Bone Changes Related to Eruption of the Teeth*

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Introduction

THE AIM of this report is to describe the histological changes in the bony structures associated with eruption of the teeth. The investigation is based on the study of 47 human jaws ranging in age from birth to 74 years.

Eruption, in the usual sense, means the movement of the tooth from the moment it emerges through the gingivae until it reaches the occlusal plane. It has been known for a long time that this movement is only a part of the total motion which the teeth undergo during their life span. They move before they come into the place from which they emerge into the oral cavity, and they continue to move after they have reached the occlusal plane.[1] There seems to be justification for defining the term eruption as including all the movements of the teeth preparatory to their appearance in the oral cavity, their emergence into the oral cavity and also their movements after reaching the occlusal plane.

In analyzing the relationship of the position of the tooth to the jaw, differentiation between active and passive eruption[2] has been ascertained. Active eruption is the drift of the tooth in relation to the jaw. Assuming that opposing points were marked on the tooth and on the jaw, it could be observed after some time that the two points had moved apart. Passive eruption is the shifting of the epithelial attachment in an apical direction, i.e., recession of the gum. Both processes, active and passive eruption, are continuous, presumably, throughout the entire life of the tooth. For the present discussion and for a better understanding it is advisable to separate these phenomena. Our investigation is concerned only with the *active* eruption of the tooth.

In the present study it seems advisable to divide these movements into two periods; one period concerned with the active eruption of the deciduous teeth and a second one dealing with the eruption of the permanent teeth. Each period is further subdivided into three phases. It is always necessary to keep in mind that the movement of the teeth is more complicated than a diagrammatic description can indicate. The periods and phases are not clean-cut and overlap in different types of teeth and in different individuals.

The First Phase of the First Period covers the time of the growth process of the deciduous tooth germs. The rate of growth of the surrounding bone at this time is in accordance with the slow development and growth of the

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[1] Gottlieb, Bernhard; Ein Fall von scheinbarer Verkuerzung eines oberen seitlichen Schneidezahnes (A Case of So-Called Shortening of an Upper Lateral Incisor), Ztschr. f Stomatol. 22: 501, 1924.

[2] Gottlieb, Bernhard, Orban, Balint and Diamond, Moses; Biology and Pathology of the Tooth and Its Supporting Mechanism, The Macmillan Co., New York, 1938.

tooth germs. During this phase the permanent teeth make their appearance. The Second Phase is typified by an accelerated rate of eruption and extends from the appearance of the deciduous teeth in the oral cavity until they reach their antagonists. The permanent tooth germs develop slowly during this time, steadily changing their positions. During the Third Phase the deciduous teeth are in occlusion and they continue to erupt while the permanent teeth progress further in development.

The active eruption of the permanent teeth is designated as the Second Period. During this period the permanent teeth go through fundamentally the same three phases and in an analogous fashion to the deciduous teeth. The First Phase covers the development of the permanent tooth germ. The

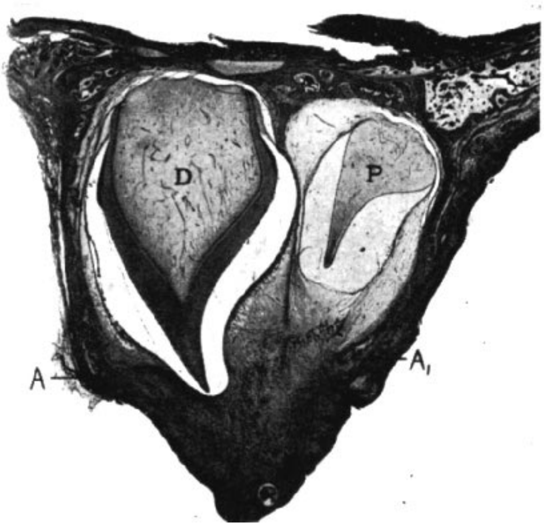


Fig. 1—Buccolingual section through upper lateral deciduous (*D*) and permanent (*P*) incisors of a 2 month old child. Apposition of uncalcified layer of bone at the fundus of the deciduous tooth germ and at the buccal (*A*) and lingual (A_1) alveolar crest. (First Phase)

Second Phase starts at the time of the appearance of the tooth in the oral cavity and ends when the teeth meet at the occlusal plane. The Third Phase covers the remaining life span of the permanent tooth.

First Phase of Active Eruption of the Deciduous Teeth

A labiolingual section through the lateral incisors of the upper jaw of a two months old child is shown in Fig. 1. The formation of the crown of the first deciduous incisor is complete while the calcification of the enamel is still progressing. A part of the root is formed. The bony crypt shows apposition of bone in the area of the fundus and rim. The area of apposition at the fundus of the deciduous lateral incisors is characterized by deposition of bone lined with osteoblasts. This apposition indicates that the tooth germ is moving in an occlusal direction. The rate of this movement is comparatively slow as is suggested by the histological fact that the new bone is being deposited layer on layer.

A higher magnification of the labial and lingual bony crest is shown in Fig. 2. A broad strip of uncalcified, coarse-fibered bone indicates the progress of new bone formation. Part of the calcified coarse-fibered bone has been replaced by lamellated bone and this transformation is continuing. The lingual alveolar plate shows signs of resorption on the side facing the permanent tooth germ caused by the growth of the permanent tooth germ. On the periosteal (palatine) surface of the alveolar plate, apposition is taking place.

