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Enamel penetration by radioactive salts of zinc, calcium, silver, plutonium, palladium and copper

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Many therapeutic technics in dentistry depend upon a penetration of medicaments into tooth structure. In some cases the extent of penetration is known because of the color of the agent; for example, dyes and silver nitrate. Little is known, however, of the depth of penetration of uncolored medicaments. If these penetrate to any considerable extent an additional explanation can be offered not only for the unexpected pulpal irritations following application of medicaments but also for the familiar hypersensitivity of dentin following exposure to oral fluids.

Of vital concern to the dentist is the mechanical and chemical efficiency of impregnation of enamel lamellae with zinc salts. Thus far knowledge of the penetration of $ZnCl_2$ beneath the surface of the enamel and its precipitation as zinc ferrocyanide as claimed for the impregnation procedure rests on three indirect observations:[1] (1) Zinc ferrocyanide is supposed to penetrate enamel lamellae because silver nitrate does; the latter can be followed because of the black color developed by its reduction to metallic silver. (2) The sensitivity of root surfaces can be reduced by the application of $ZnCl_2$. (3) Recent clinical reports indicate that impregnation with zinc ferrocyanide may reduce caries incidence.[2,3] Direct evidence is not available to show that the colorless salt zinc ferrocyanide is precipitated in the enamel lamellae or that it remains there.

The penetration of medicaments and various salts can be studied since they are available in the radioactive form.[4,5] Tests were made on extracted teeth with radioactive calcium chloride, zinc chloride, silver nitrate, plutonium citrate complex, palladium chloride and copper nitrate.

CALCIUM[45] CHLORIDE

Seven freshly extracted teeth were treated on the surface with about 0.02 ml. of a $Ca^{45}Cl_2$ solution with an activity of 126 microcuries per milliliter. Descrip-

Based on work performed under U.S. Government Contract No. W-7405-Eng-36 with the Los Alamos Scientific Laboratory of the University of California. The following radioisotopes were obtained on allocation from the Isotopes Division of the United States Atomic Energy Commission: Ca^{45}, Zn^{65}, $Ag^{110, 111}$ and Pd^{109}.

Portions of this manuscript were read before the American Academy of Restorative Dentistry, October 28 1950, and the Section on Research at the ninety-first annual session of the American Dental Association, Atlantic City, November 1, 1950.

From the Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico. Now at the University of Illinois College of Dentistry, Chicago.

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4. Bartelstone, H. J. Survey of the use of radioactive isotopes in dentistry. New York J. Den. 20:320 (Aug.-Sept.) 1950.

5. Leicester, H. M. Biochemistry of the teeth. St. Louis, C. V. Mosby, 1949.

Table 1 • Penetration of dental s

Tooth		Age of patient (years)	
Number	Location		
101	Lower left third molar	21	
102	Upper left first bicuspid	37†	
103	Upper left second bicuspid	37†	
104	Upper left first molar	37†	
105	Upper right central incisor	36‡	
106	Upper left central incisor	36‡	F
107	Upper right lateral incisor	36‡	P

* All teeth showed strong surface uptak
but all carious areas and fissures were pe

† Patient S. G.

‡ Patient C. C.

§ Silicate filling free of $Ca^{45}Cl_2$ after
rounding filling.

|| Dentoenamel junction penetrated from

Silicate filling and surrounding stained

tions of the teeth and specimen
lined in Table 1.

Immediately after extraction
was scrubbed, pumiced, washe
NaF applied to the surface and
to dry for three minutes. Nine
after extraction $Ca^{45}Cl_2$ was ap
the surface of the crown. It
moist for three minutes an
wrapped in absorbent paper. O
later it was washed under run

Table 1 • Penetration of dental structures by radioactive calcium[45] chloride

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of longitudinal section	Caries	Lamellae	Fissures
101	Lower left third molar	21	Pericoronitis malposed	611	Labial third	−	+	−
				613	Middle third	+	+	−
102	Upper left first bicuspid	37†	Periodontosis	614	Buccal third	+	+	−
				616	Middle third	+	−	−
103	Upper left second bicuspid	37†	Periodontosis	617	Buccal third	−	−	−
				618	Lingual third	+	+	−
				619	Middle third	+	+	+
104	Upper left first molar	37†	Periodontosis	620	Outer buccal quarter	−	+	−
				621	Outer lingual quarter	−	−	+
				622	Inner buccal quarter	+	+	+
				623	Inner lingual quarter	−	−	−
105	Upper right central incisor	36‡	Preparation for denture	624§,‖	Mesial third	+	−	−
				626	Middle third	+	+	−
106	Upper left central incisor	36‡	Preparation for denture	627‖	Mesial third	+	−	−
				628#	Distal third	+	+	−
				629	Middle third	+	−	−
107	Upper right lateral incisor	36‡	Preparation for denture	630	Mesial third	−	−	−
				631§	Distal third	+	+	−
				632	Middle third	+	+	+

* All teeth showed strong surface uptake of $Ca^{45}Cl_2$ on enamel and cementum. Intact enamel was not penetrated but all carious areas and fissures were penetrated. All lamellae seen were penetrated.

† Patient S. G.

‡ Patient C. C.

§ Silicate filling free of $Ca^{45}Cl_2$ after four hours under running tap water. Dense uptake in stained dentin surrounding filling.

‖ Dentoenamel junction penetrated from gingival margin.

Silicate filling and surrounding stained dentin densely penetrated.

tions of the teeth and specimens are outlined in Table 1.

Immediately after extraction tooth 101 was scrubbed, pumiced, washed, dried, NaF applied to the surface and allowed to dry for three minutes. Nine minutes after extraction $Ca^{45}Cl_2$ was applied to the surface of the crown. It was kept moist for three minutes and then wrapped in absorbent paper. One hour later it was washed under running tap water for 30 minutes, sectioned under water and dried overnight at 37°C.

Tooth 102 was similarly treated except that it was not pumiced, and the isotope was applied 58 minutes after extraction.

Tooth 103 was treated like Tooth 101 except that NaF was not used, and the isotope was applied 61 minutes after extraction.

Tooth 104 was treated like tooth 101 with the exception that the isotope was

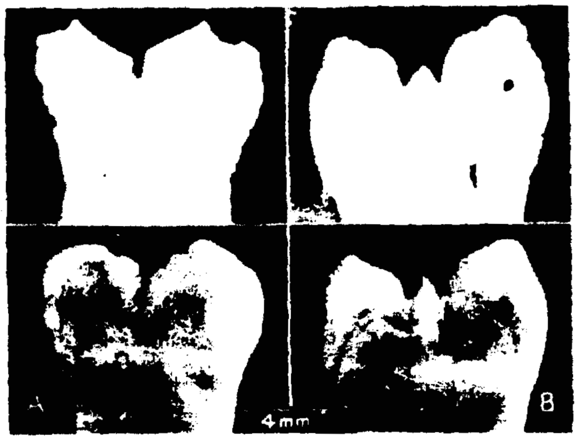

Fig. 1 • A: Dense surface uptake of $Ca^{45}Cl_2$. Intact enamel not penetrated. Faint penetration of two cracks in mesial cusp; dense penetration of carious enamel and carious fissure (Spec. 620, Neg. 15470; R.A.-723, Neg. 15471.) B. Dense surface uptake of $Ca^{45}Cl_2$. Faint penetration of enamel lamella on mesiogingival. Intact enamel not penetrated. (Spec. 611, Neg. 15486; R.A.-717, Neg. 15485)

applied 65 minutes after extraction.

