.

The *pulp* shows the same picture of stasis and the results thereof. Numerous large vessels, (v, Fig. 16), hemorrhages, (h, Fig. 16), and entire degeneration of the odontoblastic layer in wide areas, (od, Fig. 16), are present although there are some parts with an approximately normal odonto-



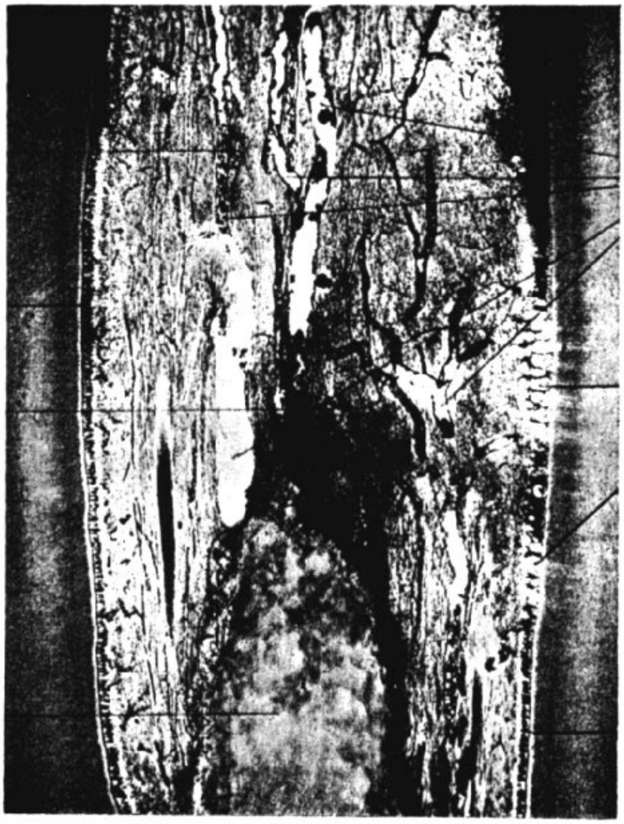
Specimen V (Figs. 18 to 22) Figure 20
Part on the line lm of Fig. 18; traction side; magnification 60; direction of movement is indicated by the arrow; B, old bone; ost, new bone; Ki demarcation line between old and new bone; obl, osteoblasts; Ps, periodontal space; C, cementum; D, dentin; lm, line of measure.

blastic layer. However, where there is no total disappearance, vacuol-formation, which entails dispersion and destruction of the odontoblasts, prevails.

Specimen V (1): Boy of thirteen. The appliance used was the Angle expansion arch. The tooth was banded and provided with two spurs to securely hold the ligature. Treatment began on March 13, 1933. The screw on the archwire was tightened with a half turn every fortnight and fixed in its position by a wire ligature. The ligature was changed three times within sixteen and one-half weeks when the archwire was entirely passive and lying in close contact with the tooth. Since the last renewal of force and the extraction, July 5, 1933, a fortnight has elapsed. The extent of the tooth movement was 1 mm. *The whole time of treatment was one hundred and fifteen days,—sixteen and one-half weeks of intermittent, elastic force of the weakest character.*

In this case I tried to secure the best possible biologic effect by the application of the weakest possible intermittent force so as to prove thereby my constantly defended theorem that this method of procedure best meets the biological demands. The movement was carried through with exaggerated slowness. The treatment deals with a case where the two upper lateral incisors were not present (congenitally missing) and the space they should occupy was almost closed. For a compensating space-reduction in the lower arch, in order to obviate a threatening lingual position of the upper *1/1,* a lower incisor was extracted and the closing of the gap was left to nature, which, in the course of some months, really ensued. To avoid further closing of the gap in the upper jaw during that time, conforming to the purpose of the extraction, a lingual retainer was fixed to the *3/3* of the upper jaw until the gap in the lower jaw had closed. As soon as no lingual position of the *1/1* was to be feared, this retaining device was removed, so as not to prevent the further closing of the gap in the upper jaw and also to favorably influence the same movement in the lower jaw. In spite of the continued treatment of four months, by which the tooth was moved 1 mm. labially (direction of movement is indicated by the arrow), the labial alveolar wall remained at its original level and, therefore, shows its upper crest intact, (ac, Fig. 18). This alveolar crest is to be observed in magnification in Fig. 19, where one can follow the insertion of the fibrous connective tissue fibers between the cementum and the periostal side of the upper bone spicule, (bi, Fig. 19).

In the lacunar borderline of the bone, facing the periodontal space, there are no osteoclasts to be seen but only a regular epithelial-like layer of osteoblasts with a formation of thin osteoid, (obl., Fig. 19). The bony wall is rather thin and is covered, on its periostal outer side, from the alveolar crest to just opposite the resorption, with a thin layer of newly built bone, (ost., Fig. 19). For the first time a real *osteophyt-formation,* distinctly to be perceived, presents itself. In spite of the extremely slow movement (much less than 1 mm. per month) *cementum resorptions* have formed at the area of pressure, (a and b, Fig. 19), as a result of the compression of the periodontium, surpassing the degree of physiologic measure. These resorptions(as well as the bone also) show the effect of the stage of rest by the



Specimen V (Figs. 18 to 22) Figure 21
Magnification 24; P, pulp; od, odontoblast layer; v, vessels; V, vacuoles; d, diapedesis of blood through the walls of the vessels; D, dentin; in the lower part, between the two root canals is cementum, C.

beginning of a formation of secondary cementum, (sC, Fig. 19). Other than these, no cementum resorptions are noticeable. Nor are there any in the lingual traction area. In the whole area of pressure, especially within and above the cementum resorptions, we again find the marked *angioma-like increase* and augmentation of the vessels, (v, Fig. 19).