The First Phase of active eruption of the deciduous teeth is characterized

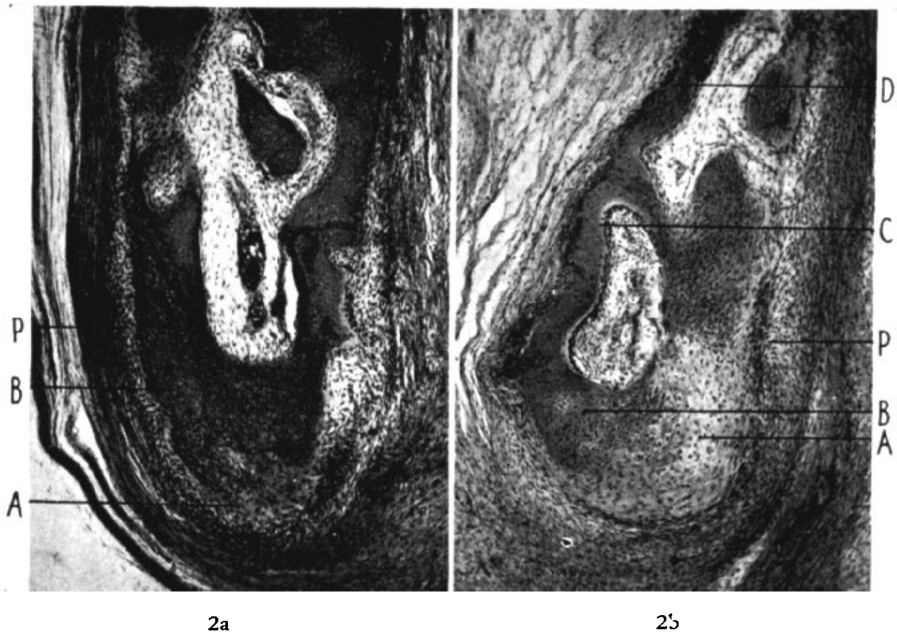


Fig. 2—Higher magnification of the buccal alveolar crest (2a, *A* in Fig. 1) and of the lingual alveolar crest (2b, A_1 in Fig. 1). Apposition of uncalcified, coarse-fibered bone (*A*) on calcified, coarse-fibered bone (*B*). The coarse-fibered bone is replaced by lamellated bone (*C*) from the side of the marrow space. *D*, resorption on the side toward the permanent tooth germ. *P*, periosteum.

by apposition of bone occurring layer on layer at the fundus and the margin of the crypt.

Second Phase of Active Eruption of the Deciduous Teeth

The following illustrations demonstrate this phase on an upper deciduous cuspid. The general view (Fig. 3) shows the area of the deciduous upper cuspid and first molar of a one and one half year old child. While the tip of the deciduous cuspid has just appeared in the oral cavity, the first deciduous molar has reached the occlusal plane, and is therefore in the Third Phase. The alveoli of these two teeth present a striking difference. On the fundus of the transitory alveolus of the deciduous cuspid approximately eight concentric layers of bone trabeculae can be differentiated and almost

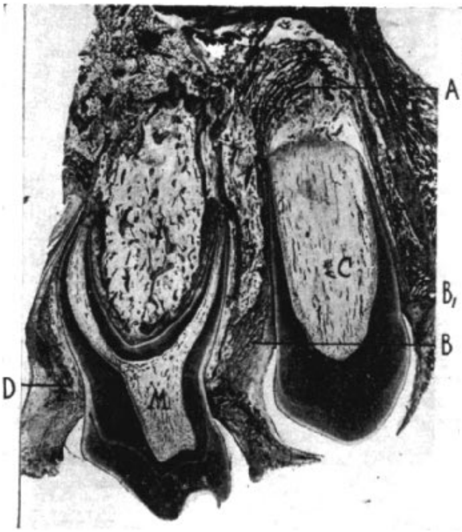


Fig. 3—One and one-half year old child. Upper deciduous cuspid (*C*) rapidly erupting and first deciduous molar (*M*) in occlusion. Parallel arrangement of bone trabeculae separated by marrow spaces at the fundus (*A*) and at the alveolar crest (*B* and B_1). (Second Phase). Apposition of bone in the bifurcation and at the alveolar crest (*D*). (Third Phase)

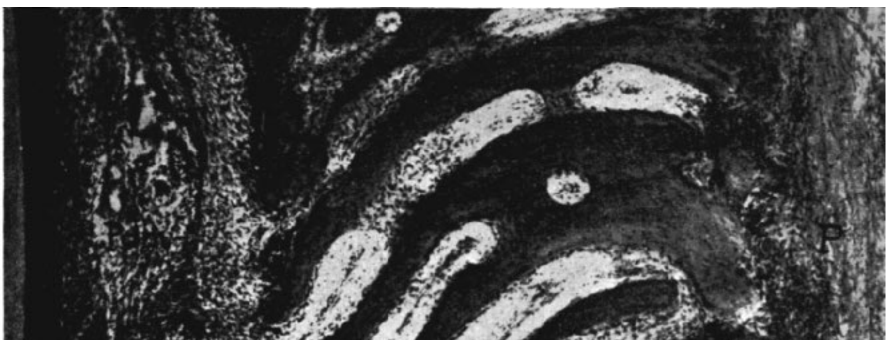


Fig. 4—Higher magnification of area B_1 in Fig. 3 on the mesial side of rapidly erupting deciduous cuspid. The surface toward the gingiva is covered with a thin, uncalcified layer of bone and is lined by a row of osteoblasts. *Pdm*, periodontal membrane. *P*, periosteum.

the same number of trabeculae are visible on the mesial and distal sides at the crest. The trabeculae run approximately at a right angle to the long axis of the tooth. The wide space between Hertwig's epithelial sheath and the apical bone trabeculae indicates the comparatively rapid movement of the deciduous cuspid. An accumulation of connective tissue cells, occlusally from the last trabecula, shows that a new bone trabecula is starting to develop. A zone of loose connective tissue indicates the area which will become a new bone marrow space bordered by the last bone trabecula and the new one which is developing.