Teeth 105, 106 and 107 received similar treatment to tooth 101 except that they were pumiced and NaF applied prior to extraction. The isotope was applied 13 minutes after extraction and the teeth were sealed moist in a bottle overnight. The next day they were washed under tap water for four hours and dried overnight at 37°C. Tooth 105 was dehydrated in alcohol and embedded in Selectron.[6]

The radioactivity of the sections was counted in a constant position 1 mm. from a mica window tube (2 milligrams per square centimeter, TGC-2) with a Tracerlab laboratory monitor and ranged from 140 to 2,500 counts per minute.

Survey radioautographs[7] were made; the findings are surveyed in Table 1. Typical radioautographs and the corresponding specimens are illustrated in Figures 1, 2 and 3.

All of the teeth showed a strong surface uptake of Ca^{45}, as seen in the radioautographs in the upper portions of the figures. The NaF treated teeth did not differ in this respect from the untreated teeth. Every carious defect was penetrated to the grossly visible limits of the lesion regardless of whether the tooth had been cleansed or not. Each tooth, although kept moist until the time of isotope application, was carefully dried with air blast just before applying the $Ca^{45}Cl_2$. All fissures were penetrated.

Figure 1, A illustrates a tooth in which there is a dense surface uptake of Ca^{45} not removed by 30 minutes of washing. All surface defects (cracks, fissures and carious lesions) were penetrated. The radioautograph of Figure 1, B shows exactly the same findings with the addition of lamellar penetration of the mesiogingival enamel. Figure 2, A shows the same findings but the number of enamel cracks is much greater and there is considerable penetration along the dentoenamel junction from the labiogingival surface. This tooth had carried a partial veneer crown for years. It would be of interest to know whether the manipulations incident to crown preparation were the source of the cracks and subsequent permeation of the enamel by dissolved substances.

Figure 2, B shows the radioautograph of a tooth in which the pulp chamber had

6. Wainwright, W. W. Dentistry and the atomic energy program. New York J. Den. 19:325 (Oct.) 1949.

7. Wainwright, W. W. Detail and survey radioautographs. Science 109:585 (June 10) 1949.

Fig. 2 • A: Penetration ... R.A.-801, N. ... of labial en... extensively p... Neg. 15478)

been opened. Alth... applied to the sur... effort was made t... pulp chamber ther... of all of the surrou... of four hours of w... tap water the Ca^{45} ... $CaCl_2$ is an extrem... so the Ca^{45} must ... been taken up by ... of the calcified su... change.[8] In additio... uptake there is p... caries, exposed in ... lamella in the ling...

Figure 3, A sho... from a distal sectio... as in Figure 2, A. T...

Fig. 3 • A: Dense su... with penetration of ... cervical enamel and ... uptake by silicate cem... dentin of cavity floor. R.A.-727, Neg. 15472 ... take of $Ca^{45}Cl_2$ with ... enamel defects. Faint ... enamel crack near inci... filling shows freedom ... stained dentin shows d... in a band surrounding ... to the surface. (Spec. 797, Neg. 15480)

Fig. 2 • A: Dense surface uptake and dense penetration of enamel cracks by $Ca^{45}Cl_2$. Penetration along dentoenamel junction from labiogingival. (Spec. 627, Neg. 15482; R.A.-801, Neg. 15481.) B: Dense surface uptake with penetration of incipient caries of labial enamel, exposed incisal dentin, and linguogingival enamel. The dentin is extensively penetrated from the open pulp chamber. (Spec. 626, Neg. 15479; R.A.-795, Neg. 15478)

been opened. Although the isotope was applied to the surface and no special effort was made to introduce it to the pulp chamber there is great penetration of all of the surrounding dentin. In spite of four hours of washing under running tap water the Ca^{45} was fixed in the tooth. $CaCl_2$ is an extremely soluble compound so the Ca^{45} must be considered to have been taken up by the apatite crystals of the calcified substance by ionic exchange.[8] In addition to the dense surface uptake there is penetration of enamel caries, exposed incisal dentin and a lamella in the linguogingival enamel.

Figure 3, A shows a radioautograph from a distal section of the same tooth as in Figure 2, A. The findings are similar with the exception of the silicate cement filling. The cement has been penetrated completely by the isotope and has retained the Ca^{45} throughout its structure

8. Neuman, W. F. Bone as a problem in surface chemistry. University of Rochester unclassified document, UR-110, March 22, 1950.

Fig. 3 • A: Dense surface uptake of $Ca^{45}Cl_2$ with penetration of exposed incisal dentin, cervical enamel and cementum defects. Dense uptake by silicate cement filling and stained dentin of cavity floor. (Spec. 628, Neg. 15473; R.A.-727, Neg. 15472.) B: Dense surface uptake of $Ca^{45}Cl_2$ with penetration of cervical enamel defects. Faint penetration of lingual enamel crack near incisal edge. Silicate cement filling shows freedom from $Ca^{45}Cl_2$; underlying stained dentin shows dense retention of $Ca^{45}Cl_2$ in a band surrounding the filling and extending to the surface. (Spec. 630, Neg. 15398; R.A.-797, Neg. 15480)

Table 2 • Penetration of dental structures by radioactive zinc^{65} chloride

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of section	Caries	Lamellae	Fissures
113	Upper left third molar	22	Malposed	649	Transverse midcrown	–	–	–
				650	Transverse cervical	–	–	–
114	Upper right second molar	49†	Periodontosis	651	Transverse midcrown	+	–	–
				652	Transverse cervical	+	–	–
115	Upper right first molar	49†	Periodontosis	653	Transverse midcrown	+	–	–
				654	Transverse cervical	+	–	–
116	Upper right central incisor	30‡	Periodontosis	655	Transverse midcrown	+	–	–
				656	Transverse cervical	–	–	–
117	Upper left cuspid	30‡	Periodontosis	657	Transverse midcrown	+	–	–
				658	Transverse cervical	+	–	–
118	Upper right cuspid	30‡	Periodontosis	659	Transverse midcrown	–	–	–
				660	Transverse cervical	–	–	–
119	Upper right lateral incisor	30‡	Periodontosis	661	Longitudinal labial half	+	–	–
				662	Longitudinal lingual half	+	–	–
120	Upper left central incisor	30‡	Periodontosis	663§	Transverse midcrown	+	–	–
				664	Transverse cervical	–	–	–

* All teeth showed strong surface uptake of $Zn^{65}Cl_2$ on enamel and cementum. Intact enamel was not penetrated but all carious areas and fissures were penetrated.
† Patient S. H.
‡ Patient E. H.
§ Silicate filling penetrated with $Zn^{65}Cl_2$ to the dentin.

in spite of four hours of washing under running tap water. In addition to the silicate cement the stained dentin bordering the filling has also retained the Ca^{45}. It would seem that in life this filling was porous to oral fluids and that the underlying dentin was exposed to the action of oral fluids.

The tooth in Figure 3, B is from the same mouth as those of Figures 2 and 3, A; it shows similar dense surface uptake and penetration of enamel defects. The silicate cement filling in this case, however, did not retain the Ca^{45}. Why this filling should behave differently from that of Figure 3, A is not known. The stained dentin and enamel bordering the filling, however, has again retained the Ca^{45} notwithstanding four hours of under running tap water.

RADIOZINC CHLORIDE (Zn^{65}, Zn

Twenty-two teeth were treate radiozinc according to Gottlieb's tions[1] except that all but five of t were not pumiced. The teeth whi pumiced are: 136, 137, 138, 1 142. All of the teeth were benzene except 140, 141 and 148 throug All teeth were dried in air blast the application of $ZnCl_2$. The time extraction until application of th tope varied from eleven minutes hours; the time for teeth 136, 13 and 139 was between seven an minutes; for 113, 114, 115, 140, 14 between 22 and 35 minutes; for 116, 117, 118, 119, 120 between 67 minutes; 150 through 154, 95 utes; 148 and 149, two hours. Aft application of zinc ferrocyanide all were washed for one hour under ru tap water. With the exception of 113 through 120, all teeth were imm in $AgNO_3$ for at least five minute then in 10 per cent Formol for at five minutes.

