Résumé of the Literature on Root Resorption*

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IT HAS BEEN known for many years that roots of the deciduous teeth resorb and by resorbing permit the tooth to be shed. Also it has been known that certain permanent teeth when extracted show areas where the root has been resorbed. Dr. Frederick B. Noyes once mentioned that when William Bebb x-rayed the skull of a Mexican Peon, which skull is in the museum of Northwestern University, that the roots of all of the teeth had been nearly completely resorbed. Thus root resorption of permanent teeth is not a peculiarity of our own race or times. One of the earliest observations published on root resorption is that of Dr. John Tomes in 1859, when he said, this "is exemplified in the teeth of the grampus in the Oxford Museum, in which, owing apparently to a twist in the jaws, all the teeth of one side, in place of interdigitating, came to be exposed to destructive attrition, with the result that their implanted portions were enlarged and absorbed in an extraordinary way." Thus root resorption is not limited to man alone.

Dr. Broomell was the first person to be given credit for using the term "resorption" when referring to roots of permanent teeth, this was in 1898. Previously the term absorption had been used entirely, and for the following thirty years, the two words were used and confusion of ideas existed. In 1932 the discussion of which of these terms should be used came to a showdown when Dr. Hermann Becks and Dr. John A. Marshall wrote an article on the terminology. They seem to have cleared the situation by deciding upon the word "resorption" which they believed preferable. Their reason was: calcium, phosphorus, and the other materials constituting a tooth are first absorbed by the blood from the food, then deposited as a tooth; occasionally the calcium, phosphorus, and other materials in a tooth are "absorbed again" from the root by the blood. The term "resorb" means, by its derivation, "absorb again," hence, resorption is the preferable term to use.

THE DECIDUOUS DENTITION

Since resorption is not limited to permanent teeth, the subject of deciduous teeth will be first discussed. In *Kirke's Manual,* 1848, it is stated concerning deciduous teeth: "Its fang, with its bony sheathing in vascular nervous pulp, degenerates and is absorbed. The degeneration is accompanied by some unknown spontaneous decomposition of the fang, for it could not be absorbed unless it was so changed as to be soluble. And it is degeneration, not death, which preceded removal; for when a fang dies (sic), as that of the second tooth does in old age, then it is not absorbed but is cast out entire, as a dead part." Some twenty-eight years later, in 1876, Dr. Charles S. Tomes reviewed the contemporary knowledge of his times and concluded:

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1) resorption of the deciduous root may commence at the site of the permanent tooth follicle, but not necessarily so as it may begin on the opposite side of the root or even in many places at once; 2) the resorption is not always continuous, but may stop, and repair may take place before resorption once again commences; 3) resorption starts with the cementum but eventually dentin and enamel may be involved; 4) the part next to the pulp is most resistant to resorption and may persist as a hollow cone. He ends with the remark, "We must conclude that not every resorption in a normally resorbed deciduous tooth is necessarily due to the action of the permanent successor." Not much has been added to our knowledge during the 65 years following this observation. Dr. J. Lowe Young mentioned that root resorption is an inherent quality in deciduous teeth; it will do part of the work and leave the rest of the job up to the follicle, thus, if there is no permanent tooth following, the deciduous tooth will last for a long time. Dr. Rudolph Kronfeld similarly called it "a kind of senescence in deciduous teeth which results in these being resorbed sooner or later, even though they have no successors." Dr. Newton G. Thomas explained it as an "inherited predisposition of the teeth."

Many well executed histologic studies have contributed to our knowledge of the subject. An important experimental discovery made recently is that human deciduous teeth resorb from the cementum inward only, while deciduous teeth of animals, such as the dog and cat, resorb not only from the cementum inward, but also from the pulp outward. The roots of deciduous teeth are not always completely resorbed. This seems to occur where the root becomes resorbed at its junction with the crown and is broken off when the crown is shed; years later the deciduous root remnant still may be harmlessly present. Where the pulp canals of the deciduous roots have been filled, the resorptive process is slower; where the root canal is infected, the root is not shed normally but is pushed out "in toto" as if it were a sequestrum. There is no set chronologic order for resorption of deciduous roots. Experimental animals on an inadequate diet shed their teeth late and may have the deciduous teeth and permanent teeth both erupted and functioning at the same time.

