The Lamina Dura in Roentgenographic Interpretation: Changes During Tooth Movement*

MAURY MASSLER, D.D.S., M.S.
Chicago, Illinois

I. INTRODUCTION

THE LAMINA DURA is a term commonly used by the dental roentgenologist to describe that narrow portion of the alveolar bone which borders upon the periodontal membrane and which appears as a well-defined radiopaque (white) layer in the roentgenogram. The term lamina dura or "hard layer," is derived from the fact that it is more radiopaque than the adjacent bone. (Fig. 1.)

Although the lamina dura is one of the first structures to be noted in the roentgenogram, the dental and medical literature gives scant consideration to the nature and significance of the lamina dura. The purpose of this paper is (a) to investigate the significance and the structural characteristics of the lamina dura, (b) to describe changes in its appearance during various types of tooth movements and in systemic diseases and (c) to point out the value of such knowledge in roentgenographic interpretation.

II. METHODS AND MATERIALS

About 250 full-mouth, and a larger number of single, roentgenograms were obtained from the files of the Child Research Clinic. Fifty roentgenograms were of patients in the Department of Orthodontia at the University of Illinois, College of Dentistry. The roentgenograms were of patients from two years of age to adulthood and were examined with an ordinary hand lens at a magnification of about six times.

A study was also made of the roentgenograms and histologic sections of sixteen human jaws ranging in age from birth to adulthood.

The relative density or radiopacity of the alveolar bone was judged by comparing it with the dentin in the same film. The thickness of enamel and dentin in a given tooth is fairly constant and does not vary greatly in different individuals (Schour and Massler, 1940). While the calcification of these structures during their formative period is extremely sensitive to metabolic upsets, once formed and calcified, the enamel and dentin, because they are avascular, cannot and do not lose their calcium. The density of the enamel and dentin in the roentgenogram has been shown to remain comparatively stable under even relatively severe systemic conditions (Albright, Aub and Bauer, 1934). The bone, on the other hand, readily reflects disturbances in mineral metabolism and systemic disease,

* From the Child Research Clinic, University of Illinois College of Dentistry, Chicago, Illinois.

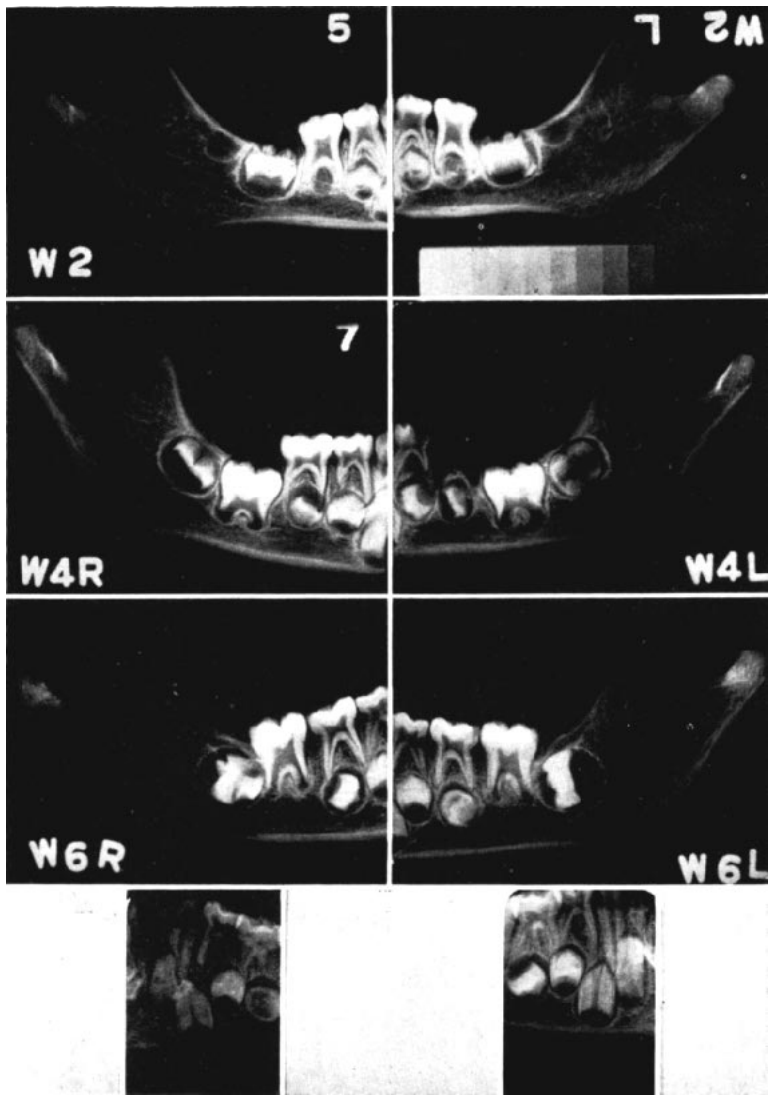
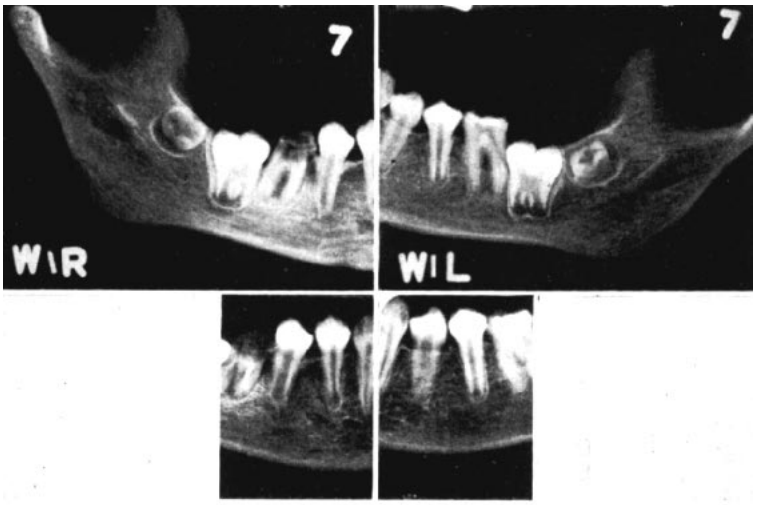