The $Zn^{65}Cl_2$ was prepared fr copper target by cyclotron irradi and added to commercial Zin-Ferr 2 solution. The activity of the sol and the activity of the specimens not determined. The teeth treated Zn^{65} are described in Table 2.

The teeth described in Table 3 dehydrated in alcohols and embedd Selectron. All teeth were sectioned u water.

The teeth described in Table 3 treated with Zn^{65}. Teeth 136 thro 142 were treated with a solution $ZnCl_2$ prepared by adding 0.010 ml a $Zn^{65}Cl_2$ solution containing 18.75 m curies per milliliter to 10 ml. commer Zin-Ferro No. 2 solution. The specin varied in activity from 100 to 300 cou per minute. Teeth 148 through 154 w withstanding four hours of washing under running tap water.

RADIOZINC CHLORIDE (Zn^{63}, Zn^{65})

Twenty-two teeth were treated with radiozinc according to Gottlieb's instructions[1] except that all but five of the teeth were not pumiced. The teeth which were pumiced are: 136, 137, 138, 139 and 142. All of the teeth were benzene washed except 140, 141 and 148 through 154. All teeth were dried in air blast before the application of $ZnCl_2$. The time from extraction until application of the isotope varied from eleven minutes to two hours; the time for teeth 136, 137, 138 and 139 was between seven and ten minutes; for 113, 114, 115, 140, 141, 142 between 22 and 35 minutes; for teeth 116, 117, 118, 119, 120 between 56 and 67 minutes; 150 through 154, 95 minutes; 148 and 149, two hours. After the application of zinc ferrocyanide all teeth were washed for one hour under running tap water. With the exception of teeth 113 through 120, all teeth were immersed in $AgNO_3$ for at least five minutes and then in 10 per cent Formol for at least five minutes.

The $Zn^{63}Cl_2$ was prepared from a copper target by cyclotron irradiation and added to commercial Zin-Ferro No. 2 solution. The activity of the solution and the activity of the specimens were not determined. The teeth treated with Zn^{63} are described in Table 2.

The teeth described in Table 3 were dehydrated in alcohols and embedded in Selectron. All teeth were sectioned under water.

The teeth described in Table 3 were treated with Zn^{65}. Teeth 136 through 142 were treated with a solution of $ZnCl_2$ prepared by adding 0.010 ml. of a $Zn^{65}Cl_2$ solution containing 18.75 millicuries per milliliter to 10 ml. commercial Zin-Ferro No. 2 solution. The specimens varied in activity from 100 to 300 counts per minute. Teeth 148 through 154 were treated with the undiluted $Zn^{65}Cl_2$ solution containing 18.75 millicuries per milliliter; the activity of the specimens was not determined.

The structures penetrated are summarized in Tables 2 and 3. All teeth showed a surface uptake of radioactive $ZnCl_2$ which was not removed by washing. Intact enamel was not penetrated but all enamel defects, carious areas, fissures and observable lamellae were penetrated.

Typical radioautographs are shown with the respective specimens in Figures 4, 5 and 6. The dense surface uptake with penetration of minute surface carious lesions and lack of penetration of intact enamel is seen in Figure 4, A. Figure 4, B is similar but with penetration of carious lesions extending to the dentoenamel junction. Figure 4, C also shows penetration of lamellae in thicker enamel. Figure 5 shows similar findings with complete penetration of carious lesions of the enamel and outer layers of dentin.

Figure 4, B and C and Figure 5 do not show complete plugging by zinc ferrocyanide since the silver nitrate stained the same lamellae and defects. In Figure 6, A, however, the arrow marks a buccal lamella which appears in the middle radioautograph but not in the specimen. The system of cracks and fissures connected with the lingual surface also shows lines of zinc penetration in the radioautograph which did not stain in the specimen. Although this apparently provides an instance of plugging by zinc ferrocyanide it is not conclusive. The upper radioautograph of Figure 6, A (exposure time one hour) shows the usual surface uptake and penetration of carious lesions and fissures. The middle radioautograph (exposure time seven and a half hours) shows more detail in the less radioactive areas.

Figure 6, B shows surface uptake by enamel, cementum and the amalgam filling. The radioactive $ZnCl_2$ has penetrated the carious enamel and dentin

Table 3 • Penetration of dental structures by radioactive zinc^{65} chloride

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of section	Caries	Lamellae	Fissures
136	Upper left second molar	40	Periodontosis	701	Longitudinal buccal third	+	−	−
				703	Longitudinal middle third	+	−	+
137	Upper left first molar	41	Periodontosis	704	Longitudinal buccal third	+	−	+
				705	Longitudinal lingual third	+	−	+
				706	Longitudinal middle third	−	+	−
138	Lower right second bicuspid	38	Pathologic exposure	708	Longitudinal lingual third	+	−	−
				709	Longitudinal middle third	+	−	−
139	Upper right first molar	16	Total pulpitis	712	Longitudinal buccal cusp	+	−	−
140	Upper left first bicuspid	34	Pulpitis	715	Transverse midcrown	+	+	−
				716	Transverse cervical	+	+	−
141	Lower left first molar	21	Pulpitis	718	Transverse cervical	+	−	−
142	Lower left first molar	41	Periodontosis	719	Transverse midcrown	+	+	−
				720	Transverse cervical	−	−	−
148	Upper right first bicuspid	49[†]	Periodontosis	736	Transverse cervical	−	+	−
149	Upper right second bicuspid	49[†]	Periodontosis	737	Longitudinal mesial half	+	−	−
150	Upper right second molar	28	Caries	739	Transverse midcrown, buccal half	+	−	−
				740	Transverse midcrown, lingual half	+	−	−
				741	Transverse cervical	+	+	−
151	Lower right deciduous first molar	7[‡]	Pathologic exposure	742	Transverse midcrown	+	+	+
				743	Transverse cervical	+	+	−
152	Lower right deciduous second molar	7[‡]	Pathologic exposure	744	Transverse midcrown	+	+	−
				745	Transverse cervical	+	+	−

Tooth	
Number	Location
153	Upper le third molar
154	Upper rig first molar

* All teeth showed su all carious areas and fis
† Patient S. H.
‡ Patient R. P.

completely aroun more dense uptak exposed cervical surface.

Figure 6, C is radiozinc has app metamorphosed c than the silver ni to penetrate in a

Fig. 4 • A: enamel not surface upta enamel not uptake of Zn carious dentin

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of section	Caries	Lamellae	Fissures
153	Upper left third molar	34	Caries	746A	Transverse midcrown	+	+	−
				746B	Transverse midcrown	+	+	−
				747	Transverse cervical	−	−	−
154	Upper right first molar	42	Pulpitis	748	Transverse midcrown	+	−	−
				749	Transverse cervical	+	−	−

* All teeth showed surface uptake of $Zn^{65}Cl_2$ on enamel and cementum. Intact enamel was not penetrated but all carious areas and fissures were penetrated. All lamellae seen were penetrated.
† Patient S. H.
‡ Patient R. P.

completely around the filling. There is a more dense uptake on the surface of the exposed cervical dentin on the buccal surface.

Figure 6, C is of interest because the radiozinc has apparently penetrated the metamorphosed dentin more uniformly than the silver nitrate. The latter failed to penetrate in a series of broad stripes. The zinc appears to have penetrated enamel a third of the way down from the cusp.