The bone of the alveolar crest on the *traction side* shows, on its periodontal aspect, a *regular, surface-like* deposition of osteoid bone, (ost., Fig. 20), separated by a distinct borderline (Kittlinie) (Ki, Fig. 20) from the old bone (B), which indicates the approximate extent of the performed movement. It is bordered by osteoblasts, (obl, Fig. 20). But this osteoid-formation is bigger than the periostal deposition (osteophyt) on the labial pressure side, (ost., Fig. 19), so that even in the case of extremely slow movement, the periostal deposition (osteophyt) could not keep in balance with the periodontal resorption, if we assume as correct that the width of the osteoid formed on traction side, (ost., Fig. 20), corresponds to the extent of the tooth movement.

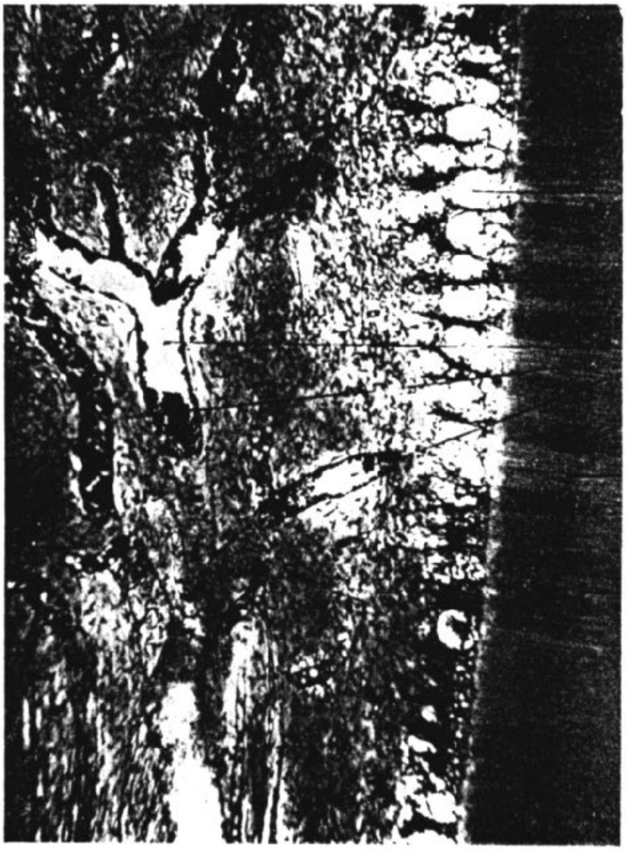
The osteoid formation on the traction side, (ost., Fig. 20), has the width of 0.03 mm.; on the pressure side the formation of osteophyt has a width of 0.01; i.e., a third. Therefore, if the extent of the tooth movement was as great as the osteoid (0.03 mm.) which has deposited on the lingual side, the bone was reduced on the labial side of pressure to the same extent while the osteophytic bone formation has only reached a third of this extent. Consequently equal compensation has not occurred but an actual thinning of the buccal alveolar wall has resulted.

The measurements of the periodontal width on the pressure and traction sides, along the line lm, in Figs. 18, 19 and 20, read as follows: On the pressure side 0.10 mm., on the traction side 0.09 mm.,—the inverse ratio of the expected proportion.

In spite of the long duration of the movement, no deviation of the apex, which has a divided foramen, (b, d, Fig. 18), can be reported. Hence the intact state of the cementum on the presumed apical pressure side. The broadening of the periodontal space on the presumed apical traction side, (t, Fig. 18), is traumatic in character and occurred at the surgical removal of the tooth.

Although the position of the apex is apparently unchanged yet we find advanced degeneration symptoms in the *pulp*, (Fig. 21). These consist of stasis and vacuole formations (V) in the odontoblast layer, together with degeneration; greatly expanded vessels (v); and numerous spots of diapedesis of the blood-globules from the tensely filled capillaries into the stroma, (d, Fig. 21). The normal odontoblast is found only in narrowly limited areas of the root-pulp, (od, Fig. 21). The vacuole formation is shown in high magnification in Fig. 22. The signs of degeneration are found in the whole pulp. A specially localized increase of this appearance, corresponding to the cementum resorption, on which G. Fischer[2] reports, could not be ascertained.

Specimen VI (4): A girl of thirteen. The appliance used was the Angle expansion arch (0.80 mm. thick), of platinum-gold alloy. When passive it stood away 2 mm. from the tooth. After one ligation, treatment was interrupted for ten months. It was resumed October 31, 1932, with the same



Specimen V (Figs. 18 to 22) Figure 22
Higher magnification (80) of the vacuoles (V) of Fig. 21. D, dentin; v, vessels; V, vacuoles; od, odontoblasts, spread and compressed by the vacuoles.

adjustment of mechanism. The tooth was then ligated, alternately, on seven and fourteen days, to the passive archwire and pulled within 1 mm. distance of the archwire. Within the duration of a period of treatment lasting forty-four days (six weeks), the tooth was ligated four times and then released (December 13, 1932) and for seven weeks previous to the time of removal

(February 3, 1933) was afforded an opportunity to relapse to its original position. The measure of the movement was 2 mm. *The entire time of elastic, intermittent force was forty-four days,—six weeks, succeeded by a secondary period of seven weeks without any appliance in position.*

We find, in accordance with the described course of treatment, all indications of almost complete repair within the tooth structures. In the bone is to be seen all signs of rebuilding processes as provoked by the relapse of the tooth. This readjustment of the tooth was not at all disturbed or hastened by occlusal forces from contact with the lower teeth for the reason that these latter dental units had not yet erupted to occlusal contact. The relapse movement, therefore, proceeded entirely without any occlusal influences.

