Liberation by Electrolysis of Calcium and Phosphorus from the Tooth Substance.

(Preliminary Experimental Study.)

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The possible effects of the passage of a dry cell battery electric current through the hard tooth substance were studied in a series of three experiments and three control tests. It was presumed that the passage of an electric current through recently extracted human teeth would produce electrolysis and thus liberate certain tooth elements.

The composition of the various hard tooth tissues has been analyzed by BIBRA who obtained the following results:

	For dentine %	For enamel %	For cementum %
$Ca_3(PO_4)_2$	66.72	89.82	58.73
$Mg_3(PO_4)_2$	1.08	1.34	0.99
$CaCO_3$	3.36	4.37	7.22
$CaFe_2$	trace	trace	trace
Other salts	0.88	0.88	0.82
Organic matter	28.01	3.59	32.24

It is apparent from these analyses that calcium and phosphorus in their various and mutual combinations dominate the inorganic matters of the tooth substance. Accordingly, we employed in the present experiments an electrolyte of known composition which did not contain any of the mentioned elements. After the completion of the series of experiments the electrolyte was studied in order to ascertain whether or not calcium or phosphorus had been dissolved from the tooth substance as a result of the passage of the electric current. Precautions had been taken to exclude these elements from other sources but the tooth substance. Arrangements were likewise made to study the effect at each pole separately.

The experiments were conducted during 16 days. Physiological saline solution (0.85 % NaCl) was employed as an electrolyte.

Experimental Method.

Six human teeth were employed. By using two teeth in each experiment, we could conduct three approximately parallel experiments. Three control tests were conducted besides these three experiments and altogether we employed two teeth with electrolytes and an electrolyte without a foreign body.

The enamel was removed from each tooth in the manner in which the tooth is ground for a metal crown. The enamel of seven teeth was then replaced with a corresponding number of aluminium caps which were cemented to the teeth. Each cap was supplied with a spike-like projection made of the same metal. These projections were connected with an isolated electric wire in couples through a dry cell torch lamp battery, as shown in Fig. 1. The couples of connected teeth were then submerged separately in quarts-vessels into which were pipetted 19 cc. of physiological salt solution. The metal and the adjacent parts of the tooth surfaces had previously been isolated from the salt solution by means of a paraffin layer. The conductive chain was made with a U-shaped quarts-tube filled with a mixture of gelatine and salt solution. The metal and the adjacent parts of the tooth surfaces had previously been isolated from the salt solution by means of a paraffin layer. In this manner was obtained a conductive connection between the containers with a minimum of transferred ions. The arrangement of the experiments is shown in Fig. 1.

Three paraffin-coated glass-vessels were employed in the control tests and each vessel contained 19 cc. of salt solution. A

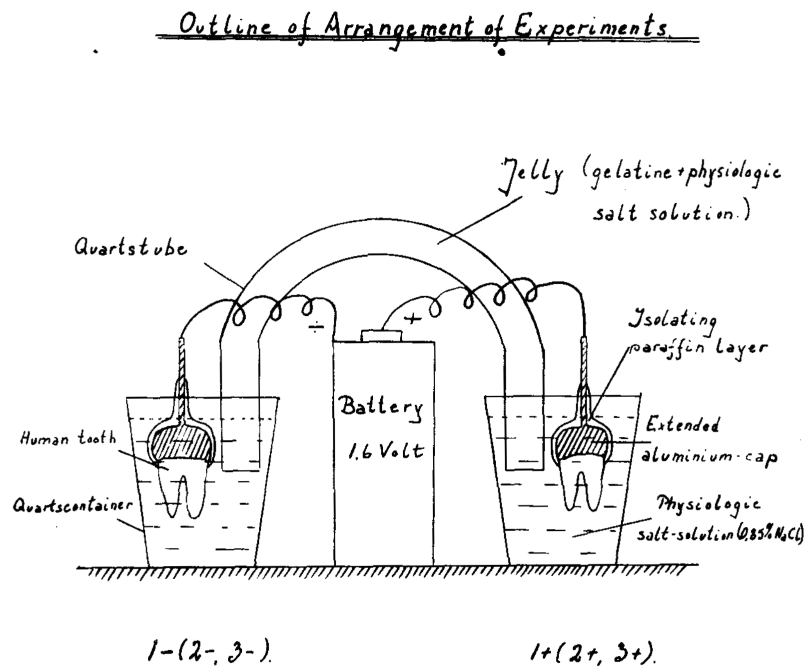

Fig. 1.

tooth without enamel was placed in one vessel. A similar tooth supplied with a cemented aluminium cap, isolated from the salt solution by means of a paraffin layer, was placed in another vessel. The third vessel contained only salt solution.