The Permanent Dentition

According to Albin Oppenheim, Schwartzkopf noticed root resorption on permanent teeth first in 1887, and Ottolengui reported on it in 1914. Root resorption occurs under many circumstances other than as a result of orthodontic treatment. Dr. J. L. Zemsky proposed a classification including nine etiological factors, and orthodontic treatment was considered a variety of trauma. Dr. Rudolph Kronfeld proposed a classification of six types. From the standpoint of orthodontia, these and other classifications can be reduced to three definite groupings dependent upon X-ray observation.

The first group includes instances where there is some visible cause for the root resorption, such as permanent tooth follicles, granulomas, cysts, neoplasms, juxtaposed roots, and the like (Fig. 1). Where these are in contact with the root, resorption occurs in such a manner that these tissues seem to cut their way into, or even through the root. There is no question of the

etiology under these circumstances, as resorption seems to occur regardless of the systemic condition of the patient. The histologic picture has been well shown by many men, although the exact process of the cells, blood, and lymph in the decalcification and removal of the cementum and dentin is still unanswered. A recent contention is that an enzyme produced by the osteoclasts decalcifies the cementum and dentin. The prognosis is best for this group, for this resorption can be stopped immediately by removal of the causative factor. It is of little interest to the orthodontist other than being a splendid reason for the taking of X-rays as a precautionary measure

FIG. 1 FIG. 2 FIG. 3

Fig. 1.—This is one of the varieties of root resorption in Group I. The distal root of the second molar has been resorbed by the follicle of the third molar. The follicle of the third molar is the visible cause.

Fig. 2.—Group III, not treated orthodontically. One of the varieties where there is no visible cause for the resorption occurring. The opening on the root surface could not be reached clinically.

Fig. 3.—Same as Figure 2, six months later. Resorption has been progressive, the tooth pulp involved and painful, extraction necessary. When the extracted root was opened, there was no decay whatsoever in the resorbed area.

before commencing treatment, and as a warning not to tip roots of teeth too close together, or into the path of an erupting follicle.

The second group presents, on the X-ray, root resorption with no visible cause, and concerns only non-vital teeth, such as those with root canal fillings, implanted and replanted teeth, root resected teeth, and the like. The roots of these teeth occasionally seem to melt away as the years pass leaving the root canal filling imbedded in the bone which replaces the resorbed root. Usually the X-ray picture of this resorption is hazy, and the resorption involves most of the root surface. There is not the clear cut picture of resorption evident in the case of follicles, and cysts, etc.

One explanation is that the devitalized root acts as a foreign body, and so produces a chronic irritation. Sometimes the histologic sections of such resorptions show the cellular pictures seen in the foreign body reaction of vital tissue. The prognosis for this group is unfavorable, for there is nothing which can be done to stop this type of resorption. After the root canal of a tooth is filled, the peridental membrane often appears indistinct when seen in the X-ray. This fuzziness is caused by the presence of alternate resorption and repair occurring on the root surface, and may result in the tooth eventually becoming ankylosed. The question of why some of the devitalized

teeth and their roots completely resorbed and most others do not is still unanswered and probably is linked with the answer of why some cases of orthodontic treatment have root resorption and other similarly treated cases do not.

The third group consists of vital teeth, apparently normal in every respect, which have root resorption with no cause visible in the X-ray. There are cases to be mentioned later where the systemic health seems to have been the cause, yet there are many more cases where there is no apparent systemic disturbance whatsoever. Dr. C. E. Rudolph showed that out of 739 orthodontically untreated cases between the ages of 7 and 21 years of age, 5% showed root resorption. Ketcham and Hemley separately reported that, when gross pathological causes were excluded, of 1037 individuals x-rayed, only 1% showed root resorption. Perhaps because the gross pathologic causes were not ruled out in 4560 cases from 7 to 79 years of age Rudolph found 13% with root resorption.

Thus, the third group can be divided into two subdivisions: Those which have had orthodontic treatment and those which have not. The latter subdivision of root resorption has a vicious variety which appears as an area of resorption on the side of the root, and generally is progressive until the pulp is involved (Figs. 2 and 3). This usually produces a toothache requiring extraction of the tooth since nothing can be done about the resorption when it is so far below the gingival crevice. This may occur on only a single root in the entire mouth.