RADIOSILVER NITRATE (Ag^{111}, Ag^{110})

Ten teeth were treated with radioactive silver nitrate. In this form there was an opportunity to compare visual perception

Fig. 4 • A: Dense surface uptake of $Zn^{65}Cl_2$ with penetration of carious dentin. Intact enamel not penetrated. (Spec. 739, Neg. 15368; R.A.-A343, Neg. 15339.) B: Dense surface uptake of $Zn^{65}Cl_2$ with penetration of enamel defects and lamellae. Intact enamel not penetrated. (Spec. 736, Neg. 15267; R.A.-A346, Neg. 15254.) C: Surface uptake of $Zn^{65}Cl_2$ with penetration of enamel defects and lamellae. Dense uptake in carious dentin. (Spec. 741, Neg. 15272; R.A.-A108, Neg. 15251)

Fig. 5 • A: Surface uptake of $Zn^{65}Cl_2$ with penetration of silver nitrate stained lamella on buccal surface. The apparent expansion of the $Zn^{65}Cl_2$ penetration in the inner half of the enamel is owing to radiation from deeper layers of the enamel. (Spec. 744, Neg. 15270; R.A.-A99, Neg. 15195.) B: Dense penetration of $Zn^{65}Cl_2$ in two areas of penetrating enamel caries, and in the large open cavity. (Spec. 743, Neg. 15268; R.A.-A351, Neg. 15196.) C: Dense surface uptake of $Zn^{65}Cl_2$ with penetration of open cavities and carious dentin. (Spec. 749, Neg. 15370; R.A.-A373, Neg. 15343)

with the sensitivity of the radioautographic method. Table 4 describes three teeth which were treated with $Ag^{111}NO_3$. This isotope was separated from a target of palladium foil. Two solutions were prepared. The one used for the first two teeth (157, 158) was carrier-free $Ag^{111}NO_3$ in water. The activity of the solution was not determined. The activity of the specimens ranged from 450 to 3,000 counts per minute. The second solution, used to treat tooth 159, was diluted with ammoniacal silver nitrate. The activity of the specimens was 1,100 and 1,450 counts per minute.

Table 5 describes seven teeth which were treated with $Ag^{110}NO_3$. The solution was prepared by adding 0.1 ml. of an $Ag^{110}NO_3$ solution containing 0.647 millicurie per milliliter to 1 ml. of ammoniacal $AgNO_3$ solution. The activity of the specimens ranged from 600 to 6,000 counts per minute. Most of the specimens were between 1,000 and 2,000 counts per minute.

Of the 10 teeth 157, 158 and 159 were miscellaneous ones which had been in 10 per cent Formol for two months. The remaining teeth were kept moist and treated with the isotope within two hours after extraction. None of the teeth were pumiced; they were washed under tap water and dried with air blast before treatment. The radioactive $AgNO_3$ was applied for 10 minutes and then the teeth were immersed in 10 per cent Formol for 10 minutes. All teeth were dehydrated in alcohol and embedded in Selectron.

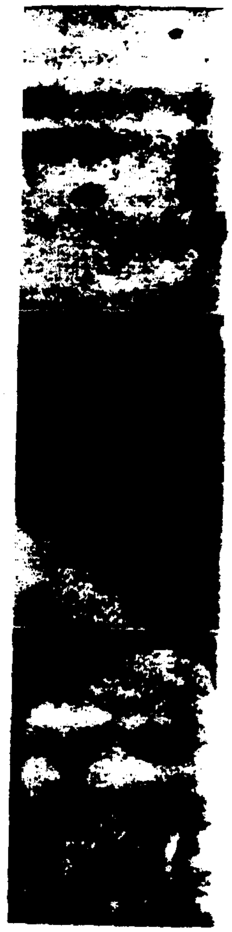

*Fig. 6 • A: …
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Fig. 6 • A: The upper radioautograph (exposure time one hour) shows dense uptake of $Zn^{65}Cl_2$ in carious enamel, carious fissures, and carious dentin. The middle view is a radioautograph exposed for seven and one-half hours and shows more detailed $Zn^{65}Cl_2$ penetration in the buccal enamel lamella (see arrow). In the specimen (below) the same area (see arrow) showed no apparent penetration by silver nitrate applied subsequent to the $Zn^{65}Cl_2$-$K_4Fe(CN)_6$ treatment. In the system of cracks and fissures connected with the lingual surface, there are areas which the lower radioautograph indicates are penetrated by $Zn^{65}Cl_2$ but in which the specimen does not show as much silver nitrate penetration. (Spec. 742, Neg. 15264; R.A.-A371, Neg. 15592; R.A.-A353, Neg. 15249.) B: Overexposed radioautograph shows surface uptake of $Zn^{65}Cl_2$ on enamel, cementum and amalgam filling. Penetration occurs only in the carious cementum and around the margins of the leaking filling. (Spec. 737, Neg. 15266; R.A.-A436, Neg. 15250.) C: Mesiobuccal cusp of upper first molar shows lack of penetration of enamel by $Zn^{65}Cl_2$. The stripes of dentin not stained by silver nitrate show slight penetration by $Zn^{65}Cl_2$. (Spec. 712, Neg. 15366; R.A.-944, Neg. 15349)

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Table 4 • Penetration of dental structures by radioactive silver[111] nitrate

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of section	Caries	Lamellae	Fissures
157	Lower right first bicuspid	†	Unknown	754	Transverse midcrown	+	−	−
				755	Transverse cervical	+	−	−
158	Upper right first bicuspid	†	Unknown	757‡	Transverse midcrown	+	−	−
				758	Transverse cervical	+	−	−
159	Lower right first bicuspid	†	Unknown	759	Transverse midcrown	+	+	−
				760	Transverse cervical	+	+	−

* All teeth showed surface uptake of Ag^{111} on enamel and cementum. Intact enamel was not penetrated but all carious areas and fissures were penetrated. All lamellae seen were penetrated.
† Miscellaneous teeth; two months in 10 per cent Formol.
‡ White opaque enamel penetrated. Stained dentin not penetrated.

The results of the radioautographic study are outlined in Tables 4 and 5. All teeth showed a surface uptake of radioactive $AgNO_3$ on enamel and cementum. Intact enamel was not penetrated but all carious lesions, fissures and observed

zinc specimens, instances were found where radiozinc penetrated but stable silver nitrate did not. This could be accounted for by lack of visual penetration of stable silver; yet it might still be present in the same subvisual amounts

in the carious fissures
autographic density ob-
central portion. Figure
strong uptake in the larg
dentin, in the occlusal fi
adherent periodontal tis-
Figure 9 shows an ir
exposed dentin is not
eburnated dentin, althou
from previously active c

Table 5 • Penetration of dental

Tooth		Age of patient (years)
Number	Location	
160	Upper right third molar	24†
161	Upper right second molar	24†

in the carious fissures that the radioautographic density obscures the entire central portion. Figure 8, C also shows strong uptake in the large area of carious dentin, in the occlusal fissures and in the adherent periodontal tissues.

Figure 9 shows an instance in which exposed dentin is not penetrated. The eburnated dentin, although it is stained from previously active caries, is not generally penetrated, visually or by the isotope. The area of active caries is penetrated by both. Adherent periodontal tissue is strongly active.

The specimen in Figure 10, A shows an increased number of enamel defects near a large amalgam filling. The defects and carious dentin are penetrated both visually and by the isotope.