Fig. 1.—Roentgenograms of jaw specimens showing the changes in the lamina dura during the different stages in the eruption of the teeth. Note the prominent lamina dura lining the bony crypt around the developing tooth; its thickness and radiopacity as long as the tooth is actively erupting and its loss of prominence in the fully erupted tooth.

(Fig. 1—*continued*)



ca 12 years

and in the roentgenogram, varies greatly in absolute and relative density as well as in structural characteristics.

Since the relative density of the enamel, dentin and pulp is fairly constant, these structures can serve somewhat in the nature of a densiometer in a given intraoral roentgenogram. After a little practice the relative radiopacity of the surrounding bone is easily judged by this method.

It has been suggested that the appearance of the lamina dura in the roentgenogram might be the result of an artifact produced by the superposition of the peripheral layers of the bony crypt. This hypothesis is not valid on the basis that its accentuation in the young and its disappearance in older individuals is constant. In addition, the lamina dura is quite apparent in films which are variously angulated to eliminate the effects of superposition.

III. Findings

A. Changes in the Lamina Dura During Eruption

A statistical evaluation of the full-mouth roentgenograms of about 300 individuals from two to fifty years of age showed that the appearance, the structural characteristics and the degree of the radiopacity of the lamina dura depends upon the *rate of the eruption* of the teeth and changes with each stage of eruption.

From the moment the bony crypt appears in the roentgenogram until the tooth is in full clinical occlusion, a thick and distinctly radiopaque border is present on the bone immediately surrounding the tooth. At the same time, the periodontal membrane tends to be rather wide. The radiopacity of the lamina dura around the actively erupting tooth is as great as the much thicker and more highly calcified dentin in the same film (Fig. 2).

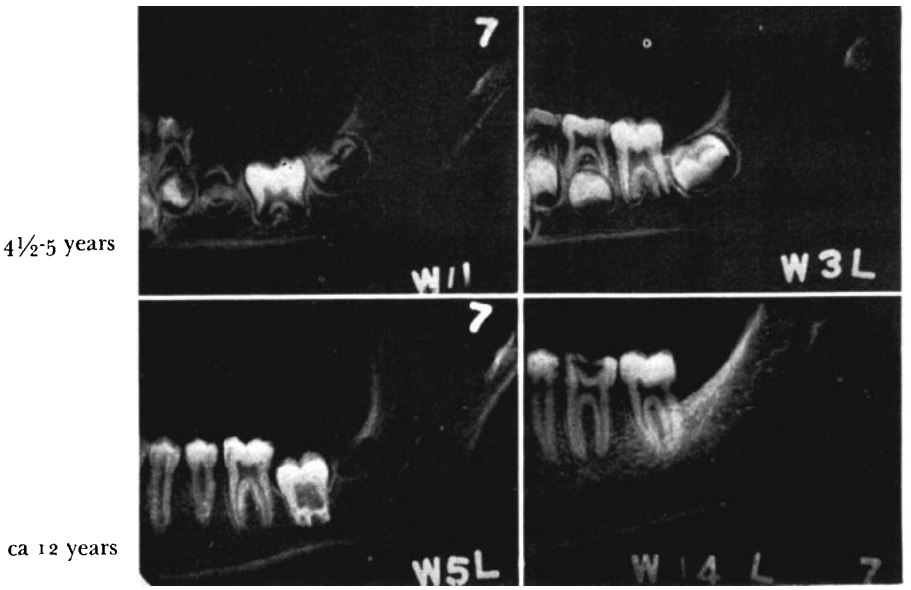


Fig. 2.—Roentgenograms of jaw specimens showing the changes in the lamina dura during different stages in the eruption of the lower bicuspids and permanent molars. Note the prominence during the period of active eruption of the tooth and growth of the alveolar bone proper.