When root resorption appears as a blunting or cutting off of the apex of the root, there seems to be no effect on the pulp or vitality (Figs. 4 and 5). It is often difficult to differentiate "blunting" from anomalous root formation unless previous X-rays are available as a guide. In those rare cases where the entire root seems resorbed, the tooth never aches, shows all the tests for vitality, and usually is as sound and firm as the adjacent teeth, color remains normal, and the tooth may continue functioning in this way for 20 years or longer.

As for the subdivision of the third group, dealing with orthodontically treated cases, four men in different parts of the country have made noteworthy contributions. Dr. A. H. Ketcham made several reports covering a number of years; his final report covered over 500 cases treated by himself and other orthodontic specialists in their own private practices. He found that 21% of these cases showed root resorption after treatment. At first he thought the type of appliance used had some bearing upon the occurrence of resorption, but his later investigation showed this not to be the case. Dr. Hermann Becks of the University of California found that 20% of the cases treated there showed root resorption. Dr. S. Hemley of New York University finished an experiment where each case started was completed by the same graduate student. There were 165 cases completed in all, and his results showed root resorption in 21.5% of these cases. These three men show a remarkable unanimity in their studies. However, Dr. C. E. Rudolph of the University of Minnesota recently reported on the work done at the Undergraduate Clinic there and reported these startling results: "At the end of the first year of treatment 49% of the 439 patients showed root resorption; and at the end of two years' treatment, 75% of the remaining 277

patients demonstrated root resorption." A table is presented breaking down these figures into age groups and years of treatment. From the table, one must judge that the cases were treated up to seven years; at the end of two years of treatment, those cases started at 16 years of age and over, had root resorption in 57% of the cases, and at the end of three years of treatment there was root resorption in 100% or all the cases; while of those started at eight years or younger, only 16% showed root resorption after two years of treatment, but 100% or all of them showed root resorption after six years of treatment.

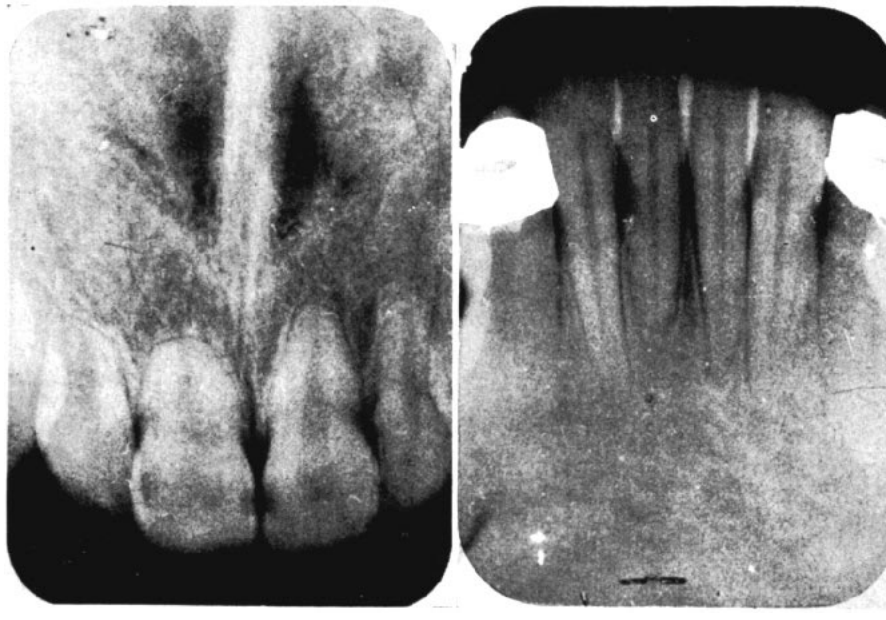

FIG. 4 FIG. 5

Figs. 4 and 5.—Treated orthodontically, resorption is without any visible cause. Sometimes it is difficult to differentiate between this type of resorption and anomalous root formation.

(My gratitude to Drs. H. B. Clark and H. C. Nelson, both of St. Paul, for these illustrations.)

Naturally, one wonders why these results are so very different from the reports of the other three men. The explanation may lie in one of several conditions in the treatment of the cases reported by Dr. Rudolph. These cases were treated mostly by undergraduates who had never before used an orthodontic appliance clinically. Adjustments were made weekly, except during the three summer vacation months, when patients would be seen perhaps twice by someone else; the next Fall another student would carry on the case unless the former one did not graduate; and finally, the presence or absence of root resorption was not determined by one individual but by "members of the orthodontic staff."