The radioautograph of Figure 10, B

Table 5 • Penetration of dental structures by radioactive silver[110] nitrate

Tooth Number	Tooth Location	Age of patient (years)	Reason for loss	Specimen Number	Specimen Plane of section	Penetration* Caries	Penetration* Lamellae	Penetration* Fissures
160	Upper right third molar	24†	Pulpitis	761	Longitudinal outer buccal quarter	+	−	−
				762	Inner buccal quarter	−	−	−
				763	Longitudinal inner lingual quarter	+	−	−
				764	Longitudinal outer lingual quarter	+	−	−
161	Upper right second molar	24†	Pulpitis	765	Transverse midcrown	+	+	−
				766	Transverse cervical	−	+	−
162	Lower left first molar	19	Pulpitis	768	Longitudinal buccal third	+	−	−
				770	Longitudinal lingual third	+	−	−
163	Upper right third molar	25‡	Pulpitis	771	Transverse midcrown	+	−	+
				772	Transverse cervical	+	−	−
164	Upper right second bicuspid	25‡	Pulpitis	774	Longitudinal mesial half	+	−	+
165	Lower left second molar	27	Periodontal abscess	778	Longitudinal middle third	−	−	+
166	Upper left second bicuspid	50	Pulpitis	780	Transverse buccal cusp	+	−	−
				781	Transverse lingual cusp	+	+	−

* All teeth showed surface uptake of Ag^{110} on enamel and cementum. Intact enamel was not penetrated but all carious areas and fissures were penetrated. All lamellae seen were penetrated.

† Patient C. Z.

‡ Patient E. B.

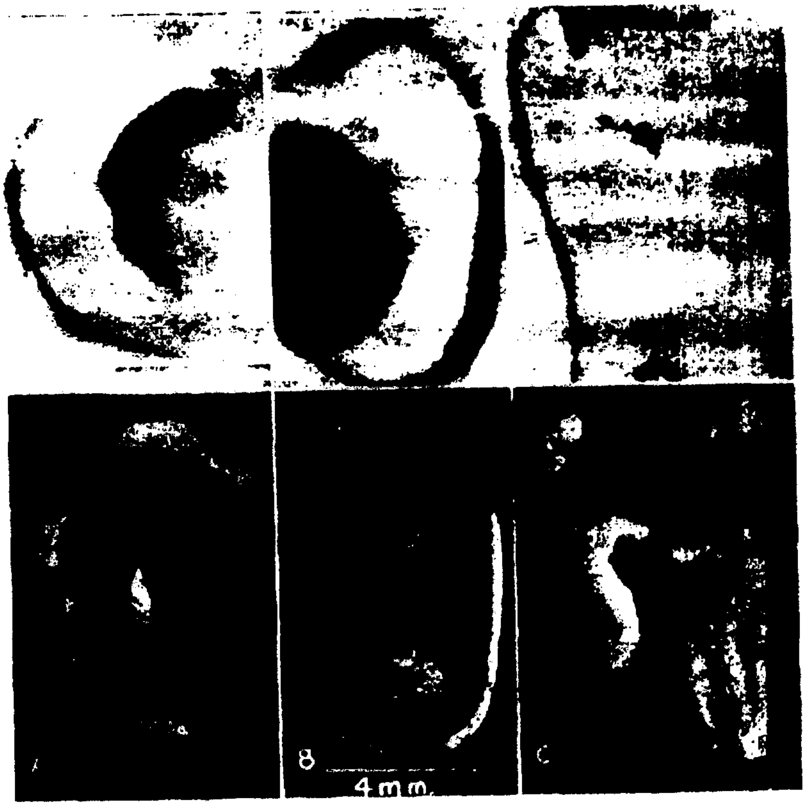

Fig. 7 • A: Dense surface uptake of $Ag^{111}NO_3$. Intact enamel not penetrated. Carious dentin penetrated. (Spec. 754, Neg. 15613; R.A.-979, Neg. 15358.) B: Dense surface uptake by $Ag^{111}NO_3$ with penetration of carious enamel and dentin. (Spec. 758, Neg. 15394; R.A.-932, Neg. 15488.) C. Dense surface uptake of $Ag^{110}NO_3$ on enamel and cementum, in occlusal fissure and on surface of amalgam filling. (Spec. 778, Neg. 15452; R.A.-A345, Neg. 15451.)

shows strong surface uptake, penetration of carious dentin and of the opaque area of enamel caries. The stained enamel and dentin under the opaque area are not penetrated. The specimen is not blackened in spite of the dense exposure of the radioautograph. As in the case of Figure 7, A and B the $Ag^{111}NO_3$ was carrier-free.

The amalgam fillings of Figure 10, C do not show leaks at the margins either by the stable $AgNO_3$ or by the isotope. The amalgam filling of Figure 10, D on the other hand shows a slight penetration at the gingival margin by stable $AgNO_3$ and a dense penetration by the Ag^{110}.

PLUTONIUM^{239} (+6)
CITRATE COMPLEX

A suggestive observation at variance with all of the findings in previous sec-

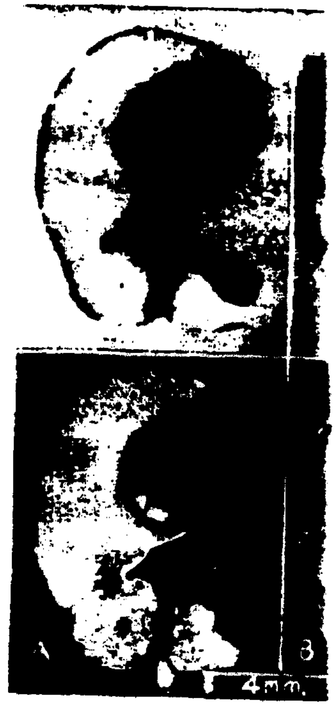

*Fig. 8 • A: Dense surfac
caries, fissure and carious
B: Dense surface uptake
fissures and lamella. (Spe
uptake of $Ag^{110}NO_3$ on e
caries, enamel fissures and
(Spec. 774, Neg. 15515; (*

tions of this report is found
Pu^{239} radioautograph of Figure
enamel surface was penetrated
short distance but in a narrow
band. Obvious defects readily st
subsequent immersion in stable
were not penetrated by Pu^{239}. T
solution was acid, pH 4.5, and
etched the enamel surface as th
complete staining of the otherwi
enamel surface by $AgNO_3$. In F
the staining is visible especially a
upper, buccal surface. Pu^{239} (+6
is known to complex onto organ
rial and it is possible that per

Fig. 8 • A: Dense surface uptake of $Ag^{110}NO_3$ with penetration of incipient enamel caries, fissure and carious dentin. (Spec. 771, Neg. 15373; R.A.-A434, Neg. 15340.) B: Dense surface uptake of $Ag^{110}NO_3$ on enamel with penetration of surface caries, fissures and lamella. (Spec. 765, Neg. 15415; R.A.-A656, Neg. 15355.) C: Surface uptake of $Ag^{110}NO_3$ on enamel and cementum, with penetration of cervical enamel caries, enamel fissures and carious dentin. Dense uptake by adherent periodontal tissue. (Spec. 774, Neg. 15515; R.A.-A433, Neg. 15514)

tions of this report is found in the Pu^{239} radioautograph of Figure 11. The enamel surface was penetrated only a short distance but in a narrow parallel band. Obvious defects readily stained by subsequent immersion in stable $AgNO_3$ were not penetrated by Pu^{239}. The Pu^{239} solution was acid, pH 4.5, and evidently etched the enamel surface as there is a complete staining of the otherwise intact enamel surface by $AgNO_3$. In Figure 11 the staining is visible especially along the upper, buccal surface. Pu^{239} (+6) citrate is known to complex onto organic material and it is possible that penetration was limited by this process.

The Pu^{239} solution had an activity of 15.3 microcuries per milliliter. Four hours after extraction the moist tooth was pumiced, washed, dried and benzene washed. It was immersed in the Pu^{239} solution for 33 minutes, placed in a vacuum chamber, and the pressure reduced to 20 inches of mercury. The excess Pu^{239} solution was washed from the surface with 15 ml. distilled water, delivered in 30 seconds. The tooth was then immersed in a 1 per cent ammonium oxalate solution, returned to the vacuum for 20 minutes, treated with silver nitrate and 10 per cent Formol, surface dried and embedded in Selectron. The sections were ground under water. The specimens are described in Table 6.