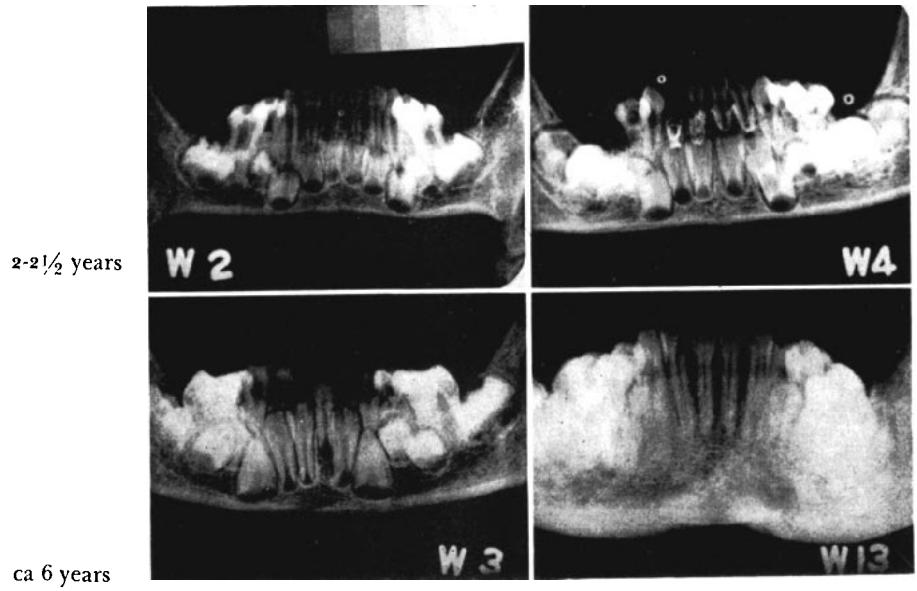


Fig. 3.—Roentgenograms of jaw specimens showing the changes in the lamina during different stages in the eruption of the lower anterior permanent teeth.

As the tooth comes into full clinical occlusion and the rate of eruption slows down, the lamina dura becomes thinner and much less radiopaque. The periodontal memberane also becomes thinner. This is particularly apparent when the teeth of the same individual are examined roentgenographically over a period of time. One can easily follow the gradual loss in the thickness and the radiopacity of the lamina dura in the radiograms as the clinical eruption of the tooth progresses (Fig. 3). The lamina dura persists as a distinct entity but its radiopacity tends to approach that of the surrounding bone.