The appliance used most was the labial expansion arch, and strangely enough in the hands of Dr. Ketcham, only 1% of root resorption resulted

on his cases treated with it. Thus, the most logical conclusion to draw from these facts is that made by Dr. Milo Hellman when he discussed Dr. Ketcham's paper; "It is not the kind of appliance that has really any connection with the character of resorption, it is what the appliance does that may be brought into connection with this phenomenon." The latter part of his comment might well be altered to read "what the appliance is made to do."

The fact that Dr. Rudolph reports 100% root resorption proves conclusively that orthodontic appliances are capable of producing root resorption in *any* patient whatever; and this warns us as orthodontists to be careful of the manner in which we treat our cases. He further leads one to believe that any patient treated over a certain number of years, beginning at a certain age, is bound to have root resorption, but the work of Ketcham, Becks, Hemley and others disagree with this statement. Dr. Hemley aptly concluded: "The incidence of root resorption can be reduced to the extent that it need not be regarded as a hazard to orthodontic treatment." This is borne out in many specialized orthodontic practices.

The experiment of Dr. A. Martin Schwarz using a finger spring pressing on three adjacent teeth with different pressures is most interesting to mention at this time. He found that where the spring exerted pressures of 5 and 17 ounces, no root resorption resulted, but near the knee of the spring where the pressure was 67 ounces, root resorption resulted. The explanation for the root resorption being that the capillary blood supply is cut off by too great a pressure.

The question then arises why does one patient show root resorption while another patient with a similar malocclusion does not, although, both may have been treated alike so far as it is possible to judge? Drs. Ketcham, Becks, and Hemley came to the conclusion that certain patients have a predisposition to root resorption, and in these, orthodontic treatment will cause root resorption, while those who do not have this predisposition will not be affected.

The nature of this predisposition to root resorption is still unknown, but there must be different varieties. Dr. J. A. Marshall believed that improper diet is one of the most important causes. He shows that the diet cannot be determined entirely by the foods eaten. Many foods are raised under soil conditions which are deficient in the necessary elements, so that the food is deficient in the necessary elements which it normally would contain; consequently, the one who eats this food is deficient in these elements also. Thus, nutrition in all of its phases may well be an important predisposing factor of root resorption in some cases.

The possibility of its being a family trait came to my attention recently. There were two sisters; one received orthodontic treatment by a practitioner other than myself and some years after treatment ended, full mouth X-rays exhibited a minor blunting of the four upper incisor roots; the other sister had no orthodontic treatment but her dentist informed me that at about 17 years of age there appeared a resorption on the distal surface of the distal root of the upper second molar half way between the apex and the gingival crevice. This resorption continued until the pulp was involved, and resulted in a toothache. The resorption was so far below the gum that nothing could be done about it except remove the tooth, and the third molar erupted in

its place eventually. There was no apparent cause for this resorption since the third molar follicle was not near the area of resorption. Thus, one might be permitted to infer that these children had a familial predisposition to root resorption.

Dr. Becks states that endocrine disturbances very often are the predisposing cause of root resorption, but the question remains of how often this is actually so. Yet, there is no doubt but that it can be the predisposing cause as shown by the case of Dr. J. Lyndon Carman who reported that he undertook a case of orthodontia, and after one year's treatment, found that root resorption was occurring. He removed the appliances and sent the patient for a medical examination which revealed that she was "hypothyroid, hypoglycaemic, and hypocalcaemic." Medical treatment over a period of one year so greatly improved the health and weight of the patient that appliances were replaced and orthodontic treatment continued until the case was completed with no further root resorption. Thus, it may be safe to assume that an endocrine disturbance can be a predisposing factor to root resorption.

Root Resorption without Orthodontic Treatment

Systemic disturbances may cause root resorption without appliances. Dr. Emil Mueller reports his observation of a young lady with rapidly progressive root resorption so severe that it was necessary to remove some of the teeth. In her case a medical examination revealed: "General neurasthenia, vasomotor instability, and functional hepatic disturbance of unknown origin." She was treated over a period of six weeks, and the hepatic disturbance was improved greatly; at this time another tooth had to be extracted. Histologic examination of the resorbed areas showed that there was a definite evidence that the active root resorption present in the teeth extracted before the start of medical treatment was lessening, and in certain places, repair was in progress. Six months later histologic examination of another extracted tooth showed no signs of active root resorption and repair in areas of previous resorption. Dr. Mueller, in his concluding remarks, mentions other cases of sudden onset of root resorption without orthodontic treatment, and as sudden cessation of the resorption. He hesitates to state that the hepatic disturbance was the actual cause calling it coincidental with the root resorption. However, there seems to be sufficient circumstantial evidence to warrant a suspicion on the part of anyone with a similar systemic disturbance.