A high magnification of the mesial side of the deciduous cuspid (Fig. 4) shows a parallel arrangement of the bone trabeculae indicating the fashion

Fig. 5—Higher magnification of the alveolar crest of the deciduous molar (*D* in Fig. 3). The alveolar crest consists of coarse-fibered bone. At the tip of the crest uncalcified bone (*A*) is deposited on calcified, coarse-fibered bone. Lamellated bone lines the marrow space. *Pdm*, periodontal membrane. *P*, periosteum.

in which they were formed. The gingival surface of each trabecula is covered with a thin, uncalcified layer of bone and, adjacent to it, a row of osteoblasts.

During the Second Phase of active tooth eruption the growth of the jaw and the eruption of the tooth proceed faster than the development of the root. The distance between the end of the root and the fundus of the transitory alveolus increases and the space between them becomes filled with new bone as the eruption of the tooth advances. At the same time new bone is formed also at the bony crest. The characteristic feature is the formation of bone in trabecular arrangement at the fundus and crest of the crypt, which can be interpreted as a sign of rapid growth.

Third Phase of Active Eruption of the Deciduous Teeth

While the deciduous cuspid in Fig. 3 is still in the Second Phase of rapid eruption, the deciduous molar, which has reached the occlusal plane, is already in the Third Phase. The alveolar wall, composed of lamellated bone, and the arrangement of the fibers of the periodontal membrane show that the tooth is in function. A higher magnification (Fig. 5) of the region at the distal alveolar crest demonstrates that the surface is covered with a layer of uncalcified, newly-formed bone. This alveolar crest is growing by the apposition of bone one layer on top of another, and not by the formation of trabeculae separated by marrow spaces, which is characteristic of the Second Phase. The calcified, coarse-fibered bone has been resorbed and is being replaced by lamellated bone.

The Third Phase is represented by another specimen showing the frontal region of the upper jaw of a child of about two years (Fig. 6). Both

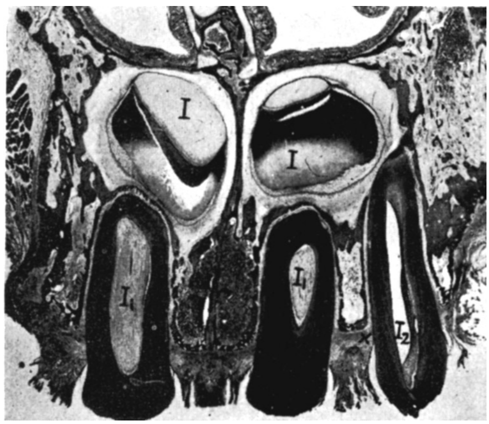


Fig. 6—Frontal region of the upper jaw of a two year old child. The crowns of both deciduous central incisors and the lateral incisor show decay. Bone apposition is found at the fundus as well as the alveolar crest as an indication of slow eruption. (Third Phase) *I*, tooth germs of permanent central incisors. I_1, deciduous central incisors. I_2, lateral deciduous incisors.

central and lateral incisors show signs of severe decay. This observation and the location of the epithelial attachment indicate that the teeth have been in the oral cavity for some time. Tangential sections of both permanent central incisors show that calcification of the enamel is in progress. A higher magnification (Fig. 7) illustrates the alveolar crest on the mesial side of the lateral incisor. The surface of the bony crest is formed by a layer of uncalcified bone lined by osteoblasts indicating that growth of the bone is progressing.

In the Third Phase the characteristic findings are apposition of bone, layer upon layer, at the fundus and alveolar crest, which indicates slow growth.

First Phase of Active Eruption of the Permanent Teeth

The permanent teeth go through the same stages, principally, as the deciduous teeth. There may be slight differences due to the topography of various tooth germs. Some of the permanent teeth have temporary predecessors, while others do not. Accordingly they undergo different, sometimes complicated, movements before they reach the place from which they will

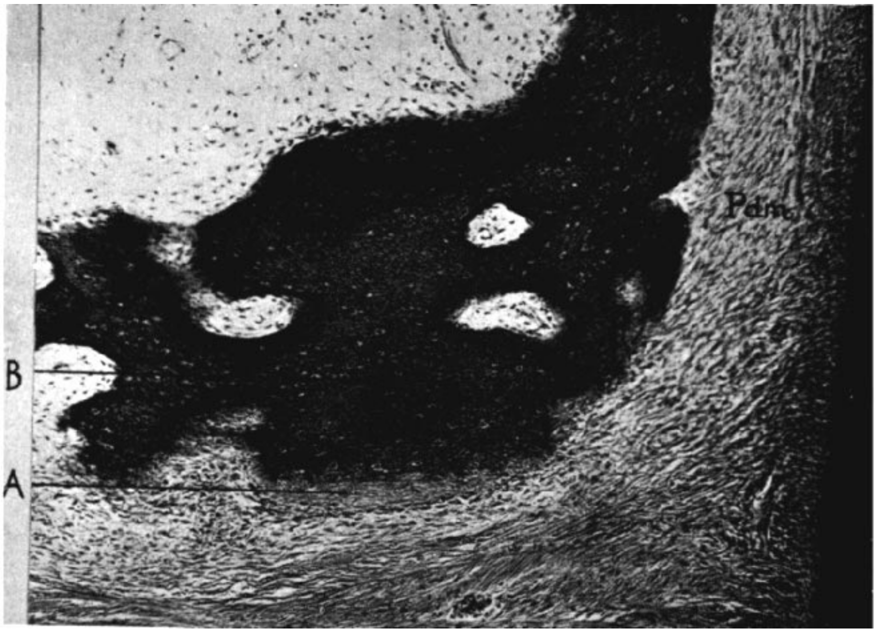


Fig. 7—Higher magnification of x in Fig. 6. Alveolar crest on the mesial side of the deciduous lateral incisor. *A,* uncalcified, coarse-fibered bone. *B,* calcified, coarse-fibered bone. *Pdm,* fibers of periodontal membrane.

eventually emerge. This can be seen in the different movements of the bicuspids (Fig. 7) and molars.