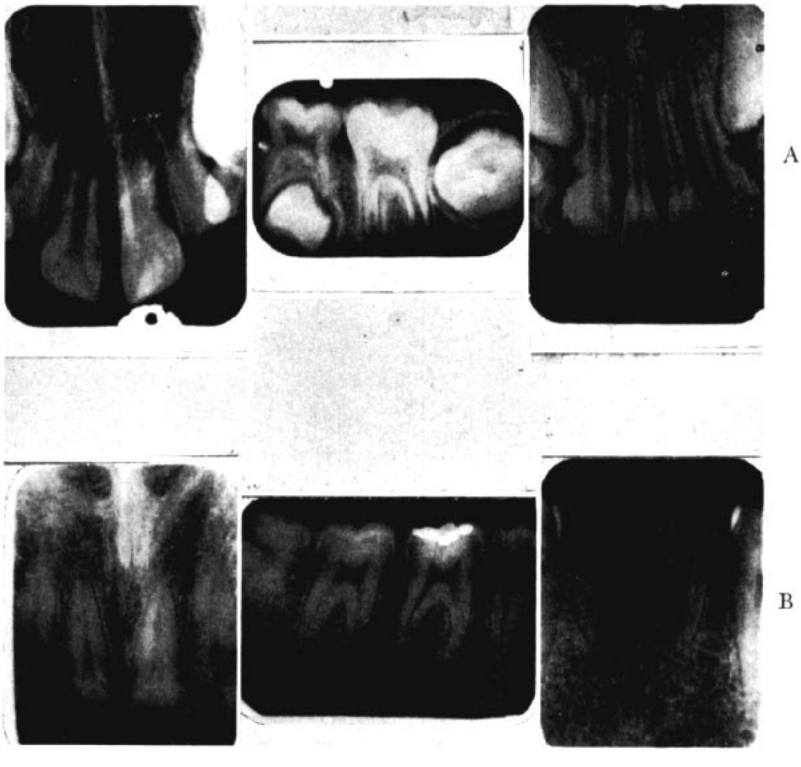


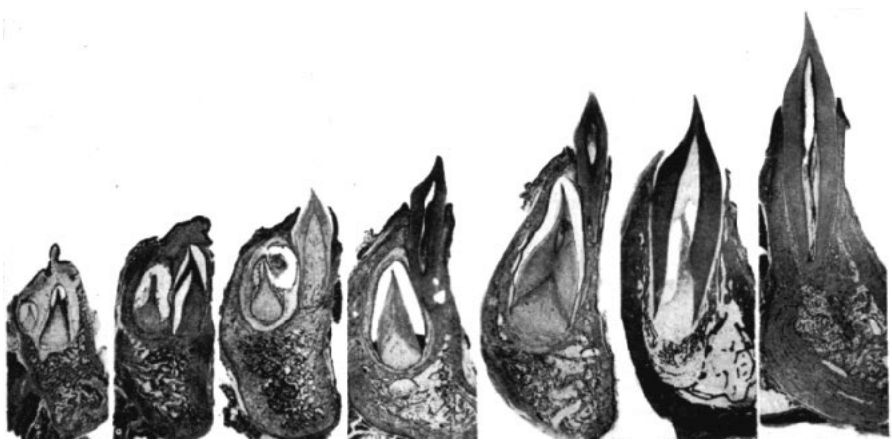
Fig. 4.—(A) Intra-oral roentgenograms of the incisors and lower molar area of a girl, age 6 years. Note the prominent lamina dura at the fundic area of the alveolus, the area which histologically shows active bone deposition at this stage. Compare with Figure 5. Contrast with (B), roentgenogram of a young woman.

The lamina dura is less prominent in the upper incisor region than in the bicuspid and molar regions of the arch (Fig. 4). This probably is due to the fact that proper angulation is more difficult in the incisor area.

Thus it was observed that the lamina dura is thicker, more radiopaque, and associated with a wider periodontal membrane in actively erupting teeth. These characteristics diminish as a given tooth comes into clinical occlusion and the rate of tooth occlusal migration slows down.

Changes with Age. The thickness and radiopacity of the lamina dura continues to diminish after the tooth is in full clinical occlusion and as the individual becomes older, but normally does not disappear altogether. The lamina dura is present but not very prominent in the roentgenograms of healthy older individuals with good occlusion (Fig. 4). This can be correlated with the fact that the eruption of teeth and the growth of the alveolar bone are continuous processes and normally proceed throughout the life of the individual, although the rate decreases constantly (Gottlieb and Orban, 1938).

Lamina Dura in "Elongated" Teeth. The removal of an antagonistic tooth allows the "elongation" or supraeruption of a tooth. In these cases



New-born	3 months	9 months	2 years	4½ years	6 years	9 years

Fig. 5.—Histologic sections through the incisor area of jaw specimens ranging in age from birth to 9 years. Note the appearance of the alveolar bone proper during the period of active eruption, particularly in the fundic area. Compare with the prominent lamina dura in the roentgenograms of Figure 3. (Photomicrographs by courtesy of Dr. J. P. Weinmann.)

the lamina dura becomes markedly accentuated in thickness and radiopacity during the period of occlusal movement. This occurs even in elderly individuals whose roentgenograms normally show a very thin lamina dura Fig. 7).

The lamina dura is absent about teeth which are embedded or so ankylosed that they cannot migrate.

B. Changes in the Lamina Dura During Orthodontic Tooth Movement

Teeth often tend to shift quite markedly as a result of broken contact points resulting from interproximal caries. For example, figure 8 shows that caries has destroyed the distal side of the lower first permanent molar and has thus broken the continuity of the arch. As a result, the first molar is tipping distally about a fulcrum near the apical third of the root. The

lamina dura is thick and prominent and the periodontal space is wider at the mesial surface of the root in its gingival two-thirds. This corresponds to the area of apposition of new bone in histologic section as has been shown by Kronfeld (1939). The distal surface of the root shows a decreased width of the periodontal space and the lamina dura is thin and almost absent. This corresponds to the area of resorption. On the other hand, the second molar is migrating mesially to occupy the space left by the broken-contact area on the carious first molar. The lamina dura is thick and prominent and the periodontal space is wider along the distal and the lamina is absent along the mesial root surface. These areas correspond histologically to the areas of new bone formation and bone resorption, respectively.

Orthodontic Tooth Movement. An even more accurately controlled and truly experimental analysis of the relation of the lamina dura to tooth movement and the formation of new bone is offered during orthodontic treatment. Rehak (1935) has made a careful analysis of the "Roentgenographic Interpretation of Bone Changes in Orthodontic Tooth Movement." The following findings are in complete agreement with those published by Rehak.

Before orthodontic treatment is instituted, most roentgenograms show a lamina dura of the usual thickness and radiopacity. During treatment and after tooth movement has been instituted, the roentgenogram reveals a lamina dura that is distinctly wider and markedly radiopaque on the bony surface from which movement is occurring (area of tension). The periodontal membrane is also distinctly wider on that surface (Figs. 9-11). Thus the surface upon which new bone formation occurs as a result of the orthodontic procedure shows a wider and more radiopaque lamina dura. The surface toward which the movement is progressing (area of pressure) is the area upon which resportion occurs. The periodontal space is markedly thinner and the lamina dura is usually entirely absent along that surface.

During the period of retention following active tooth movement, the formation of new bone occurs upon the *entire* bony surface surrounding the tooth, including that surface of the bony crypt which was being resorbed during active treatment. Roentgenograms taken during the period of retention show a thick, distinctly radiopaque lamina dura around the entire root, particularly on the surface that was being resorbed *during* the treatment and is *now,* during the period of retention, an active area of new bone formation. Thus the roentgenographic picture of the lamina dura tends to become reversed during the retention period.