The voltage of the dry cell battery was measured seven times during the experiments, as shown in Table 1. The polarization-voltage and the current were each measured six times. At the close of each experiment the contents of the vessels were poured separately into paraffin-coated glass-jars supplied with a bakelite screw-lid. The nine containers were sent to the Institute of Chemistry at the University in Oslo where the contents were analyzed chemically by K. E. Gloppe, M. Sc., for the amount of calcium and phosphorus present in the electrolyte. The technical procedure and the quantitative results are given in the analytical report and Table 1 presents the measuring results.

Table I.

Tabular Statement of Measuring-Results.

Battery-voltage: Measured on the pinch-screws of battery while running (tube-voltmeter).
Polarization-voltage: Measured immediately after declutching of battery (tube-voltmeter).
Current: Measured by coupling of a galvanometer in circuit (Siemens rotating-spool instrument).

Experiment number	Number of days	Battery-voltage. Volt.	Polarization-voltage. Volt.	Current Milliamp.	Comments.
I	0	1.6			
	3	1.6	0.74	0.1	Escape of gas at both eloctrodes.
	7	1.6	0.76	0.1	Intense escape of gas. Small crevices in paraffin layer.
	9	1.6	0.76	0.1	
	12	1.6	0.63	0.14	Part of paraffin layer on cathode broken off because of gas.
	14	1.5	0.69	0.14	
	16	1.5	0.75	0.11	
II	0	1.6			
	3	1.6	0.64	0.05	Escape of gas at both electrodes.
	7	1.6	0.74	0.09	Intense escape of gas.
	9	1.6	0.74	0.10	Intense escape of gas.
	12	1.6	0.82	0.30	Intense escape of gas, precipitate.
	14	1.5	0.85	0.23	Intense escape of gas. Crevice formation in paraffin layer of cathode.
	16	1.5	0.88	0.35	
III	0	1.6			
	3	1.6	0.63	0.013	Slight escape of gas at cathode.
	7	1.6	0.70	0.14	Intense escape of gas.
	9	1.6	0.72	0.13	Intense escape of gas.
	12	1.6	0.75	0.17	Intense escape of gas.
	14	1.5	0.76	0.17	Intense escape of gas. crevice formation in paraffin layer of cathode.
	16	1.5	0.77	0.17	

Chemical Analyses.

The quantitative determination of calcium and phosphorus in the nine paraffin-coated containers with electrolyte, submitted to chemical analysis, are given in the analyst's report which follows:

Analyst's Report.

The contents of each container were quantitatively transferred to calibrated 25 ml. measuring flasks together with the distilled water washings of the emptied container. Any undissolved residue was dissolved in 2 N solution of HCl. The contents of the measuring flasks were made slightly acid with HCl (pH approximately 5.0) and the flask was filled with distilled water to the calibrated mark. For the determination of calcium, 10 ml. were removed with officially calibrated pipettes while 5 ml. were removed for the determination of phosphorus. For the tests 1+, 2+ and 3+ it was necessary to remove only 1 ml. on account of the excessive phosphorus content.

Calcium was determined by a modified KRAMER and TISDALL micromethod for determination of calcium in the blood serum. Phosphorus was determined by KUTTNER and LICHTENSTEIN's colorimetric method for phosphorus in the bloood serum.

The standard deviation for the calcium determination was calculated to $\pm$ 0.015 mg. for each determination, and for phosphorus to approximately 3 percent of the obtained quantity of phosphorus.

The glasses were marked 1+ and 1— for the first tests, 2+ and 2— for the second tests and 3+ and 3— for the third tests. The tests were found to contain:

Glass marked	Calcium mg.	CaO calculated in mg.	Phosphorus mg.	P_2O_5 calculated in mg.
Physiol. salt sol.	trace	—	trace	—
Control I	0.63	0.88	0.14 (1)	0.65
Control II	0.71	0.99	0.13 (8)	0.63
Glass 1—	0.13	0.19	0.13	0.59
Glass 1+	8.63	12.07	1.61	7.36
Glass 2—	0.23	0.32	trace	—
Glass 2+	6.45	9.03	0.91	4.18
Glass 3—	trace	—	0.08	0.36
Glass 3+	4.05	5.67	0.72	3.29

Discussion.

The three parallel tests in these experimental series have produced identical results. It is assumed, therefore, that the obtained changes follow definite natural laws. The apparent feature in the chemical analyses is the relatively large concentration of calcium and phosphorus at the anode and that the cathode showed less concentrations of calcium and phosphorus than the control experiments.