The tissue changes during this phase are characterized by slow formation of new bone and resorption according to the movements and growth of the respective tooth germs, just as it occurs in the First Phase of the eruption of the deciduous teeth.

Second Phase of Active Eruption of the Permanent Teeth

During the Second Phase in the active eruption of the permanent teeth the same processes can be observed as occurred during the fast eruption of the deciduous teeth. Again we find rapidly growing bone at the fundus and crest of the developing alveolus. This phase is illustrated by an upper central incisor of an eight year old child (Fig. 8). The bottom of the gingival crevice is located at the border between the occlusal and middle third of the anatomical crown. The alveolar crest extends above the cemento-enamel junction and is formed by a network of spongy bone. The alveolar bone in the fundus of the alveolus is composed of parallel trabeculae. Between the last bone trabecula and Hertwig's epithelial sheath a wide space is observed which will become filled with new trabeculae in the course of eruption. This picture closely resembles the one found in the rapidly erupting deciduous tooth (Figs. 3 and 4).

Third Phase of Active Eruption of the Permanent Teeth

When the permanent tooth reaches the occlusal plane, the Third Phase of continuous active eruption of the permanent teeth begins. The following figures were taken from the jaw of a 64 year old man who died of uremia. Fig. 9 shows the upper left first and second bicuspids. According to the

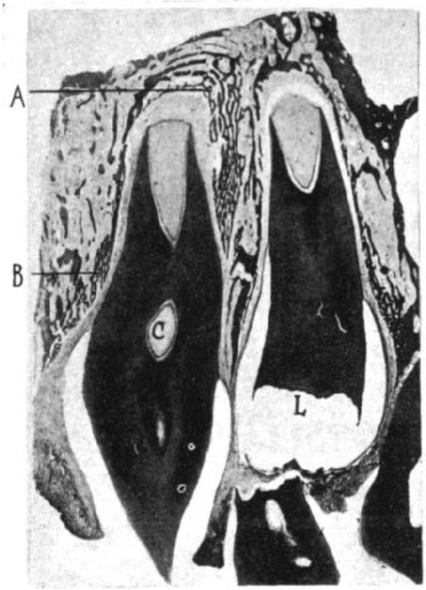


Fig. 8

Eight year old child. Permanent upper central (*C*) and lateral (*L*) incisors. The root of the deciduous lateral incisor is resorbed. Parallel bone trabeculae at the fundus (*A*) and at the alveolar crest (*B*) is an indication of rapid eruption. (Second Phase)