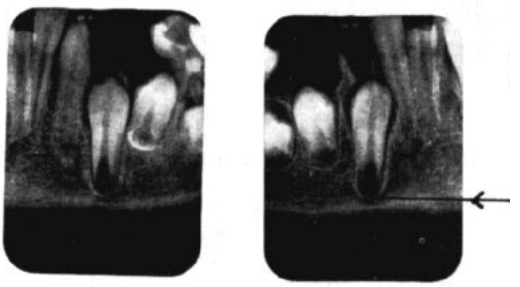
In roentgenographic interpretation and analysis of the lamina dura, the time and stage of tooth movement is therefore important. A prominent lamina dura indicates the area of *new bone formation* rather than the direction of movement. The direction of movement is also indicated, but only *during* active movement.

C. Histophysiologic Correlations

As has already been indicated in the preceding section, the area occupied by the lamina dura in the roentgenogram corresponds in histologic

sections to the area of new bone formation around the teeth that are moving as a result of eruption, mesial drifting or orthodontic treatment.

A direct microscopic examination was made of areas corresponding to the lamina dura in the roentgenogram. This study showed that the lamina dura is actually the alveolar bone proper, or the cribriform plate of the



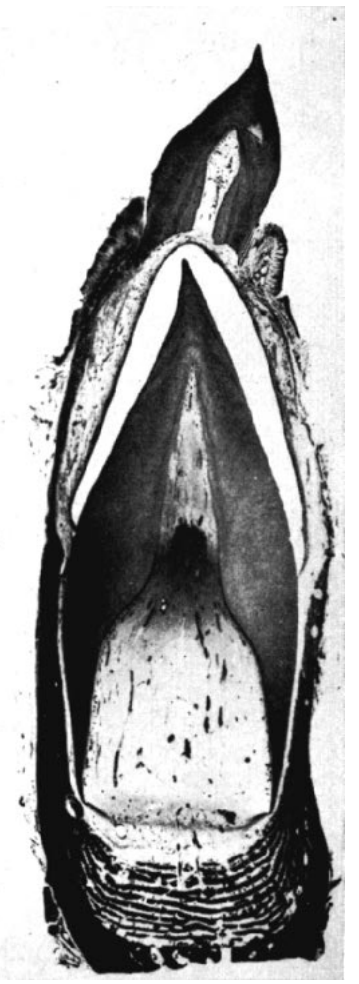


Fig. 6.—Histologic section and comparable roentgenograms of an actively erupting lower permanent cuspid. Compare the fundic area in the section and in the roentgenogram. (Photomicrograph by courtesy of Drs. J. P. Weinmann and B. Orban.)

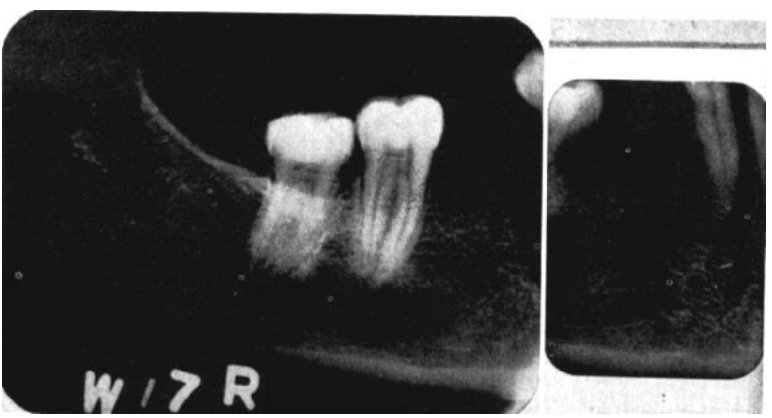
alveolar process. Histologically the lamina dura appears to be the *newly formed and calcified layer* of bone immediately adjacent to the periodontal membrane (Figs. 5-6). The newly formed bone is fibrous in character and is eosinophilic. This layer of active bone formation bordering upon the periodontal membrane has been variously termed the inner compacta, the alveolar bone proper, the inner cortical layer and the cribriform plate.

The works of Weinmann (1941), Kronfeld (1939) as well as our own observations show that the newly formed bone of the alveolar bone proper

that is deposited during tooth eruption (Weinmann, 1941), mesial drift (Stein and Weinmann, 1922) and orthodontic tooth movement (Kronfeld, 1939) is of a definitely fibrous nature. This fibrous bone soon becomes reorganized into lamellar bone.

Correlation of the roentgenographic and the histologic pictures shows that the lamina dura is very wide and radiopaque when the bone is *newly* deposited and of a fibrous character and that when the fibrous bone is transformed into lamellar bone, as seen in the histologic section, the lamina dura in the roentgenogram becomes thinner and less radiopaque.

Although the newly formed and calcified layer of the alveolar bone proper is radiopaque, historically this layer appears to be no more dense



A ↑ B

Fig. 7.—(A) Roentgenograms of an adult jaw specimen showing "elongating" or supra-erupting lower molars which had no antagonists. Note the accentuated lamina dura.