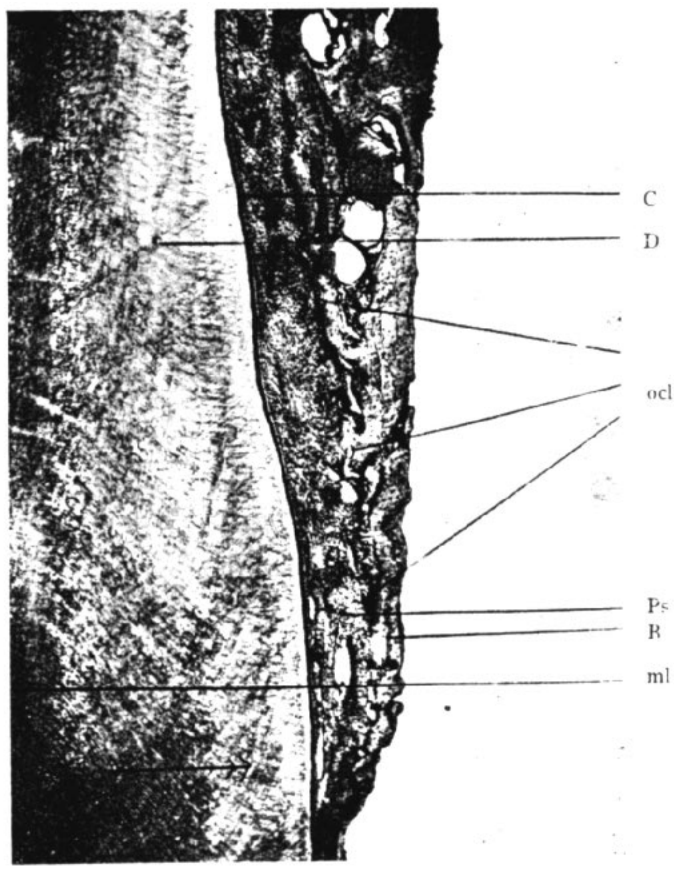
The active buccal movement proceeded in the direction of the single arrow, (Fig. 23). Therefore the corresponding surface-like extended resorptions on the buccal side, which reach to the upper third of the root, (a and b, Fig. 23), represent reactions that took place after a treatment of but six weeks! Between the two resorptions, a stretch of normal cementum has remained, (nC, Fig. 23). This part is reproduced in Fig. 25, in high magnification. We see, therein, the resorption corresponding to the alveolar crest, in the depth of which thick layers of secondary cementum (s C) are deposited. The length of this is 1.8 mm. There then follows a stretch of normal cementum, (n C), with a length 1.08 mm. Next, in turn, is a second resorption area, (b, of Fig. 23). In this, also, where only the lower part is visible, we see the deposition of secondary cementum, (sC., Fig. 25). This second place of resorption comprises an area of 2 mm. The whole resorption area, from the upper border of the upper resorption to the lower border of the lower resorption, measures 4.88 mm., which, with the total length of the root being 9.80 mm., is almost one-half of the entire length of the root.

Corresponding to the tilting of the apex we find resorptions at "e" and "d," Fig. 23. Resorption "e" is not visible in this particular slide. The point "d," likewise in the stage of full repair, is shown in Fig. 26 in high magnification. In the intra-radicular cementum, in the area of pressure, (pr., Fig. 23), there has been no injury to the cementum which may be considered an exception.

There are no traces to be seen of the treatment of a year ago which was only of short duration. These signs have been covered by the resumed treatment and the changes resulting therefrom. The alveolar crest has disappeared as a result of the active treatment, so that it no longer reaches the lower border of the most gingivally situated cementum resorption, (ac, Figs. 23 and 25). The shortening of the alveolar crest certainly occurred intravital, as demonstrated by the fibers between the bone and cementum which are still intact, (bi, Fig. 25). As a result of the relapse movement, (double arrow, Fig. 25), this alveolar crest and the whole lower half of the