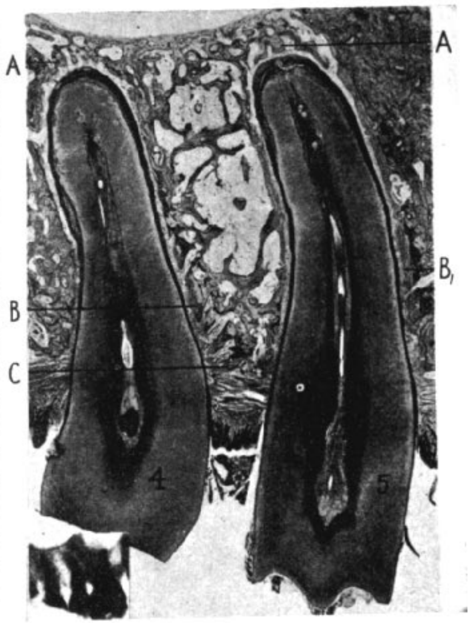


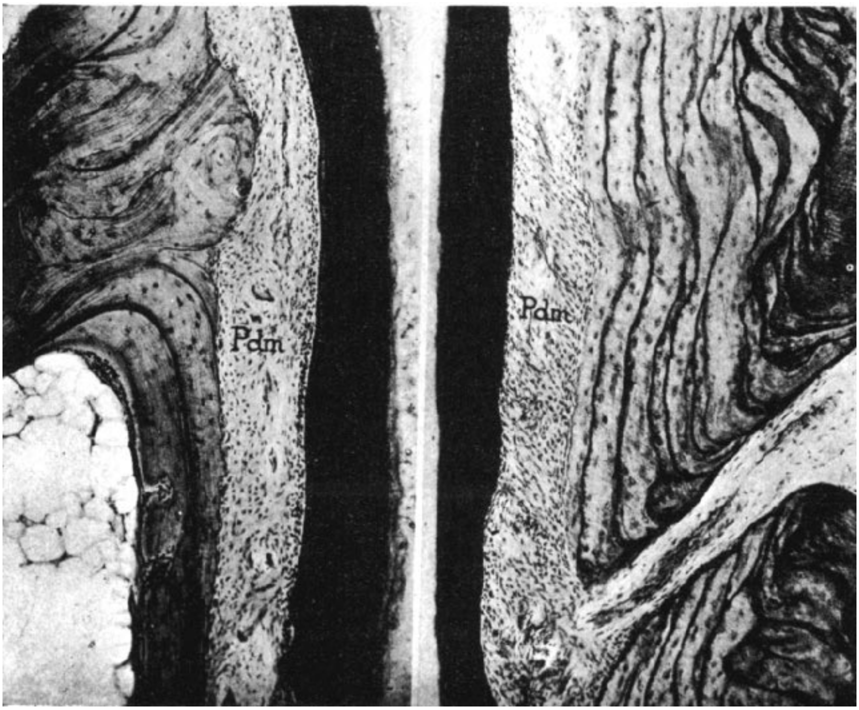
Fig. 9

First (*4*) and second (*5*) bicuspids of a sixty-four year old person. The root of both bicuspid teeth are curved mesially as seen in the roentgenogram. Bundle bone at the fundus (*A*), at the distal wall (*B* and B_1) and at the alveolar crest (*C*) as an expression of slow, continuous migration. (Third Phase) On the mesial side of both teeth bone resorption is taking place.

photographs and records made before the histologic preparations, the second bicuspid shows moderate wear on the lingual cusp and extensive wear on the buccal cusp. The first bicuspid is abraded more than the second. Both teeth were in occlusion at the time of death.

The gingiva of these teeth shows signs of slight inflammation. The distal surface of the alveolar wall in the region of the apex of both teeth is lined with a comparatively thick layer of bundle bone; whereas, on the mesial side of both teeth, lamellated bone borders the periodontal space. A higher magnification of some of the areas of the "alveolar process proper" may illustrate the details.

The mesial, and the distal surfaces of the second bicuspid are illustrated in Figs. 10a and 10b respectively. In the distal alveolar bone (Fig. 10b) bordering the periodontal membrane many resting lines can be seen running parallel to the surface of the root. In the area where the bone borders a nutritional channel the resting lines are bent, which is indicative of the occluso-mesial direction in which the bone was deposited. The occlusal component is connected with the active eruption of the tooth; the mesial



a b

Fig. 10—a. Mesial periodontium of the second bicuspid showing resorption of the lamellated alveolar bone. b. Distal alveolar bone (*B* in Fig. 9) showing bundle of fibers incorporated. The resorption on the mesial side (a) is a sign of pressure, while the bundle bone formation (b) is a sign of tension.

component with the mesial drift. The direction of the principal fibers in the periodontal membrane and of the Sharpey's fibers in the bundle bone is such as is found on normally functioning teeth. The bone surface facing the periodontal membrane is covered with a thin layer of uncalcified, newly-formed bone. In some areas the adjacent osteoblasts are arranged in a row.

The cementum on the mesial side (Fig. 10a) shows a picture similar to that found on the other side; in addition, it is covered with a delicate, light-stained layer of cementum lined with a distinct row of cementoblasts. The alveolar bone is formed by lamellated bone, the cementing lines of which are parallel to the adjacent bone marrow spaces which are filled with fat marrow and lined with a thin strip of connective tissue. The periodontal surface of the alveolar bone in this region shows a continuous row of shallow osteoclastic lacunae. In these lacunae mostly uninuclear and a few multinuclear osteoclasts are observed. On the surface of the bone marrow spaces osteoblastic apposition is in progress.

These histological findings demonstrate that the second bicuspid has moved in a mesial direction for a long time. The continuous apposition of bone on the distal side of the alveolar process and the progressing resorption

Fig. 11—Higher magnification of the region *C* in Fig. 9. Interdental space between first and second bicuspids. Formation of bundle bone (*A*) is an expression of the migration of the tooth. Resorption (*B*) of the lamellated bone caused by a slight pressure of the migrating tooth.

on the mesial side indicate that this process had not stopped until the individual died.

A very similar picture, which is interpreted in the same way, can be observed by comparing the mesial side of the second bicuspid and the distal side of the first bicuspid. In Fig. 11 showing the interdental space and the alveolar crest, the resting lines of the bundle bone on the distal side of the first bicuspid run parallel to the surface of the tooth but are bent in areas where the bone borders nutritional channels and on the crest of the alveolar ridge. From the arrangement of the resting lines it is evident that the tooth was moving in an occlusal-mesial direction. The distal alveolar crest of the second bicuspid shows the same characteristic course of the resting lines and Sharpey's fibers in the bundle bone as was seen in the alveolar crest between the first and second bicuspids. A thin line of uncalcified bone and cementum demonstrates that the apposition of bone, as well as apposition of cementum, was still progressing in this region.

The histological evidence of slow apposition of bone, layer upon layer at the fundus as well as at the alveolar crest proves beyond any doubt that even in this sixty-four year old man, the teeth were still erupting. Different pathologic conditions frequently met in human jaws will often obscure the picture, destroying part of the alveolar bone and removing evidence of con-

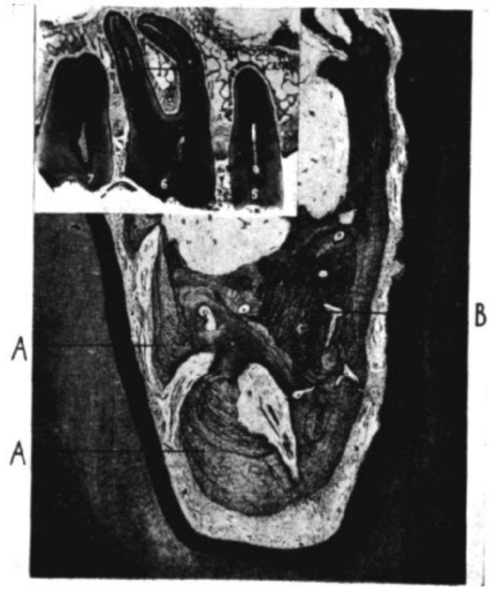


Fig. 12—The insert shows the second bicuspid (5), first (6) and second (7) molars of a sixty-four year old person. At *A* and *B* gingival part of the septum is resorbed. The epithelial attachment on all teeth is on the cementum. The interradicular septum (*C*) is well preserved. Bundle bone at the fundus of the bicuspid and molars. The higher magnification of *C* in the general view shows that the direction of fiber bundles in the bundle bone (*A*) is in the direction of the movement of tooth and growth of bone. *B*, remnant of bundle bone from an earlier life period surrounded by lamellated bone.