The case of Dr. Mueller's patient, due to his well executed experimental procedure, has presented us with splendid histologic pictures of human active root resorption, beginning of cessation of active resorption, and complete repair of areas previously resorbed. Noyes, Schour and Noyes also have covered this histologic picture of resorption and repair.

Other Conditions Associated with Root Resorption

The condition of bone is frequently mentioned, but little has been published in the way of actual correlation between root resorption and bone peculiarities. Dr. J. Albert Key mentioned, "In generalized bone atrophy, the entire skeleton is affected, and the condition is practically always due to some nutritional defect or metabolic disturbance. It is of special interest to

orthodontists because atrophic bone tends to bend under forces which would not affect normal bone." However, he makes no mention of any effect it may have on root resorption. Dr. Becks found in animal experimentation that lack of codliver oil with adequate calcium intake, produces atrophic and dystrophic bone changes of the entire skeleton including the jaws, and was accompanied by root resorption in varying degrees on every tooth, yet no orthodontic appliances were used. He concludes regarding human beings, "After nine years of study, it is still impossible to say what is the causative factor in any single given case." He further states that there is no one single factor alone responsible, not connected with periapical infection or extreme mechanical stress or pressure.

The Histologic Changes in Root Resorption

The histology of root resorption of both deciduous and permanent teeth has been studied for a long period of time by many men. Dr. Gottlieb states, "One can find a great many teeth in man as well as animals on the cementum surface, of which, no marks of any previous resorption are seen." Thus, histologic evidence shows that root resorption is not a natural condition. The best answer to root resorption, under orthodontic treatment, is that given by Dr. A. G. Brodie, which is, that it is the scar resulting from the orthodontic treatment, just as any scar is the result of any operation. It is possible to find histologic evidence of root resorption on teeth where there is no indication of such resorption in the X-ray. Such resorption is very shallow and usually involves only the cementum, and as soon as the cause is removed, the resorbed cementum is repaired by a new deposition of cementum which restores the previous contour of the root, and consequently, can not be seen in the X-ray.

Where resorption pierces the cementum and involves the dentin, repair is produced by a deposition of cementum on the surface of the remaining dentin, and a building-in of bone into the resorbed area so that a normal width of peridental membrane is produced between the newly deposited cementum and the new bone; of course, this results in an interlocking of bone and root, producing a securely anchored tooth. Where only the apex of a root is involved, the repair is identical, but there is no interlocking unless the sides of the root also have been resorbed into the dentin. Furthermore, once the cementum has been pierced by resorption and the dentin involved, repair never can restore the previous root contour. Drs. J. A. Marshall and Rudolph Kronfeld found that under the resorbing area, the dentinal fibers enlarge and seem to show a greater number of interlocking fibers. Occasionally secondary dentin forms in the pulp beneath the resorbed area.

Resorption generally is an osteoclastic action. Enamel can be resorbed also, but resorption must come through the dentinal surface because it never pierces the epithelial attachment. In repaired cases, where the enamel resorption has extended to the lateral surface at the gum margin, the epithelial attachment grows inward over the surface of the resorbed enamel.

Dr. Kronfeld sums up the histologic findings of resorption as follows: "From all of these findings, we must justly feel that the cementum of the tooth reacts in much the same way as bone does to external forces." Dr. Gott-

lieb states that where root resorption is present, the same cellular elements are present as in bone resorption: osteoclasis and osteolysis.

There are a few cases on record of internal root resorption of teeth, where the dentin has been resorbed from the pulpal surface, then later repaired by a type of osteodentin, and later, apparently, dentin has been deposited upon the osteodentin, giving the impression of a beautiful piece of inlaid bone. There also are cases of internal absesses recorded. Dr. Boyd S. Gardner makes a fitting conclusion to be applied to the histologic reaction of the root when he states, "Cementum responds to external forces in much the way as bone, but not to the same degree."