(B) Roentgenogram of the alveolus of a lower second bicuspid of the same specimen as in A. The biscuspid has been removed to better visualize the lamina dura.

than the adjacent bone. On this basis the term "hard layer" (lamina dura) does not seem to be justified. It would be more accurate to call it the *alveolar bone proper* and to regard it as the site of the newly calcified layer of bone in the roentgenogram or the newly formed layer of bone in histologic sections (the alveolar bone proper, cribriform plate or inner compacta). However, common usage has implanted the term firmly in the dental vocabulary. It is now important to define the term accurately as has been attempted above.

Radiopaque Borders In Other Bones. While we can only speculate as to the reason why the newly calcified alveolar bone is more radiopaque than the older adjacent bone, this phenomenon is not peculiar alone to the bone surrounding the tooth. A similar phenomenon is observed in the growing inner table of the bones of the cranial vault, the growing margins of the cranial sutures and the growing epiphyses of the long bones. These

↗ ←

Fig. 8.—Roentgenogram of a jaw specimen showing tooth movement as a result of broken interproximal contact caused by caries. The first molar is tipped distally about a fulcrum near the apical third of the distal root while the second molar has drifted mesially without tipping. Note the prominent lamina dura at the areas of apposition and its disappearance on the surface which histologically show resorption. See text for details. The third molar is still actively erupting.

sites of active bone deposition appear distinctly radiopaque and have also been described as "lamina dura" (Bernstein, 1933). In fact, the radiopacity of the epiphyseal plate during the period of rapid bone formation prior to epiphyseal union is used as a diagnostic sign of rapid bone growth when the radiogram of long bone are interpreted. Newly calcified bone, therefore, is radiopaque in any part of the body which can be observed radiographically.

It should not be supposed that *all* radiopaque borders are sites of new bone formation. In the interpretation of all radiograms, the effects of superposition must always be considered. However, the radiopacity produced by super-position and that associated with new bone formation are different and, with little experience, can easily be differentiated. The radiopacity produced by superposition is of a grayish quality and quite in proportion to the thickness of the structure. The radiopacity associated with new bone formation is distinctly greater, producing a much whiter appearance, quite out of proportion to the thickness of the structure.

IV. Discussion

A. Possible Reasons for the Radiopacity of the Lamina Dura

The correlation between the thickness and the radiopacity of the lamina dura and the active formation of bone as a result of tooth movement does not, of course, explain the cause of the radiopacity. Two possibilities suggest themselves and merit further investigation.

The radiopacity may be a result of some peculiarity in the crystalline structure of the *newly precipitated inorganic calcium salts*. The radiopacity disappears as the bone becomes older and more calcified, possibly due to some rearrangement of the inorganic elements in the bone.

The other possibility is that the newly formed border of bone is thicker than usual and therefore its radiopacity is accentuated by contrast to the adjacent trabeculations of bone. The thickness of the lamina dura and therefore its radiopacity are then reduced by the reorganization (resorptions and rebuildings) of bone following active growth.

B. Relation Of Lamina Dura To Health And Disease

The thickness and radiopacity of the lamina dura diminishes rapidly after the clinical occlusion of the tooth but a distinct lamina dura is still

a characteristic finding in the roentgenograms of healthy, normal individuals up to at least 50 years of age. In individuals who are suffering from debilitating diseases, the lamina dura tends to become indistinct. The progressive disappearance of the lamina dura may be observed in Paget's disease and in hyperparathyroidism (generalized osteitis fibrosa cystica) and has been reported many times.

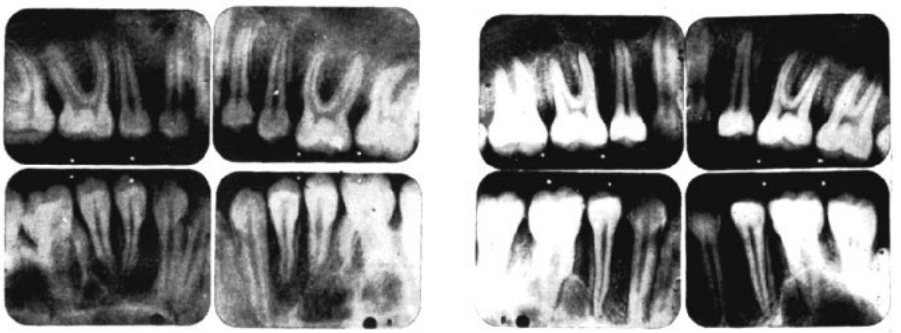
An early sign of a diffuse alveolar atrophy or a generalized alveoclasia is the disappearance of the lamina dura. This occurs long before the final

Fig. 9.—(A) Intra-oral roentgenograms of a patient undergoing orthodontic treatment. The upper cuspids and lateral incisors were moved bodily in a distal direction. Note the very wide lamina dura on the mesial side of the alveolus. The lower first molars were tipped distally and occlusally about a fulcrum near the apex of the distal root. Note how the lamina dura indicates graphically in which direction the tooth is being moved and where bone deposition has occurred. (Arrows indicate direction of tooth movement.)