PALLADIUM[103] CHLORIDE

Two uncleansed teeth were treated with a solution of $Pd^{103}Cl_2$ an hour and a half after extraction. The Pd^{103} solution was prepared from a palladium foil target in a concentration of 40 per cent $Pd^{103}Cl_2$. The activity of the solution was not determined. The activity of the specimens ranged from 100 to 400 counts per minute. The $Pd^{103}Cl_2$ solution was applied to the teeth for 14 minutes. Subsequent treatment included drying and applica-

Fig. 9 • A, B and C: Dense surface uptake of $Ag^{110}NO_3$ on eburnated dentin, enamel and cementum of upper right third molar. Penetration of the eburnated dentin occurs only in an active lesion and not in the stained exposed tubuli. Carious enamel and adherent periodontal tissue are penetrated. (A: Spec. 763, Neg. 15504; R.A.-A335, Neg. 15503. B: Spec. 761, Neg. 15446; R.A.-A334, Neg. 15443. C: Spec. 762, Neg. 15374; R.A.-A347, Neg. 15359)

Fig. 10 • A: Surfa tration of carious A543, Neg. 15356. intact enamel. W carious dentin not 15416; R.A.-931, amalgam filling an enamel and adher A349, Neg. 15507. cementum. Dense periodontal tissue.

tion of potassium ferroc for 10 minutes. Tooth 1 with silver nitrate. Both face dried and embedded

The specimens are desc 7. Figures 12 and 13 show uptake, penetration of a lack of penetration of Figure 13 shows penetra lamellae.

COPPER[64] NITRATE

Four teeth were pumiced, with benzene, dried and

Fig. 10 • A: Surface uptake of $Ag^{111}NO_3$ on enamel and amalgam filling; dense penetration of carious dentin and lingual enamel cracks. (Spec. 781, Neg. 15417; R.A.-A543, Neg. 15356.) B: Dense surface uptake of $Ag^{111}NO_3$ on enamel. No penetration of intact enamel. White opaque enamel penetrated; underlying stained enamel and carious dentin not penetrated. Exposed mesial dentin penetrated. (Spec. 757, Neg. 15416; R.A.-931, Neg. 15516.) C: Dense surface uptake of $Ag^{111}NO_3$ on enamel, amalgam filling and cementum. No penetration of margins of fillings. Surface caries of enamel and adherent periodontal tissue penetrated. (Spec. 768, Neg. 15508; R.A.-A349, Neg. 15507.) D: Surface uptake of $Ag^{111}NO_3$ on enamel, amalgam filling and cementum. Dense penetration of leaking gingival margin of filling and of adherent periodontal tissue. (Spec. 770, Neg. 15506; R.A.-A329, Neg. 15505)

tion of potassium ferrocyanide solution for 10 minutes. Tooth 168 was treated with silver nitrate. Both teeth were surface dried and embedded in Selectron.

The specimens are described in Table 7. Figures 12 and 13 show strong surface uptake, penetration of all defects and lack of penetration of intact enamel. Figure 13 shows penetration of several lamellae.

COPPER^{64} NITRATE

Four teeth were pumiced, dried, washed with benzene, dried and treated with $Cu^{64}(NO_3)_2$ for five minutes. Two of the teeth (121, 122) were treated within 10 minutes after extraction; the other two (123, 124) were miscellaneous teeth which had been fixed in 10 per cent Formol for two months.

The $Cu^{64}(NO_3)_2$ solution was prepared from a cyclotron irradiated copper target. The activity of the solution was not measured; the activity of the sections ranged around 15,000 to 20,000 counts per minute.

The treated teeth were dried on absorbent paper and potassium ferrocyanide solution was applied for five minutes,

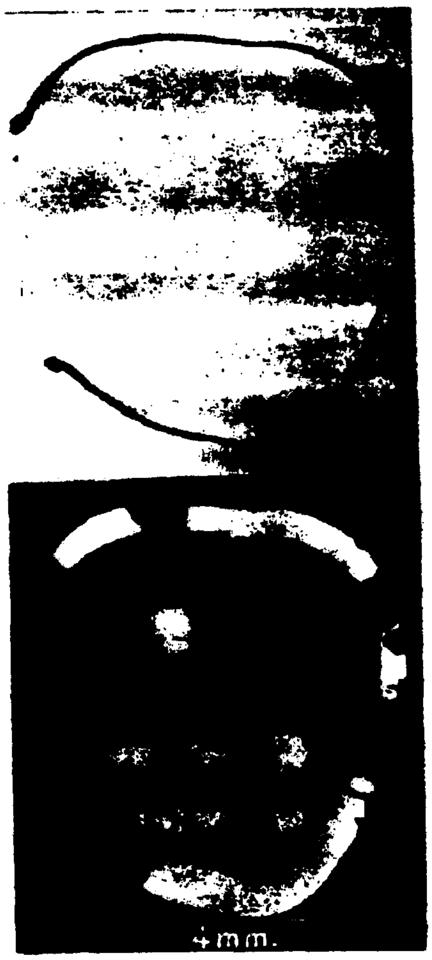

Fig. 11 • Strong surface uptake of Pu^{239} (−6) citrate complex, pH 4.5, with remarkable lack of penetration of enamel structures subsequently stained with silver nitrate. (Spec. 12' Neg. 15389; R.A.-A659, Neg. 15455)

washed in running tap water for 30 minutes and sectioned under water.

The specimens are described in Table 8; typical radioautographs are shown in Figure 14. Figure 14, A shows dense surface uptake of Cu^{64} on the enamel and cementum. The dentin was exposed by bur cuts prior to treatment. The Cu^{64} appears to have penetrated the dentin but part of the spreading may be owing to halation from the intense penetrating radiation. Figure 14, B also shows lack of penetration of intact enamel. The occlusal fissure shows a strong uptake, as do enamel defects. The pulp chamber was penetrated through an artificial opening. Figure 14, C shows dense surface uptake and penetration of carious dentin.

DISCUSSION

The fact that every tooth treated with these eight isotopes did not show penetration of intact enamel indicates that these compounds have different properties from those reported separately.[9,10,11] Three classes of substances are evident from these studies according to their behavior with enamel. The first (nicotinamide, urea) has the property of diffuse penetration of intact enamel. The second (calcium, zinc, silver) does not penetrate intact enamel but does penetrate every damaged portion of a tooth. The third group ($plutonium^{239}$) attaches itself only to the surface and does not penetrate defects.

Arrested caries proved to be a difficult lesion to penetrate. This has often been observed with dyes and acids. All other enamel defects and carious lesions of dentin were penetrated by all of the iso-

9. Wainwright, W. W., and Lemoine, F. A. Rapid diffuse penetration of intact enamel and dentin by carbon[14]-labeled urea. J.A.D.A. 41:135 (Aug.) 1950.

10. Wainwright, W. W. Time studies of the penetration of extracted human teeth by radioactive nicotinamide, urea, thiourea, and acetamide. I. Diffuse penetration from the enamel surface. In press.

11. Wainwright, W. W., and Belgorod, H. H. Time studies of the penetration of extracted human teeth by radioactive nicotinamide, urea, thiourea and acetamide. II. Penetration of dentin from the pulp chamber. In press.

Table 6 • Penetration of dental str

Tooth		Age of patient (years)
Number	Location	
227	Lower left third molar	30

* Tooth showed strong surface uptak

topes, with the exception c penetration of the isotopes with the gross extent of areas.