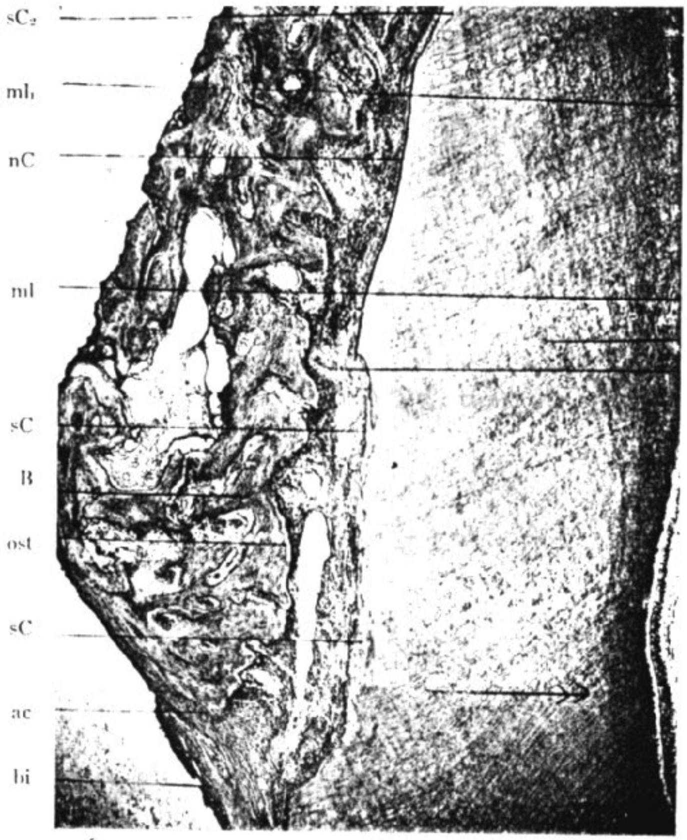
Specimen VI (Figs. 23 to 29) Figure 23
Magnification 8: direction of active movement, single arrow; direction of the relapse movement, double arrow; ac, alveolar crest; a, b, d, cementumresorptions; nC, normal cementum; P, pulp; pr, pressure sphere within the intraradicular septum during the active movement; ml, ml_1, ml_2, lines of measure.

buccal alveolar wall is in a state of apposition. (Osteoid seams beset with layers of osteoblasts,—ost, Fig. 25). This forms a contrast with the lingual alveolar wall, which now represents the area of pressure and therefore shows distinct marks of this influence. Fig. 24, a high magnification of the part "h," from Fig. 23, illustrates numerous resorption-lacunae with osteoclasts, (ocl., Fig. 24), in some places. This area was the area of traction during the active movement where osteoid bone was formed which, at the inversion of



Specimen VI (Figs. 23 to 29) Figure 24
Point "h" of Fig. 23; magnification 33; pressure side during the relapse movement (double arrow); B. bone; ocl. osteoclasts; C, cementum; D, dentin; Ps, periodontal space; ml, line of measure.

the movement, became resorbed. This resorption took away the whole osteoid, small individual parts being excepted, without the least trace of an alteration of the cementum. This movement, it must be admitted, was performed *almost biologically* without any external mechanical influence. During this self-movement of the tooth, which brought it almost completely back to its original position (2 mm.), we find, as also in another case which was examined under similar conditions, that the apposition and resorption take place



Specimen VI (Figs. 23 to 29) Figure 25
Point "a" of Fig. 23; magnification 33; direction of relapse movement, double arrow; ac, alveolar crest; B, bone; ost, osteoid; Ps, periodontal space; D, dentin; sC, secondary cementum; sC_2, secondary cementum in the resorption "b" of Fig. 23, the lowest part of which is visible; nC, stretch of normal cementum between the two resorptions; bi, fibres of connective tissue between bone and tooth; ml and ml_1, lines of measure.

without a perceptible broadening on the traction side (left in Fig. 23) and a narrowing of the periodontal space on the pressure side (right). In some places, an actual difference of but a hundredth of a mm. can be ascertained by measuring.

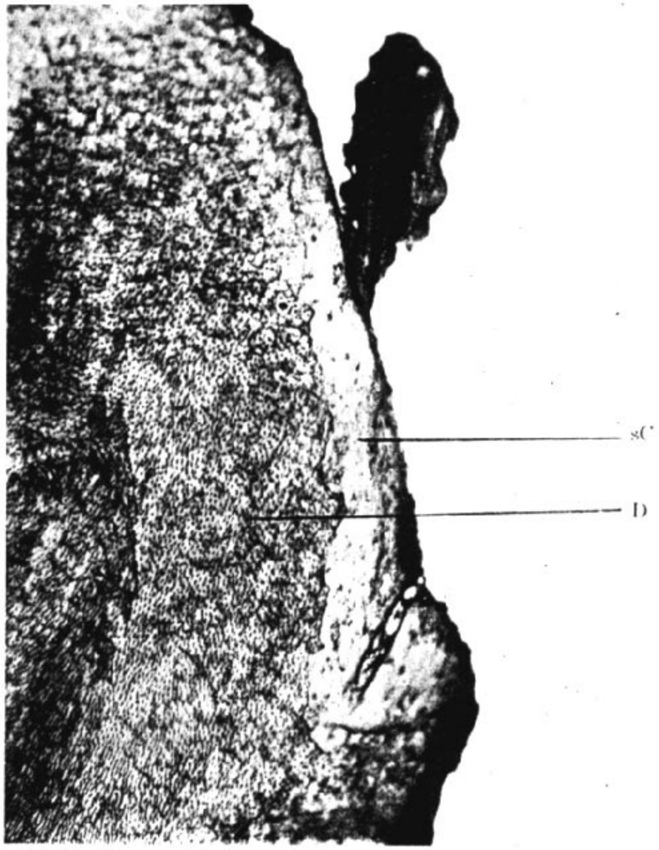
If, however, there is found, by actual measurement, an ascertainable microscopic narrowing of the periodontal space on the pressure side, with a corresponding broadening on the traction side, then it is not to be considered as a biological feature. A *biological picture* is only one which shows the resorbing processes on the bone without any injuries of the cementum and with almost unvaried periodontal width on the pressure and traction side, as in Figs. 24 and 25. The deposition of osteoid during the relapse movement happened in surface-like apposition on the buccal side which, by the reversal of the tooth movement, became the traction side, (ost., Fig. 25).