Summary

In conclusion then, it is evident that there is no one single cause for root resorption of permanent teeth, nor is root resorption a disturbance in itself. It merely seems to be a manifestation of some disturbance of the surrounding tissues. In group I, the causative factor is definitely known as being the follicle, cyst, granuloma, juxtaposed roots, or whatever is seen in the X-ray. In group II, there seems to be a rather special variety of resorption which deals only with devitalized teeth, and this but rarely. In the first subdivision of group III, dealing with orthodontically untreated vital teeth, root resorption occurs without any visible clue in the X-ray as to its cause; occasionally, a very rapid type of resorption occurs, and sometimes this is associated with a systemic disturbance. If this systemic disturbance can be cured the root resorption will cease. In the second subdivision of group III, which deals with root resorption of orthodontically treated cases, we can believe it may be due to too excessive a force, if such has been used; or a predisposing factor, which may or may not be diagnosed and treated medically; or malnutrition from poor diet, poor food, or other causes. That some individuals will have root resorption no matter how the case may be treated, and others will not no matter how the case may be treated within reason, is common knowledge. With our present knowledge of bone response to forces, and the variety of appliances available, root resorption need not occur in much over 20% of our cases, and may with the exercise of care and caution be further reduced.

Finally, the most encouraging thing of all is that the prognosis of teeth whose roots have resorbed during orthodontic treatment is most favorable. The teeth remain firm, vital to all tests, and do not change color or feel different to the patient from other teeth. There is a reported case where the roots of the upper incisor roots were two-thirds resorbed at the end of orthodontic treatment, and the orthodontist so informed the patient. Some twenty years later, this same patient was in town for a day and dropped in to tell this dentist that her rootless front teeth were still working fine; that the color was unchanged, he could see for himself, but she was in too much of a hurry to have their vitality tested.

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Bibliography

ANDERSON, HERBERT W. "Resorption of Root Ends," *Dental Students Magazine,* Vol. VIII, Jan. 1930, 4, p. 1.

ANONYMOUS. "Causes of Root Resorption of the Temporary Set of Teeth." *Dental Items of Interest,* Nov. 1921, Vol. 43.

APPLEBAUM, EDMUND. "Internal Resorption of Teeth, Part II." *Dental Society of City of New York,* Vol. 5, Jan. 1938.

APPLETON, J. L. (see Johnson, A. LeRoy)

BECKS, HERMANN; MARSHALL, J. S. "Resorption and Absorption, Part I." *Journal A. D. A.,* Vol. XIX, Sept. 1932, p. 1528.

BECKS, HERMANN. "Bone Changes from a Pathologic Standpoint." *Pacific Dental Gazette,* Vol. 39, April 1931, p. 254.

BECKS, HERMANN. "Root Resorptions and Their Relation to Pathologic Bone Formation."

BRODIE, ALLAN G. *Dental Science and Dental Art* (Gordon)

CARMAN, J. LYNDON. "Arrested Root Resorption during Orthodontic Treatment." *International Journal of Orthodontia,* Vol. 23, Jan. 1937, p. 35.

GARDNER, BOYD S. "Mineralization and Demineralization of Bone." *Journal A.D.A.,* Vol. XXIX, June 1935, p. 995.

GORDON. *Dental Science and Dental Art.*

HEMLEY, SAMUEL. "The Etiology of Root Resorption of Vital Permanent Teeth." *Dental Society, City of New York,* Jan. 1938.

HEMLEY, SAMUEL. "The Incidence of Root Resorption of Vital Permanent Teeth." *Journal, Dental Research,* Vol. 20, April 1941.

HERZBERG, B. L.; "Bone Changes Incident to Orthodontic Movement in Man." *Journal A.D.A.,* Oct. 1932.

HOPEWELL-SMITH, ARTHUR. "The Process of Osteolysis and Odontolysis, or So-Called 'Absorption' of Calcified Tissues: A New and Original Investigation." *Dent. Cosmos,* Vol. LXXII, May 1930.

JOHNSON, A. LEROY; APPLETON, J. L., JR.; RITTERSHOFER, L. S. "Tissue Changes Involved in Tooth Movement." *Intern'l Journal of Orthodontia,* Vol. XII, 10, p. 889.

KETCHAM, A. H. "A Preliminary Report of an Investigation of Apical Root Resorption of Permanent Teeth." *Intern. Journal of Orthodontia,* Vol. XIII, 2; Feb. 1927.

KETCHAM, A. H. "A Radiographic Study of Orthodontic Tooth Movement: A Preliminary Report." *Journal A.D.A.;* Sept. 1927.