tinuous eruption. But closer examination of such cases will reveal at least in some protected or undamaged regions conclusive signs of this process. A good example is found in the teeth on the right side of the same individual 64 years old, the left side of which was before described. The general view in Fig. 12 shows the upper second bicuspid and first and second molars of the right upper jaw of this individual. Severe inflammatory processes have destroyed a comparatively large part of the alveolar bone, especially in the region of the two molars. But those areas which were not reached by the inflammation show continuous apposition of bone as a sign of continuous active eruption. Such regions are the alveolar fundi of the two molars and the bicuspid tooth (Fig. 12) and the interradicular septum of the first molar which appears unaffected by the gingival irritation.

The high magnification of the interradicular septum of the first molar, Fig. 12, shows that the cementum covering the bifurcation of the molar contains a small area of repaired resorption. The mesial and distal sides of the periodontal membrane are of about the same thickness; whereas, the periodontal membrane covering the interradicular crest shows almost twice the thickness of the lateral parts. The crest of the interradicular septum shows several layers of bundle bone. The resting lines indicate the way in

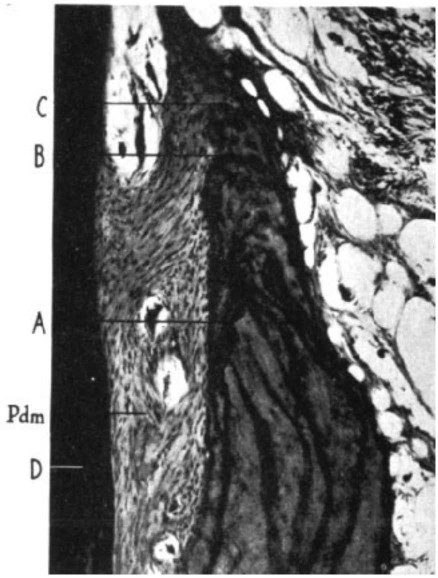


Fig. 13—Lingual alveolar crest of the second right upper molar of a sixty-four year old person. *A,* resorption line (reversing line) on which bone is deposited layer on layer separated by incremental lines (*B*). *C,* newly-formed bone. *Pdm,* periodontal membrane. *D,* cementum.

which the bone was formed. A thin layer of uncalcified bone reveals that this process was continuing. Sharpey's fibers run in an opposite direction to those we saw in the bicuspids on the other side (Figs. 10, 11). This difference can be explained by the fact that the molar had no occlusal function having lost its antagonist a long time ago. This may account too for the greater thickness of the bundle bone and wider periodontal space in this region.

While most of the old bundle bone is replaced by lamellated bone arranged in Haversian systems, some of it has escaped this transformation. This remnant indicates an earlier position of the tooth. Resorptive processes are found in some areas of the bone marrow spaces which are filled with fat marrow, while, in other places, new bone has been formed.

From the analysis of this case and from the study of the material at our disposal the conclusion can be drawn that the active eruption of teeth continues throughout life. The histological evidence is the continuous but slow apposition of bone at the fundus as well as at the alveolar crest. The frequent occurrence of inflammation of the gingivae, however, leads in many instances to a resorption of the alveolar crest and thus obscures the histologic picture.

At some time the continuous apposition of bone may have been interrupted by a destructive process but was reversed later by apposition of new bone. A photomicrograph (Fig. 13) of the alveolar crest of the left upper second molar of the same sixty-four year old individual illustrates such an occurrence. On the alveolar process two parts can be distinguished which are separated by a lacunar resorption line. The concavity of the lacunae is directed toward the gingiva. The part of the bone apical to this line is characterized by resting lines running parallel to the surface of the tooth. This part of the bone consists of typical lamellated bone. The part of the bone which lies occlusally to the lacunar line is divided into distinct layers by resting lines which run at approximately a right angle to the surface of the tooth. A thin layer of uncalcified bone covering the highest part of the crest indicates that the bone was still growing in this area.

Interpreting this histological picture we may assume that some time ago inflammation of the gum or occlusal trauma caused osteoclastic resorption of the alveolar process. The lacunar line indicates the limit to which this destruction advanced. For some reason, the inflammation or trauma subsided and new bone was deposited on this lacunar line.

Erdheim called such a cementing line a "reversing line" because the process of resorption was reversed and new bone was formed. It is important to distinguish this type of line from resting lines in order to judge whether, in a certain region, the bone was formed continuously or whether the continuous process of formation was interrupted by pathological conditions.

Discussion and Review of Literature

The findings described in this report partly confirm and partly supplement our knowledge regarding the positional changes of teeth in relation to the jaw.

Former investigators were aware of the fact that the tooth germs undergo certain movements. Orban[3] demonstrated that the distance between Hertwig's epithelial sheath and the floor of the nose steadily increases during the time the teeth develop and erupt. Logan[4] showed that the buds of the permanent bicuspids are first located occlusally with respect to the deciduous teeth, later the permanent tooth germs become situated more and more toward the cervical region until at last they are at the apex or bifurcation of the deciduous teeth. This observation may be explained primarily by the fact that the deciduous tooth germs move occlusally and at the same time the permanent tooth germs migrate to their new positions.