The measurements of the periodontal width, corresponding to the line "ml," Fig. 23, portions of which are reproduced in Fig. 24 (pressure side) and Fig. 25 (traction side) in equal magnification, read, on the lingual pressure side, a width of 0.275 mm. and on the labial traction side, a width of 0.20 mm. As a result of the often observed overshooting of the mark by the resorption when once established, the periodontal space is, on the pressure side, 0.075 wider than on the traction side. At a more apically located area the periodontal widths, on a corresponding measure-line as "ml," in Fig. 23, are equal in both parts, i.e., 0.225 mm. The pressure and traction areas in the intra-radicular septum in this relapse movement are reproduced in magnification in Figs. 27 and 28. In the area of pressure, (Fig. 27), are found distinctly ascertainable signs of resorptions in the bone, (lacunae and osteoclasts, ocl., Fig. 27). In the traction area, (Fig. 28), the bone specules are arranged in the direction of traction and framed by an evenly thick layer of osteoid bone beset with dense osteoclastic rows, (ost., Fig. 28).

In the intra-radicular *periodontal space*, on the pressure side, (P s, Fig. 27), there are numerous large vessels (v) and many extremely small ones, which conglomerate in a sponge-like formation, (v_1, Fig. 27), incomparably more pronounced than in the periodontal space on the traction side, (Ps, Fig. 28).

Although the relapse movement proceeded without any external influences, it took place at a rate that was faster than the movement of the tooth at normal evolution. This greater speed of movement, which caused a degree of pressure in the periodontal space which was more than a biological force, is responsible for the increase of vessels (pressure buffer) within the septum. That is the reason for designating this relapse movement as occurring "almost biologically," for in an actual biologic movement such a pregnant difference in the number of vessels on the pressure and traction sides is never noticeable.

The measurements in the intra-radicular septum, along the line "ml 2," (Figs. 23, 27 and 28), showed a periodontal width of 0.30 mm. on the pressure side, (Fig. 28) and 0.20 mm. on the traction side. Here, too, the overshooting of the mark by the resorption when once started, seems to be



Specimen VI (Figs. 23 to 29) Figure 26
Point "d" of Fig. 23; magnification 85; D, dentin; sC, secondary cementum.

responsible for the greater width of the periodontal space on the pressure side.

In spite of the six week's rest which had elapsed since the removal of the appliance until the extraction of the tooth, there are still to be found in the *pulp* numerous and thickly filled vessels. (v, Fig. 29), as well as injuries to the odontoblast layers caused by the presence of countless minute vacuoles, (V, Fig. 29).

Specimen VII (4): Girl of thirteen. The appliance used was a strong 0.50 mm. finger-spring 0.50 mm. in diameter and 8 mm. long, soldered to an

Specimen VI (Figs. 23 to 29) Figure 27
Point "x" of Fig. 23; magnification 33; pressure side within the septum during the relapse movement: B, bone; Ps, periodontal space; ocl, osteoclasts; C, cementum; D, dentin; v, vessels; v_1 spongelike grouped small vessels; ma, marrow spaces in the bone; ml, line of measure.

Angle expansion arch, 0.8 mm. in diameter. The spring, when passive, stood away from the tooth 2 mm. Treatment was started October 21, 1932. By means of a ligature, the spring was pulled to within a distance of ½ mm. from the tooth. In the course of four weeks (in the middle of December,

1932) the distance between 4/4 was increased 1 mm. Treatment was then interrupted for ten months. It was resumed on October 30, 1932 under the same conditions. On November 4, the spring broke and was repaired. Again on December 2 the spring broke. Once more it was repaired and put into

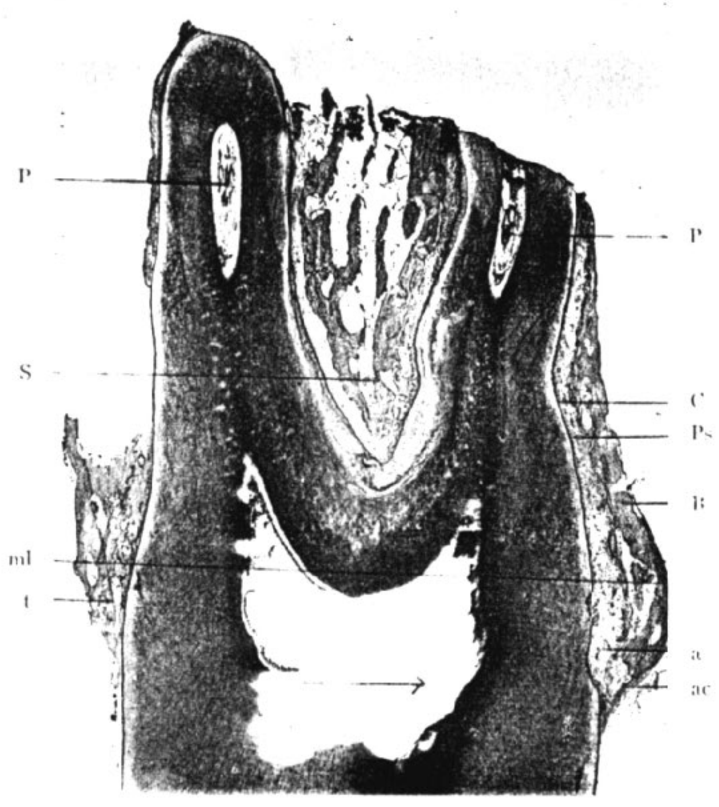
Specimen VI (Figs. 23 to 29) Figure 28
Point "y" of Fig. 23; magnification 33; traction side within the septum during the relapse movement; B, bone; Ps, periodontal space; ost, osteoid and osteoblasts; C, cementum; D, dentin; ml₂, line of measure.