(B) Roentgenograms of a case in which a space between the lower first molar and bicuspid has been closed orthodontically. Note the apposition of bone as indicated by the very wide lamina dura on the distal surface of the alveolus of the first molar and on the mesial surface of the alveolus of the bicuspid. (Courtesy of Dr. C. H. Tweed.)

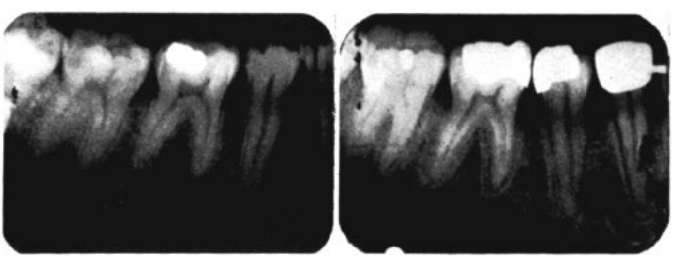
stages of tooth exfoliation and tooth drifting can be observed clinically. In fact, tooth movement without the formation of a distinct lamina dura on the side of tension is diagnostic of a failure in new bone formation, usually because of systemic disturbances or disease.

There are a number of studies reported in the literature which tend to show that the lamina dura is affected very early in nutritional deficiencies.



→ A ← → B ←

Fig. 10.—Intra-oral roentgenograms of two cases which were treated orthodontically. All the teeth were moved mesially. Note the prominent lamina dura on the distal surface of the bony alveoli. (Courtesy of Dr. C. H. Tweed.)



→

Fig. 11.—Intra-oral roentgenograms of the molar area (A) before and (B) after orthodontic treatment. The molars and bicuspids were so malposed as to be entirely out of function before orthodontic correction was accomplished. Note the prominent lamina dura as a result of the orthodontic tooth movement and the increased trabiculations of the supporting bone as a result of the normal function of the teeth. (Courtesy of Dr. A. Goldstein.)

The disappearance of the lamina dura is characteristic and almost diagnostic in vitamin D and calcium deficiencies (Schour and Massler 1945). Disturbances in the lamina dura were also shown by Mellanby (1928 and 1929-30) about the teeth of rachitic (vitamin D deficient) dogs. King (1936) found "ill-defined" laminae durae with adjacent prominently radiopaque bone trabeculae in vitamin A deficiency in dogs. Boyle, Bessey and Wolbach (1937) described rarefaction of the lingual alveolar bone in the incisors

of guinea-pigs in acute scurvy. Crandon, Lund and Dill (1940) reported that one of the earliest findings in a case of *human experimental scurvy* was a slight but definite interruption in the lamina dura in the teeth. They assume that this disturbance resulted from an atrophy of the alveolar bone and its replacement with collagen-free fibrous tissue, and suggest the possibility that the interruption in the dental lamina "may be one of the best criteria of incipient scurvy."

C. Clinical Correlations

A good intraoral roentgenogram is to the clinician what a good histologic section is to the experimenter. Roentgenology is but a step from clinical microscopy.

The fact that the thickness and degree of radiopacity of the lamina dura in the roentgenogram can be used as a diagnostic sign of tooth movement is of value to the orthodontist and the pedodontist. The appearance of the lamina dura should also be of interest to the prosthodontist since it will reveal to him the possibility of tooth movement both before and after the placement of an artificial appliance or even a single restoration.

The teeth move constantly under the forces of occlusion so that the alveolar bone proper is constantly resorbing and rebuilding itself. This is evidenced in the roentgenogram by the presence of a definite lamina dura in even older individuals. The absence of a lamina dura, on the other hand, is indicative of a failure in the growth of the alveolar bone proper. This fact is of particular significance to the periodontist in both his diagnosis and prognosis.

The assessment of the health of a given individual is too often a subjective procedure. The correlation of systemic health with the growth of the alveolar bone may serve to indicate to the dentist the physiologic status of a given individual just as the roentgenograms of growing epiphyses of long bones indicate to the pediatrician the systemic status of his patient.

V. Summary and Conclusions

A review of the literature shows that while the lamina dura is frequently examined in the roentgenogram, the significance of changes in its appearance is not always well understood. Only one report by Rehak in 1935 describes changes in the structure of the lamina dura during orthodontic tooth movement. No histologic interpretations or further studies were made.

About 300 full-mouth intraoral roentgenograms were examined of patients from two to fifty years of age who were regularly admitted to the dental clinic. About fifty roentgenograms were of patients undergoing orthodontic treatment. In addition, sixteen jaw specimens ranging from birth to old age were studied roentgenographically and in histologic sections. The following conclusions were drawn:

1. The character of the lamina dura was found to be directly related to the stage and the rate of eruption of the tooth which it surrounds. The lamina dura is very thick and characteristically very radiopaque during the active eruption of the tooth. It appears on those surfaces of the bony

crypt which histologically show active, new bone formation. The lamina dura of the roentgenogram is therefore the alveolar bone proper in the histologic section.