During this time, designated in our study as the First Phase in active eruption, apposition of bone takes place on the surface of bone previously laid down at the fundus as well as at the crest of the crypt. This process of apposition may stop for a time as evidenced by incremental resting lines seen in the newly formed bone, or it may be interrupted occasionally as indicated by resorption lines.

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[3] Orban, Balint; Growth and Movement of the Tooth Germs and Teeth, Jour. Am. Dent. Assn. 15: 1004, 1928.

[4] Logan, William H. G.; A Histologic Study of the Anatomic Structure Forming the Oral Cavity, Jour. Am. Dent. Assn. 22: 3, 1935.

Orban[5] demonstrated the parallel arrangement of bone trabeculae along the lateral wall of erupting teeth. Kronfeld[6] described the formation of parallel bone trabeculae at the fundus of erupting teeth. These findings have been utilized by Gottlieb-Orban-Diamond[2] and Kronfeld-Weinmann[7] in explaining the biologic processes found during eruption. Reichborn-Kjennerund[8] reported similar findings without explaining their significance. This parallel arrangement of bone trabeculae at the fundus and lateral wall of the crypt of erupting teeth is interpreted generally as an expression of the rapid movement of the respective teeth.

The present investigation has proved that the same parallel arrangement of bone trabeculae seen at the fundus of the crypt is present at the alveolar ridge during the Second Phase of continuous eruption of the deciduous teeth.

The Third Phase covers the time during which the deciduous teeth are in occlusion and in function. During this Third Phase of active eruption the deciduous teeth continue to move occlusally. This is evidenced by the findings of slow continuous apposition of bone at the alveolar fundus and crest during this phase.

The First Phase in the eruption of the permanent teeth is overlapped by all phases of the eruption of the deciduous teeth. During this time the permanent tooth germs complete a complicated course of movement from a location close to the crown of the deciduous teeth to the apical region of single-rooted and the bifurcation of multirooted teeth.[4] During this entire time bone resorption and apposition takes place in accordance with the movement and growth of these tooth germs. This transformation takes place at a relatively slow rate.

During the Second Phase of the eruption of the permanent teeth the shedding of the deciduous teeth takes place. Throughout this phase the permanent teeth move rapidly until they reach their antagonists and get into function. The anatomical structure of the growing bone at this time is similar to that correlated with the rapid eruption of the deciduous teeth. A parallel arrangement of bone trabeculae at the alveolar fundus as well as at the alveolar crest is found at this phase.

It was first pointed out by Gottlieb[1] that the process of eruption does not stop when the permanent opposing teeth come into contact (Third Phase). He came to this conclusion by interpreting his observation of a so-called "shortened tooth." Sicher[9] and Willman[10] confirmed his finding by analyzing similar cases.

[5] Orban, Balint; Dental Histology and Embryology, Rogers Printing Co., First Edition, Chicago, 1928.

[6] Kronfeld, Rudolf; The Resorption of the Roots of Deciduous Teeth, Dent. Cosmos 74: 103, 1932.

[7] Kronfeld, Rudolf and Weinmann, Joseph, P.; Traumatic Changes in the Periodontal Tissues of Deciduous Teeth, Jour. Dent. Res. 19: 441, 1940.

[8] Reichborn-Kjennerud, I.; Uber die Mechanik des Durchbruches der bleibenden Zaehne beim Menschen (The Mechanics of Eruption of the Permanent Human Teeth), H. Meuser, Berlin, 1934.

[9] Sicher, Harry; Die sogenannten verkuerzten Zaehne (Apparently Shortened Teeth), Ztschr. f. Stomatol. 26: 396, 1928.

[10] Willman, Warren; An Apparent Shortening of an Upper Incisor: Its Significance, Jour. Am. Dent. Assn. 17: 444, 1930.

In this connection I should like to refer to Willman's case to illustrate this condition. The photograph (Fig. 14a) shows the anterior region of an upper jaw of a fourteen year old boy. The examination disclosed a porcelain crown approximately two millimeters shorter than the adjacent central incisor. The history stated that it had been the same length when placed two years previously. An accident at a baseball game was the occasion of the restoration. The X-ray (Fig. 14b) reveals that the tooth is of normal length compared with its neighbors. A histological examination (Fig. 14c)

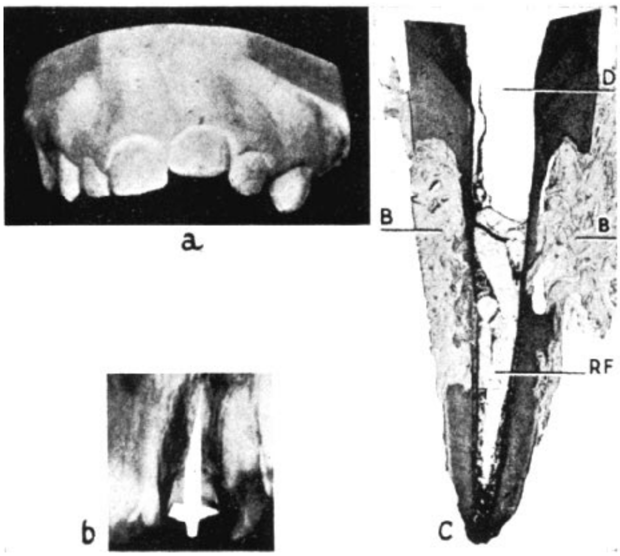

Fig. 14—a. Plaster cast of the upper anterior teeth showing the upper left central incisor to be approximately 2 mm. shorter than the right. b. X-ray of the upper central incisors. c. Mesiodistal section of the upper left central incisor showing large areas of resorption with replacement by bone. *B*, bone. *D*, space formerly occupied by the dowel supporting the porcelain crown. *RF*, pulp canal filling. (Courtesy W. Willman, *Jour. Am. Dent. Assn.* 17: 444, 1930.)