activity in the same way. On December 15, 1932, the tooth was extracted. The extent of the tooth movement was 2 mm. *The whole time of treatment was forty-three days,—six weeks of continuous force.*

Corresponding to the mode of treatment we find pictures of the active effect of force. The movement was performed in the direction of the arrow, (Fig. 30). The alveolar crest (a c), which scarcely reaches the lower border of the cementum resorption "a," as well as the whole side of the bone facing the tooth, shows signs of most vivid osteoclastic destruction. Fig. 31 shows

Specimen VI (Figs. 23 to 29) Figure 29
Point "P" of Fig. 23; magnification 96; D, dentin; od. odontoblasts; v. vessels; V, vacuoles between the odontoblasts.

this part in high magnification. If treatment had progressed further it seems certain that this osteoclastic activity would have caused a still greater destruction of the alveolar crest. The greatly widened lacunar marrow spaces also show intensive osteoclastic destruction, which proves that the whole alveolar crest undergoes a thorough reconstruction. The remains of tissue changes which would confirm the treatment begun a year ago and interrupted, are not to be ascertained. They certainly have been covered or resorbed when the second period of treatment, which led to more intensive changes, was resumed. Unique among all specimens, is the finding of an osteoclastic

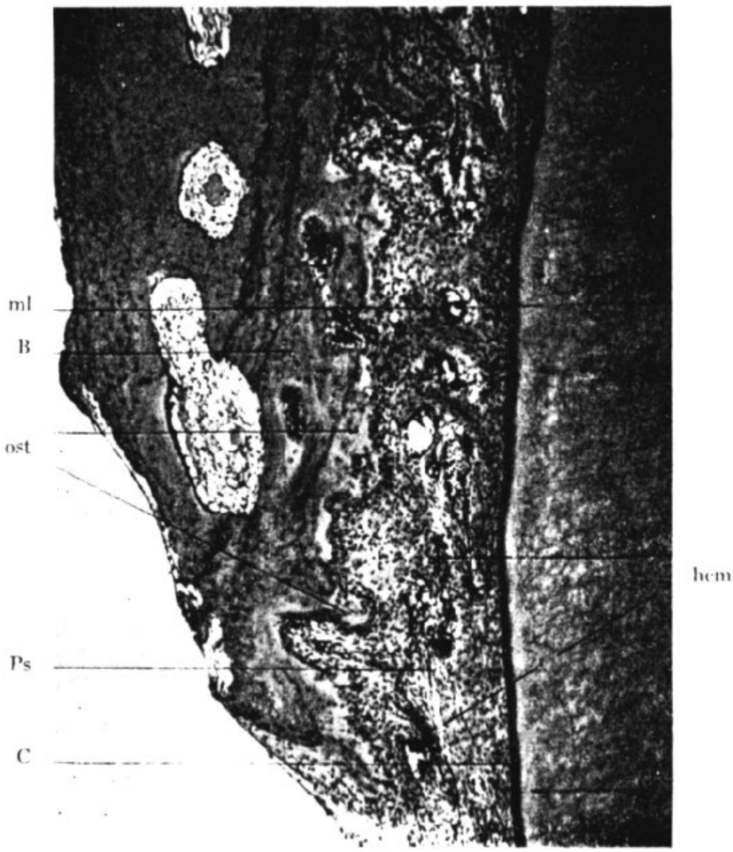


Specimen VII (Figs. 30 to 35) Figure 30
Magnification 8; direction of movement is indicated by the arrow; B, bone; ac, alveolar crest; C, cementum; a, cementumresorption; Ps, periodontal space; P, pulp of the roots; t, traction side; S, intraradicular bony septum.

resorption along the whole buccal alveolar wall down to the apex, (Fig. 33, a higher magnification of Fig. 30). The numerous osteoclasts, (ocl., Fig. 33), along the whole inside of the bone, can only be attributed to a parallel shifting of the tooth, which shifting, just as on the alveolar crest, as easily understood, varied sometimes to a greater degree, thus causing the cementum resorptions. No compensatory measures are made by nature against the quickly occurring attenuation of the alveolar wall. There is scarcely any indication of *osteophyt formation* on the periostal side of the bone.

