Physico-Chemical Studies on the Structure of Dental Enamel. II. a Quantitative Method for Determining Relative Differences in the Permeability of the Teeth

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PHYSICO-CHEMICAL STUDIES ON THE STRUCTURE OF DENTAL ENAMEL. II. A QUANTITATIVE METHOD FOR DETERMINING RELATIVE DIFFERENCES IN THE PERMEABILITY OF THE TEETH[1]

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I. INTRODUCTION

A previous communication[1] presented evidence indicating that the enamel of a dog canine may be considered a permeable membrane. This evidence consisted of electro-endosmotic, osmotic, and membrane-potential determinations. All three types of evidence indicate that enamel is a structure having the permeability of what Michaelis would call "large pored" collodion membranes. As there pointed out, a study of potential differences that arise across a membrane, when it separates two salt solutions of different concentrations, throws considerable light upon the structure and properties of the membrane. Many membranes appear to retard or prevent movement through them of ions of one electrical sign, while permitting passage of ions of the opposite sign. As a result of this selective permeability, measurable potential differences arise. Membranes having relatively large pores give rise either to no membrane potentials or to very slight ones. Membranes having very small pores prohibit the entrance of certain ions because of electrostatic forces in the pores, and give rise to potentials of considerable magnitude.

[1] The first study was published by Klein, H., and Amberson, W. R.: *Journal of Dental Research*, 1929, ix, p. 667.

An ideal membrane, which prohibits entirely the penetration of one ion of a bathing salt solution, gives rise to a maximum membrane-potential. The value for such a potential difference across an ideal membrane,[2] at 20°C., is 0.058128 volt. When a membrane is so set up that the salt solution inside is ten times more concentrated than that bathing the outside, the ensuing EMF has been termed by Michaelis the Co.P of the membrane. The Co.P for an ideal membrane as described above is then 0.058128 volt at 20°C. If a membrane gives a Co.P value lower than this, the membrane is more permeable than the ideal structure, since magnitude of Co.P is dependent upon the selective permeability of the structure for ions. The determination of Co.P, whether the membrane is egg shell, skin, collodion, frog skin, enamel, etc., gives an index of the permeability of the structure. A Co.P close to 58 millivolts indicates a membrane that is only slightly permeable; lower values show greater permeability. Very small EMF values for Co.P indicate a relatively permeable structure.

In a study of the influence of various diets on teeth of swine, it was desirable to determine quantitatively a possible effect on the porosity of tooth structure. Histological evidence[3] indicates that, in animals on deficient diets, tooth structure is inferior to that in control animals—there is delayed and defective calcification of the enamel and dentine. The question arose: do the teeth in animals on deficient diets have a greater permeability than the normal? To obtain the answer, Co.P determinations were made on both types.

II. EXPERIMENTAL

Right central incisors from groups of control and deficient swine were extracted, cleansed of all bone and soft tissue, sawed through at the enamelo-cemental junction, and the roots discarded. The crowns were thoroughly washed in distilled water, and the enamel surfaces cleansed with a small tooth brush. Each incisor crown was given a number, and placed in an individual test tube in 0.1 *M* KCl for 48 hours. The latter procedure permits the crown to become thor-

[2] Clark: Determination of hydrogen ions, p. 303; Williams and Wilkins Co., Baltimore, Md,

[3] Unpublished findings by the author.

TABLE 1

Table showing determinations of membrane potentials (Co.P) across central incisor crowns of pigs on control or deficient diets. Temperature 25°C. Co.P for ideal membrane, at 25°C., 0.05912 volt

Pig No.	Age *days*	Polarity: inside	Polarity: outside	Membrane potential *volt*	Calomel electrode readings[1] *volt*	Co.P[2] *volt*
Control diet						
9960	299	−	+	0.02952 0.03226 0.03276	0.009 inside outside + −	0.04051
5280	126	−	+	0.02973 0.03772 0.04410	0.009 inside outside + −	0.04618
9963	292	−	+	0.04702 0.04705	0.00205 inside outside − +	0.04498
5251	234	−	+	0.05445 0.05525	0.00205 inside outside − +	0.05280
Low calcium-high phosphorus diet						
5285	105	−	+	0.01853 0.01906 0.01907	0.009 inside outside + −	0.02822
5206	104	−	+	0.02235 0.01678 0.02028	0.009 inside outside + −	0.02880
5286	125	−	+	0.02455 0.02375 0.02587	0.009 inside outside + −	0.03372

[1] The difference in potential between the calomel electrodes without the crown in the circuit is *added* to the Co.P reading, when inside is minus and outside is plus. When inside is plus and outside is minus, the calomel electrode reading is *subtracted* from the Co.P readings.

[2] The Co.P values are averages of the individual determinations of membrane potential.

oughly impregnated with KCl. Into the dentine of each crown, a small cavity was drilled with a fissure bur. The drilling was so controlled as to make each cavity in each crown the same size. The teeth were then returned to their respective test tubes, and allowed to remain in 0.1 *M* KCl. The Co.P was determined in the following manner: Each crown was adjusted in an apparatus identical with that shown in Figure 1 of the earlier paper,[4] with 0.1 *M* KCl inside the cavity in the dentine and 0.01 *M* KCl outside the crown. EMF was measured with a type-K Leeds and Northrup potentiometer. A capillary electrometer was used as a null instrument.

III. RESULTS

Right central incisor crowns from animals on control and deficient diets gave Co.P values that differed significantly in their magnitude. The teeth from control animals gave in general higher Co.P readings than teeth from animals on deficient diets, as shown in *Table 1*.

Since the magnitude of Co.P is dependent upon the efficiency of the membrane as an ionic sieve, and since Co.P magnitude is greater the more impermeable the membrane and smaller the more permeable the membrane, the determinations herein described, although few in number, seem to indicate that central incisor crowns from pigs on calcium-deficient diets are more permeable than central incisor crowns from animals on control diets.

IV. SUMMARY

1. A quantitative method to express permeability differences in teeth is presented.

2. With this method central incisor crowns from pigs on deficient diets gave smaller Co.P values than those from control animals.

3. Comparison of the Co.P values indicates that the crowns from animals on deficient diets were more permeable than those from control pigs.

[4] Klein and Amberson: *Loc. cit.*, p. 669.