of the extracted, shortened tooth shows that the surface of the root was resorbed. Resorption and repair took place alternately until an ankylosis of the tooth and bone set in. At the time of trauma all teeth were at the same eruptive level. Later, however, the injured tooth was arrested by the ankylotic anchorage while the other teeth erupted normally. In this way the shortened tooth indicates the location of the occlusal plane at the time of the accident which occurred two years previously. The difference between the shortened tooth and its neighbors indicates the amount of eruption of the uninjured teeth during two years when they were undoubtedly in function.

Histological evidence for the continuous active eruption of functioning permanent teeth was brought out by Weinmann's observation[11] of the for-

[11] Weinmann, Joseph, P.; Das Knochenbild bei Stoerungen der physiologischen Vanderung der Zaehne (The Bone Picture in Cases of Disturbances of the Physiological Drift of Teeth), Ztschr. f. Stomatol. 24: 397, 1926.

mation of bundle bone at the alveolar fundus. The fact that bundle bone occasionally is found apically to and distant from the periodontium indicates, by the presence of embedded Sharpey's fibers, the previous location of the periodontium. The presence of epithelial rests in the vascular canal apically to the periodontium, far from the apex, led Orban[12] to the same conclusion.

The process of continuous active eruption is complicated by a mesial drift of the teeth. Eruption does not occur at a right angle to the occlusal plane but at an acute angle directed mesially.

Black[13] observed that teeth move physiologically in a mesial direction; and more than ten years ago Stein and Weinmann[14] were able to prove the clinical observation by histological evidence.

In the present study it could be demonstrated that the continuous eruption of teeth as indicated by apposition of bone at the fundus and the mesial drift of the teeth indicated by apposition of bone at the distal surface of the alveoli continues in all probability throughout life. In addition to this it could be shown that apposition of bone normally takes place on the alveolar crest, too. This simultaneous growth of bone at the fundus and at the alveolar crest tends to preserve the normal depth of the alveolus and thereby a normal fixation of the tooth.

Recent investigations of Hoffman and Schour[15] have shown that eruption of rat molars follows fundamentally the same rules as eruption of human teeth. By injecting alizarin they demonstrated that bone apposition at the fundus and alveolar crest on one side and cementum apposition on the other side progress throughout the life of the animal. They showed, in addition, that the rat molar drifts mesially as do human teeth. While the essential observation on rats confirm those on human dentition, a discrepancy might be found in the rate of these processes. Although histological studies on human material do not permit any calculation of the rate of continuous eruption and growth of bone, we can conclude from our observation that, while eruption is continuous, the rate of eruption of human teeth varies in different phases and in different individuals. The growth curvature of the rat molar and the surrounding bone is a steady and even one, showing a rapid rate prior to the establishment of functional occlusion and gradually decreasing with age.

Another point of difference in the observations on rat and human dentitions may be pointed out as well. Hoffman and Schour[15] demonstrated that the rate of abrasion on the rat molar is constant throughout life and that the amount of eruption is many times greater than the amount of occlusal wear. This indicates that continuous active eruption of the rat molar is not solely a compensatory process for the loss of tooth substance at the occlusal

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[12] Orban, Balint; Epithelial Rests in the Teeth and Their Supporting Structures, Proc. Am. Assn. Dent. Schools, p. 121, 1928.

[13] Black, G. V.; Operative Dentistry, Vol. I, Medico-Dental Publishing Co., Chicago, 1908, p. 104.

[14] Stein, Georg and Weinmann, Joseph P.; Die physiologische Wanderung der Zaehne (Physiological Drift of the Teeth), Ztschr. f. Stomatol. 23: 733, 1925.

[15] Hoffman, M. M. and Schour, I.: Quantitative Studies in the Development of the Rat Molar; II. Alveolar Bone, Cementum and Eruption, Amer. Jour. Orthodontics, and Oral Surg. 26: 854, 1940.

surface. In human dentition no regularity regarding abrasion could be observed. We know that the rate of wear differs widely on different teeth and in different individuals. However, we know from clinical experience that eruption and abrasion of the teeth are two independent processes. It is commonly known that there are cases where the eruption rate is increased and the teeth show no attrition. This is one reason why the clinical crown becomes larger in time. On the other hand, we know of cases where attrition exceeded the amount of eruption resulting in extremely short crowns.[2]

Summary

The analyses reported in this paper show that the eruption process of the teeth is continuous, starting with the development of the tooth germ and lasting as long as the tooth is in the oral cavity.

Active eruption was divided into two overlapping periods. The First Period covers the eruption of the deciduous teeth, the Second Period that of the permanent teeth. Each period was subdivided into three phases. A phase of slow movement is followed by one of rapid movement and there follows another phase of slow movement. During slow eruption the bone grows steadily and slowly by deposition of one layer on top of another previously laid down at both the fundus and the crest. During fast eruption the bone grows rapidly by the formation of bone trabeculae separated from each other by bone marrow spaces. This process too takes place at the fundus as well as at the alveolar crest. The simultaneous growth at the fundus and at the alveolar crest throughout the life span of the tooth indicates the tendency to preserve a relatively constant depth of the alveolus.

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