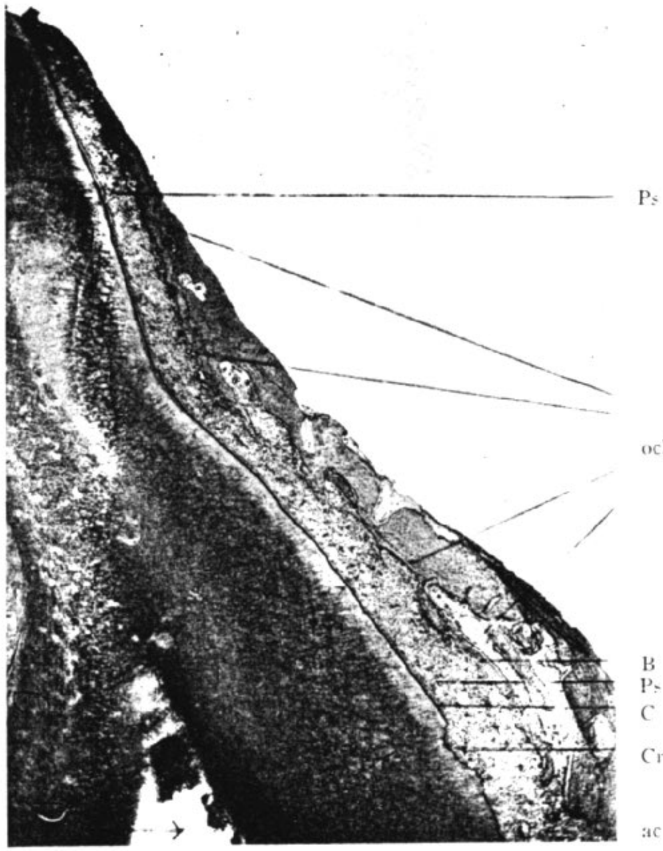
Specimen VII (Figs. 30 to 35) Figure 31
Point "a" of Fig. 30: magnification 60; direction of movement is indicated by the arrow; B, bone; ocl, osteoclasts; ac, alveolar crest; Ps, periodontal space; C, cementum; C_2 isles of normal cementum; cK, cementoclasts; ml, line of measure.

On the lingual traction side, (Fig. 32, a higher magnification of part "t" of Fig. 30). we find considerable formation of newly built osteoid bone in irregular thick layers and also in the shape of short spines, (ost., Fig. 32), which are densely beset by osteoblastic rows. Whether the periodontal space on the lingual traction side, owing to the parallel shifting, shows the same width along its full length as does the buccal side, cannot be ascertained because the periodontium and the bone are missing in the upper two-thirds of the root.



Specimen VII (Figs. 30 to 35) Figure 32
Point "t" of Fig. 30; magnification 60; direction of movement is indicated by the arrow; side of traction; B, bone; ost, osteoid; Ps, periodontal space; C, cementum; hem, hemorrhage; ml, line of measure.

In Fig. 31 we find, in high magnification, the cementum resorption, (a, Fig. 30), at the level of the buccal alveolar crest. In the upper third of the resorption we note, at C 2, two quite small isles of intact cementum between and upon which many multinuclear large cementoclasts are at work to remove these small cementum residues and to make the large lower resorption confluent with the smaller upper one. In these two large resorptions there are also numerous cementoclasts, (ck, Fig. 31), the picture of vivid progressive destruction. The length of the whole resorption area is 1.5 mm.

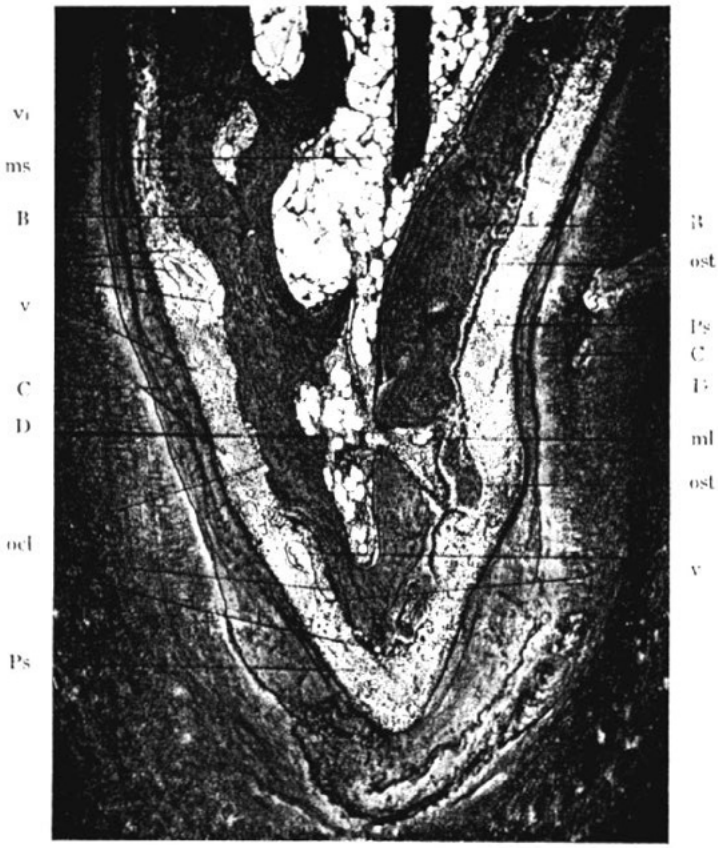


Specimen VII (Figs. 30 to 35) Figure 33
The entire side of pressure of Fig. 30; magnification 18; the lower border of the cementum resorption (Cr) is not to be seen; direction of movement is indicated by the arrow; B, bone; Ps, periodontal space; C, cementum; ac, alveolar crest; ocl, osteoclasts.

The cementum on the lingual traction side of the tooth, not being in occlusal contact, is free from resorptions, like the other portions of cementum.