The aqueous solution of sodium chloride is partly dissociated into positive Na-ions and negative Cl-ions. Na^+ migrates to the cathode and Cl^- to the anode. Both sodium and chlorine are very reactionary elements and after fluorine is chlorine the most reactionary element. Sodium has a marked affinity for water which it dissociates with the production of sodium hydroxide and hydrogen according to the following reaction:

$$2NaCl + 2H_2O = 2NaOH + H_2 + Cl_2$$

After the dissociation of chlorine at the anode, at least three things may happen:

1. The chlorine makes a direct union with the tooth substance or with parts of it which are liberated under the influence of the electric current passing through the tooth.
2. The chlorine reacts with the water in the following manner: $Cl_2 + H_2O \rightleftarrows HCl + HClO$. The tooth substanec will be attacked both by hydrochloric and subhydrochloric acids. Thus hydrogen is liberated and unites with chlorine with reproduction of hydrochloric acid.
3. The chlorine escapes.

At the cathode the following reaction will take place: $2\ Na + 2\ H_2O \rightleftarrows 2\ NaOH + H_2$. Part of the hydrogen will escape and this may explain the formation of crevices in the protecting paraffin layer at the cathode. The rest of the liberated hydrogen will cover the tooth as a protecting coat. The so-called polarization-tension is directly dependent on such a coat which counteracts the flow of current. Further it may be assumed that the NaOH concentration at the cathode is greater than is the concentration of NaCl. The effect of the ions of chlorine will on this account be less than it is in the control tests, with the result that less of the tooth's inorganic substances are dissolved. The sodium hydroxide will probably for the most part react with the tooth's organic components, while a jelly-like decomposition takes place in the protoplasm.

Conclusions.

The relatively considerable liberation of calcium and phosphorus from teeth submerged in physiological salt solution, which acted as positive electrodes, may be explained on the basis of the chemical reactions which occur in such cases (as shown in tests 1+, 2+ and 3+ of the experimental series).

The relatively small liberation of calcium and phosphorus from similarly treated teeth where they acted as negative electrodes, may also be explained on the basis of physical-chemical reactions (as shown in tests 1—, 2— and 3— of the experimental series).

As applied to the conditions within the oral cavity, one might expect that a liberation of inorganic elements from the tooth substance takes place around the metallic dental repairs which, moistened with saliva, act as anodes. Likewise, that an alkalietching from the liberation of organic tooth substances takes place around such metallic dental repairs which, moistened with saliva, act as cathodes. In accordance with this, the phenomenon of polarization will be observed at the cathode.

Summary.

The possible effects on the tooth substance of the passage of an electric current from a torch lamp battery were studied in an experimental series and control tests.

In the series, the recently extracted human teeth were surrounded by an aqueous solution of sodium chloride, and the current produced electrolysis. The experiments were controlled by physical methods while running, and the electrolytes were examined chemically after completion of the experimental series. The results were identical for all the experiments, and the chemical analyses made apparent that liberation of calcium and phosphorus had taken place at the anode on account of passage of the electric current through the tooth substance.

Zusammenfassung.

Die mögliche Wirkung des Durchgehens eines elektrischen Stromes von einem Taschenlampenelement auf die Zahnsubstanz wurde an einer Versuchsreihe und an Kontrollen studiert.

In der Versuchsreihe wurden frisch extrahierte Menschenzähne mit einer wässrigen Kochsalzlösung umgeben, in der der Strom Elektrolyse hervorrief. Die Verhältnisse wurden im Laufe des Versuchs mit physikalischen Methoden kontrolliert und die Elektrolyten nach Beendigung des Reihenversuchs chemisch untersucht. Das Ergebnis war in sämtlichen Versuchen das gleiche, und die chemische Analyse ergab, dass durch den elektrischen Strom durch die Zahnsubstanz Kalzium und Phosphor an der Anode freigesetzt worden waren.

Résumé.

Une série d'expériments, vérifiés par différents tests a permis à l'auteur d'étudier l'action éventuelle du courent électrique transmis d'une pile électrique et passant à travers la substance dentaire.

On entoura les dents humaines nouvellement extraites d'une solution aqueuse de sodium chlorique et on observa que le courent causa une electrolyse. On pratiqua des méthodes physiques pour contrôler le cours des expériments et, après avoir achevé la série des expériments, un examen chimique pour étudier les electrolytes. L'analyse chimique révéla que du calcium et du phosphore s'étaient dégagés à l'anode et que se dégagement était dû au passage du courant électrique à travers la substance dentaire.

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