KETCHAM, A. H. "A Progress Report of an Investigation of Apical Root Resorption of Vital Permanent Teeth." *Intern'l Journal of Orthodontia,* Vol. XV, April 1929.

KEY, J. ALBERT. "Factors in Bone Atrophy." *Journal A.D.A.,* Vol. XVII, Sept. 1930, p. 1660.

KIRKE'S Manual of Physiology, 2nd Edition, 1848.

KRONFELD, RUDOLPH. "The Resorption of the Roots of Deciduous Teeth." *Dental Cosmos,* Vol. LXXIV, Feb. 1932.

LERICHE AND POLICARDE. *Normal and Pathologic Physiology of Bone.* C. V. Mosby Co., St. Louis, 1928.

MARSHALL, JOHN ALBERT. *Operative Dentistry,* 1920.

MARSHALL, JOHN ALBERT. "Osseous Changes Due to Pressure Trauma." *Proceedings of the Society for Experimental Medicine,* Vol. XXVII; 1930, p. 270.

MARSHALL AND BECKS (see Becks).

MARSHALL, JOHN ALBERT. "Studies of Apical Root Resorption of Permanent Teeth II. *Intern'l Journal of Orthodontia,* Vol. XVI, 10, Oct. 1930, p. 1035.

MARSHALL, JOHN ALBERT. "A Comparison of Normal and Pathologic Bone in the Alveolar Process of the Maxilla." *Journal A.D.A.,* Vol. XVIII, Sept. 1931, p. 1591.

MARSHALL, JOHN ALBERT. "The Classification, Etiology, Diagnosis, Prognosis, and Treatment of Radicular Resorption of Teeth." *Intern'l Journal of Orthodontia,* Vol. XX, 8, Aug. 1934, p. 731.

MARSHALL, JOHN ALBERT. "Physiologic and Traumatic Apical Resorption." *Journal A.D.A.,* Vol. XXVI, Sept. 1935, p. 1545.

MARSHALL, JOHN ALBERT. "Experimental Resorption and Regeneration of Dento-Alveolar Tissues." *Journal A.D.A. & Dental Cosmos,* Vol. 24, March 1937, p. 449.

MUELLER, EMIL. "Laboratory Studies of an Unusual Case of Resorption." *Journal A.D.A.,* Vol. XVII, *Feb.* 1930, p. 326.

MUELLER, EMILE. "Histologic Study of a Case of Extensive Root Resorption in a Human Being." *Journal A.D.A.,* April 1931, p. 684.

NOYES, SCHOUR. Noyes *Dental Histology.*

OPPENHEIM, ALBIN. "Bone Changes During Tooth Movement." *Intern'l Journal of Orthodontia,* Vol. 16, May 1930.

ORBAN, BALINT. "Resorption and Repair of the Surface of the Root." *Journal A.D.A.,* Sept. 1928.

ORBAN, BALINT. "Tissue Changes in Traumatic Occlusion. *Journal A.D.A.,* Nov. 1928.

RUDOLPH, C. E. "An Evaluation of Root Resorption Occurring During Orthodontic Treatment." *Journal of Dental Research,* Vol. 19, Aug. 1940.

SCHOUR (see Noyes).

SCHWARZ, A. MARTIN. "Tissue Changes Incidental to Orthodontic Tooth Movement. *Intern'l Journal of Orthodontia,* Vol. 18, April 1932.

THOMA, K. H. "Central Osteoclastic Resorption of Dentine and Complete Repair with Osteodentine in the Permanent Tooth of an Adult." *Dental Items of Interest,* Vol. LVII, No. 1, Jan. 1935, p. 28.

THOMA, K. H. AND GOLDMAN, HENRY, M. "Relation of Types of Bone Resorption, Part II. *American Journal of Orthodontia,* Vol. 24, Jan. 1938, p. 62.

THOMAS, NEWTON G. "Significance of Absorption of Teeth and Alveolar Process." *Pac. Dent. Gaz.,* Vol. 36, Oct. 1928, p. 656.

YOUNG, J. LOWE. "Root Resorption of Deciduous Teeth." *Dental Items of Interest,* Nov. 1921, Vol. 43.

ZEMSKY, JAMES L. "Root Resorption and its Clinical Significance." *Journal A.D.A.,* Vol. 16, March 1929, p. 520.