A deviation of the apex did not occur but the findings point, on the whole, to the parallel shifting of the tooth, as was already stated. Therefore, we do not find any injuries to the cementum either at the apex (as far as the tissues are still preserved in the specimen) or in the intra-radicular septum at the areas of pressure where they might be expected.

The periodontal space, both on the labial pressure side and on the

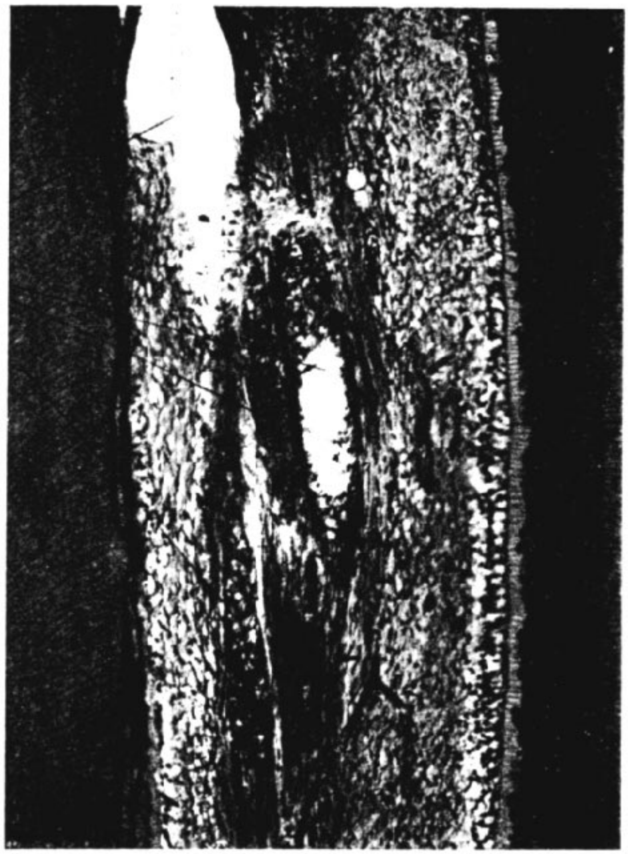


Specimen VII (Figs. 30 to 35) Figure 34
Sphere "S" of Fig. 30; magnification 26; B, bone; Ps, periodontal space; within the right side, side of traction, within the left side, side of pressure; ost, osteoid beset with osteoblasts; ocl, osteoclasts; v, vessels; v_1, spongelike conglomerated vessels; D, dentin; C, cementum; ms, marrow spaces; ml, line of measure.

lingual side, shows a normal picture in but few places. On the buccal pressure side, (Figs. 31 and 33), near the alveolar crest, the insertion of the suspensory fibers has been destroyed by the extended resorptions of tooth and bone. In the more apically situated parts, only the insertion in the bone is destroyed but this is sufficient to destroy the normal course of the fibers.

On the lingual traction side, as far as a periodontal space exists, we find traumatic injury with hemorrhage, (hem, Fig. 32).

There is no indication of an "angioma formation" on the labial pressure



Specimen VII (Figs. 30 to 35) Figure 35
Pulp; magnification 125; D, dentin; v, vessels; V, vacuoles.

side. The vitality is so much reduced by the effect of the pressure that no defensive biological reactions could occur. But in the intra-radicular periodontal space this "angioma formation" developed very distinctly along the *whole* side of pressure. In the present specimens this is the only case in which continuous force was applied wherein the buffer formation developed. This appeared only in that part of the periodontal space that was not exposed to direct pressure. In the right half of the intra-radicular septum, (Fig. 34, a high magnification of the parts of Fig. 30), we find, on the bone, distinct marks of the effect of traction. Osteoid seams appear in an even, thick layer, profusely beset with osteoblasts, (ost., Fig. 34). There are no blood vessels of any considerable diameter in the periodontal space within the area of traction. In the left half of the intra-radicular septum, on the pressure side, the whole bone adjoining the periodontal space is lacunar-bordered and has numerous osteoclasts in the lacunae, (ocl., Fig. 34). On this pressure side of the intra-radicular periodontal space we also see the haematoma-like buffer formation with numerous very small and also many large capillaries and vessels distinctly appearing, (v and v₁., Fig. 34). The contrast is striking.

The periodontal width on the measure-line, (ml, Figs. 31 and 32), which in all specimens was measured only at the places where the cementum was intact, registered 0.42 mm. on the pressure side, (Fig. 31), and 0.30 mm. on the traction side. Figs. 31 and 32 also show the inverse ratio of the expected proportions, perhaps resulting from overshooting of the mark of resorption. The usual expected and discernable reduction of the periodontal width on the pressure side, which can be seen by the microscope without measuring, and also the widening on the traction side, are found in the periodontal space of the septum. At the measure line, (ml, Fig. 34), the periodontal width on the traction side, right, is 0.25 mm.; on the pressure side, left, it is 0.18 mm. This difference in the width can readily be ascertained by merely observing the microscopic picture almost throughout the whole length of the intra-radicular periodontal space.

The *pulp* shows marked destructive changes. The odontoblasts either have been destroyed over long areas, as in Fig. 35 on the right, or the rows became considerably thinner because of numerous interspersed vacuoles, (V, Fig. 35). The vessels are increased and greatly enlarged and their walls are thickened by chalk deposition, (v., Fig. 35).

(*To be continued*)