In every case there was take of the radioactive m was not removed by washi Lamellae were penetrated isotopes, except Pu^{239}. The enamel tracts penetrated by and by stable $AgNO_3$ wa older teeth and especially in had fillings or crowns. Sog poses that all lamellae aris matic cracks and are late organic material. Certainly ability of the tooth is incr presence of so many permea

Table 7 • Penetration of dental struc

Tooth		Age of patient (years)
Number	Location	
189	Lower left second molar	46
168	Lower left third molar	26

*All teeth showed surface uptake of all carious areas and fissures were penetr

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Table 6 • Penetration of dental structures by radioactive plutonium^{239} (+ 6) citrate complex

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of transverse section	Caries	Lamellae	Fissures
227	Lower left third molar	30	Pulpitis	921	Occlusal	–	–	–
				922	Midcrown	–	–	–
				923	Cervical	–	–	–

* Tooth showed strong surface uptake. Intact enamel and surface enamel defects were not penetrated.

topes, with the exception of Pu^{239}. The penetration of the isotopes corresponded with the gross extent of the damaged areas.

In every case there was a surface uptake of the radioactive material which was not removed by washing in water. Lamellae were penetrated by all of the isotopes, except Pu^{239}. The frequency of enamel tracts penetrated by the isotopes and by stable $AgNO_3$ was greater in older teeth and especially in those which had fillings or crowns. Sognnaes[12] proposes that all lamellae arise from traumatic cracks and are later filled with organic material. Certainly the vulnerability of the tooth is increased by the presence of so many permeable tracts.

The tests of plugging by precipitation of radiozinc ferrocyanide show that the lamellae are penetrated to the same extent as they are by silver nitrate. The lamellae were subsequently penetrated by $AgNO_3$ and cannot be said to be plugged in the sense of being impermeable. In a few instances there was apparent plugging with lack of complete penetration subsequently by $AgNO_3$. This cannot be interpreted yet as complete plugging because the radioautographic method detects much smaller

12. Sognnaes, R. F. Organic elements of the enamel. IV. The gross morphology and the histological relationship of the lamellae to the organic framework of the enamel. J. D. Res. 29:260 (June) 1950.

Table 7 • Penetration of dental structures by radioactive palladium^{103} chloride

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of section	Caries	Lamellae	Fissures
189	Lower left second molar	46	Periodontosis	785	Longitudinal middle third	+	–	–
148	Lower left third molar	26	Malposed periodontal abscess	787A	Transverse near occlusal	–	–	+
				787B	Transverse near occlusal	–	+	–
				788	Transverse midcrown	–	+	–
				789	Transverse cervical	+	+	–

*All teeth showed surface uptake of $Pd^{103}Cl_2$ on enamel and cementum. Intact enamel was not penetrated but all carious areas and fissures were penetrated. All lamellae seen were penetrated.

Fig. 12 • A: Surface uptake of $Pd^{109}Cl_2$ on enamel. (Spec. 787A, Neg. 15412; R.A.-A323, Neg. 15491.) B: Dense surface uptake of $Pd^{109}Cl_2$ on enamel, amalgam filling and cementum. Dense penetration at margins of leaking amalgam filling and in adherent periodontal tissue. No penetration of intact enamel. (Spec. 785, Neg. 15493; R.A.-A321, Neg. 15492)

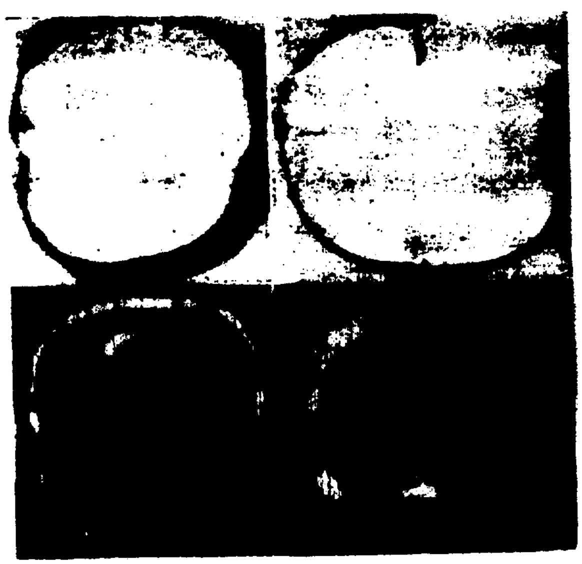

Fig. 13 • A and B: Dense surface uptake of $Pd^{109}Cl_2$ on enamel, and dense penetration of enamel defects, lamellae and adherent soft tissue. (A: Spec. 789, Neg. 15408; R.A.-A326, Neg. 15488. B: Spec. 788, Neg. 15409; R.A.-A325, Neg. 15487)

Table 8 • Penetration of dental str

Tooth		Age of patient (years)
Number	Location	
121	Lower right second mola	40
122	Lower right third molar	24
123	Lower left third molar	†
124	Upper left third molar	†

* All teeth showed strong surface upt
trated but all carious areas and fissure
† Miscellaneous teeth; two months in

*Fig. 14 • A and B: Den
dentin of upper left thir
wide areas of density in th
tration of dentin. Intact
Neg. 15462. B: Spec. 6
uptake of $Cu^{64}(NO_3)_2$ on
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. 15493;
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Table 8 • Penetration of dental structures by radioactive [illegible] nitrate

Tooth		Age of patient (years)	Reason for loss	Specimen		Penetration*		
Number	Location			Number	Plane of longitudinal section	Caries	Lamellae	Fissures
121	Lower right second molar	40	Pulpitis	665	Buccal half	+	+	−
122	Lower right third molar	24	Pulpitis	668	Lingual half	+	−	−
123	Lower left third molar	†	Unknown	670	Lingual half	−	−	+
124	Upper left third molar	†	Unknown	671	Buccal half	+	−	+
				672	Lingual half	+	−	+

* All teeth showed strong surface uptake of $Cu^{64}(NO_3)_2$ on enamel and cementum. Intact enamel was not penetrated but all carious areas and fissures were penetrated. All lamellae seen were penetrated.

† Miscellaneous teeth; two months in 10 per cent Formol.

Fig. 14 • A and B: Dense surface uptake of $Cu^{64}(NO_3)_2$ on enamel, cementum and dentin of upper left third molar. Dentin exposed with bur prior to treatment. Note wide areas of density in the prepared openings indicating spread of radiation and penetration of dentin. Intact enamel not penetrated. (A: Spec. 671, Neg. 15463; R.A.-768, Neg. 15462. B: Spec. 672, Neg. 15458; R.A.-769, Neg. 15457.) C: Dense surface uptake of $Cu^{64}(NO_3)_2$ on enamel, dentin and cementum. Carious dentin penetrated. Intact enamel not penetrated. (Spec. 668, Neg. 15460; R.A.-765, Neg. 15459) amounts of the isotope than the eye can see in blackening from silver nitrate. Thus, subvisual amounts of silver nitrate might be present and not be detected. Since zinc ferrocyanide does not plug completely this data would suggest that clinical impregnation treatments will need to be repeated at intervals in order to maintain whatever caries inhibiting effect they may have. The fact that lamellae were regularly penetrated in teeth not cleansed according to Gottlieb's[3] instructions suggests that various methods of preparation of the tooth surface be tried clinically. The teeth in this study were all dried by air blast before applying the radiozinc.

SUMMARY

1. Calcium^{45} chloride, silver^{110,111} nitrate, palladium^{109} chloride, and copper^{64} nitrate were found by radioautographic examination to penetrate enamel defects, lamellae and carious areas. Intact enamel was not penetrated although there was an uptake on the surface of enamel and cementum which was not removed by washing.