The thickness and radiopacity of the lamina dura diminishes rapidly after the tooth is in occlusion and active eruption ceases. The rate of new bone formation also diminishes. However, the lamina dura remains continuous and visible, but narrow and only moderately radiopaque, as long as the tooth is in function. This is due to the fact that a moderate amount of new bone formation occurs throughout life in the alveolar bone proper. If the alveolar bone proper shows no activity, the lamina dura disappears. If the alveolar bone proper shows excessive activity (as in tooth elongation and tooth movement) the lamina dura becomes thicker and more radiopaque.

2. During orthodontic tooth movement, the lamina dura becomes much thicker and characteristically radiopaque on the side of tension and new bone formation. Histologically the newly formed bone shows a distinctly fibrous character. After the completion of the orthodontic tooth movement, the accentuated lamina dura becomes less prominent as the fibrous bone is reorganized into lamellar bone.

The side of pressure shows a disappearance of the lamina dura during orthodontic tooth movement. This is caused by the resorption of the alveolar bone proper. After the completion of the tooth movement (during retention), a *new* lamina dura appears on this surface as a result of the formation of new bone to re-embed the new periodontal fibers.

Roentgenograms and correlative histologic sections are presented to illustrate the various changes in the character of the lamina dura during various types of tooth movement.

3. After tooth movement of any kind, new bone formation occurs on the tension side of the bony alveolus. This bone is usually fibrous in character and makes the alveolar bone proper wider and thicker. Roentgenographically, this is seen as a thicker and more radiopaque lamina dura. The reason for the radiopacity is not known. After the fibrous bone is reorganized into lamellar bone the lamina dura becomes thinner and less radiopaque.

4. Discontinuity in the lamina dura represents areas where the periodontal fibers are not embedded, and is caused by the failure in new bone formation or by bone resorptions as a result of local and/or systemic factors. A few examples are discussed.

5. The thickness and degree of radiopacity of the lamina dura in the roentgenogram can be used as a diagnostic aid to indicate the direction and amount of tooth movement and the character of the newly formed bone.

The roentgenogram is the clinician's microscope. The correlation between the appearance of the lamina dura and tooth movement should be of particular value to the orthodontist and the pedodontist. Its appearance in the roentgenogram can also be used as a measure of the health and disease of the periodontal tissues.

808 South Wood Street

VI. Bibliography

Albright, Fuller, Aub, J. C. and Bauer, Walter: "Hyperparathyroidism: A Common and Polymorphic Condition as Illustrated by Seventeen Proved Cases from One Clinic," *J.A.M.A.*, 102:1276, 1934.

Bernstein, S. A.: Über den Normalen Histologischen Aufbau des Schädeldaches," *Ztschr. f. Anat. u. Entwicklungsgeschichte*, 101:652-678, 1933.

Boyle, P. E., Bessey, Otto and Wolbach, S. B.: "Experimental Production of the Diffuse Alveolar Bone Atrophy Type of Periodontal Disease by Diets Deficient in Ascorbic Acid (Vitamin C)," *J.A.D.A. and Dent Cos.*, 24:1768-1777, 1937.

Crandon, J. H., Lund, C. C., and Dill, D. B.: "Experimental Human Scurvy," *New Eng. J. Med.*, 223(10):353-369, 1940.

Gottlieb, B. and Orban, B.: "Biology of the Investing Structures of the Teeth." Chapt. IV in *Gordon's Dental Science and Dental Art*, Lea and Febiger, Philadelphia, 1938.

King, J. D.: "Dietary Deficiency, Nerve Lesions and the Dental Tissues," *J. Physiol.*, 88:62-76, 1936.

Kronfeld, Rudolf: "Histologic Analysis of the Jaws of a Child with Malocclusion," Angle Orthod., 8:21-38, 1938.

Kronfeld, Rudolf: *Histopathology of the Teeth and Their Surrounding Structures.* Ed. 2. Lea and Febiger, Philadelphia, 1939.

Mellanby, May: "The Influence of Diet on the Development of the Teeth," *Physiol. Rev.*, 8:547, 1928.

Idem.: Diet and Teeth. Medical Research Council Special Report Series No. 140, His Majesty's Stationery Office, London, 1929; No. 153, London, 1930.

Rehak, R.: "Die Veränderung der Gewebe in Röntgenbild nach orthodontischer Beanspruchung der Zähne," *Ztschr. f. Stomat.*, 33:1424-1440, 1935.

Schour, Isaac and Massler, Maury: "Effects of Dietary Deficiencies upon the Oral Structures," *Physiol. Rev.* In press, 1945.

Schour, Isaac and Massler, Maury: "Studies in Tooth Development. The Growth Pattern of the Human Teeth," *J.A.D.A.*, 27 (11 and 12):1778-1793; 1918-1931, 1940.

Stein, G. and Weinmann, J.: "Die Physiologische Wanderung der Zahne," *Z. Stomat.*, 20:49, 1922.

Weinmann, J.: "Bone Changes Related to Eruption of the Teeth." Angle Orthod. 11 (2):83-99, 1941.