2. Zinc^{63,65} chloride was precipitated by potassium ferrocyanide on tooth surfaces and was found to penetrate lamellae, carious lesions, fissures and other defects. Since nearly all of the lamellae could be subsequently penetrated by stable $AgNO_3$ they were not considered to be completely plugged.

3. Plutonium^{239} citrate complex attached itself to the surface of enamel and cementum but did not penetrate defects and carious areas subsequently stained by silver nitrate.

Fig. 1 • *The control, gold inlay, amalgam, gold foil and cement specimens*

Penetration of radiocalcium at the margins of filling materials: a preliminary report

W. D. Armstrong, M.D., Ph.D., and W. J. Simon, D.D.S., M.S.D., Minneapolis

Buccal, Class V, cavities were prepared in eight wet, sound, extracted, lower second bicuspids. Each cavity was filled; one with amalgam, one with a gold inlay, one with a gold foil, one with an oxyphosphate of zinc cement, one with silicate and three with acrylic resin. In the three teeth filled with acrylic resin, one was filled with resin after it had been mixed on a slab, one after the resin had polymerized for 30 seconds in a sealed jar without spatulation and one after the resin had polymerized for 30 seconds in a sealed jar with spatulation.

After the fillings were inserted, the roots were coated with wax and the clinical crowns were immersed in a solution of radiocalcium (Ca^{45})[1] for 48 hours.

From the University of Minnesota, departments of dentistry and physiological chemistry, Minneapolis.

1. Specific activity 30 MC per gram calcium. This radiocalcium was obtained from the Oak Ridge National Laboratory on allocation from the U.S. Atomic Energy Commission.

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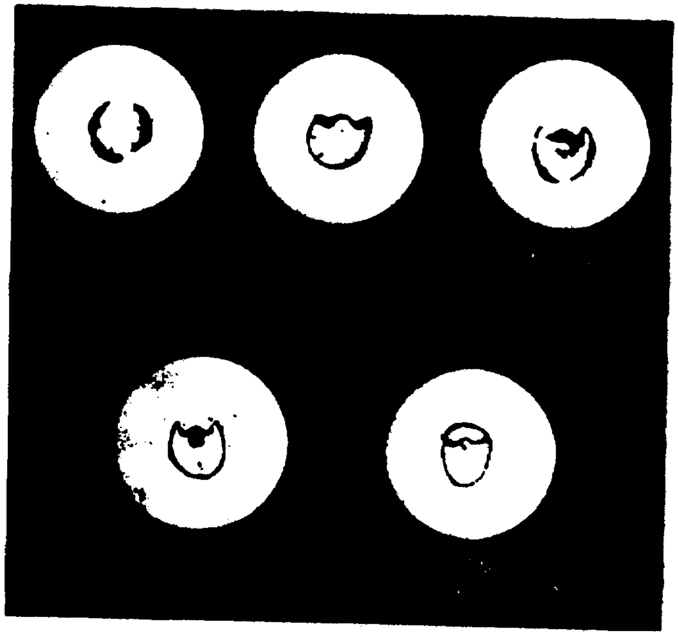

Fig. 1 • The control, gold inlay, amalgam, gold foil and cement specimens

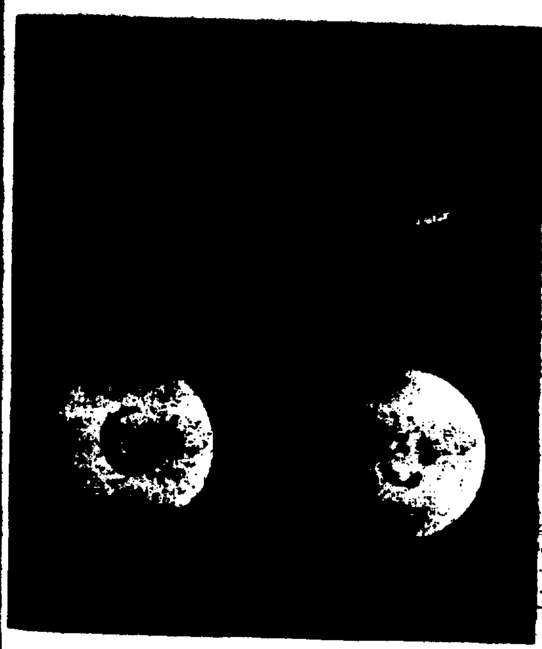

Fig. 2 • The silicate and acrylic resin specimens

The teeth were then washed with distilled water and were embedded in methyl methacrylate resin. Horizontal cross sections were prepared with a bandsaw through the widest gingivoocclusal portion of the restorations. Radioautographs were prepared on Agfa no screen film.

A control was run to determine the chance of technical contamination error. A wet, sound, extracted tooth was immersed in radiocalcium and then the cavity was prepared and filled with acrylic resin.

The radioautographs of the control sample revealed that the technical possibility of errors of contamination is minimal. They also demonstrated that the radiocalcium penetrated the margins of all of the filling materials used but in varying amounts. The amount of penetration is shown in Figures 1 and 2.

Figure 1 shows the radioautographs of the control specimen filled with acrylic resin, the inlay specimen, the amalgam specimen, the gold foil specimen and the oxyphosphate of zinc specimen. These reveal no evidence of the absorption of radioactive calcium into the filling material with the exception of gold foil and there appears to be less penetration of the radiocalcium at the margins of the amalgam restoration.

Figure 2 shows the radioautographs of the silicate specimen and the three acrylic resin specimens. All three of the differently mixed acrylic resins had been compressively retained in their respective cavities by means of a continuous band matrix until polymerization rendered the material hard. The cavities had been overfilled so that there was a flashing at the margins. The flashing was removed 30 minutes after the material had set up.

Figure 2 shows that the silicate restoration became dehydrated, with resultant shrinkage and cracking. In the slab mixing of acrylic resin no attempt was made to control proportions of monomer or polymer and the material was inserted in the consistency of wet sand. In the spatulated acrylic resins and in those not spatulated, a manufacturer's dispenser was used which delivered monomer and polymer in a ratio of approximately 1 to 3 by volume. These mixes were placed in a sealed jar for 30 seconds and were of a "tacky" consistency when inserted into the cavity. With the spatulated jar mix, definite shrinkage took place in the middle third of the restoration adjacent to the buccoaxial wall.

Use of Recorded Knowledge • Failure to make full use of recorded chemical knowledge may seriously impede a research program and make it most costly. For whenever helpful information and data recorded in the literature are overlooked, it is virtually certain that needless experimental work will be done in the laboratory. It is a rule with few exceptions that the cost of laboratory experimentation is many times greater than that involved in having a literature expert locate the record of previous experimentation. *J. W. Perry, Chem. Eng. News 28:4530, 1950.*

Problems rel
complete up

L. E. Kurth, D.

The main objectives in the cons
tion of complete upper dentures
partial lower dentures should be
restoration of masticatory efficiency
"the perpetual preservation of the
maining structures," (M. M. DeV
The other objectives, retention, stab
comfort, esthetics and patient satis
tion, should of course be recognized
striven for by the operator. The prob
of occlusion is related to the satisfac
completion of the above objectives.
problem is simplified if the partial lo
denture is primarily tooth-borne, for
the problems would be comparable
those involved in constructing a comp
upper denture to occlude with a
complement of natural mandibular te
This discussion, however, will cons
only those problems arising when a
tient is completely edentulous in
upper jaw and has six lower ante
teeth.

An intelligent understanding of
clusion presupposes a knowledge
mandibular movements for it is dur
masticatory function that the prosth
appliances will be placed under the gr
est stress. The physiologic act of masti
tion can be divided into incision,
actual mastication and finally, the sw
lowing of the bolus of food. The l
cheek, tongue, palatal area, all as
ciated musculature and mucosa, as w
as the teeth and their supporting str