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THE LIQUID MOVEMENT IN DESICCATED AND REHYDRATED DENTINE *IN VITRO*

by

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INTRODUCTION

In 1898 *Miller* suggested that the best way of making the dentine less sensitive was by desiccation of the dentinal surface. In an experimental study it was found that air drying a cavity for 5 minutes made the dentine completely insensitive as long as the dentine was kept dry (*Brännström*, 1960). In this study the maximum observation period was 20 minutes. Histologically it was noticed that the odontoblast layer behind the cavity had been sucked into the dentinal tubules. It was suggested that one reason for the elimination of sensitivity was the blocking of the outer apertures of the dentinal tubules by solid material. Water evaporates but salts and organic substances remain at the apertures. Such plugs might reduce a hydrodynamic transmission of pain stimuli. Another possibility is that the odontoblasts sucked into the tubules behaved as plugs at the pulpal ends of the tubules, or that a junction between odontoblast processes and nerve fibres, observed by *Frank* (1968), was interrupted when cells were aspirated into the tubules. Favouring the first explanation is the clinical observation that if the dentine is wetted after desiccation the sensitivity returns. This also occurs if the dentine surface is carefully removed.

Hamilton and *Kramer* (1967) found that rehydration of desiccated dentine did not change the situation in the corresponding pulp. The odontoblasts

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remain in the dentinal tubules after rehydration and undergo autolysis within a few days (*Brännström*, 1968).

In clinical experiments it has been shown that hyperosmotic solutions, such as $CaCl_2$, may produce pain when applied to exposed dentine (*Anderson & Ronning*, 1962). The main effect of such solutions seems to be dehydration and an outward flow of the contents of the dentinal tubules (*Anderson, Matthews & Gorretta*, 1967; *Lindén & Brännström*, 1967) thus mobilizing capillary forces and producing the same hydrodynamic transmission mechanism as for most other pain producing stimuli, as explained previously (*Brännström*, 1963; *Berggren & Brännström*, 1965; *Brännström*, 1966; *Brännström, Lindén & Åström*, 1967).

It has been indicated that preparation with air cooling may prevent heat damage to the pulp (*Schuchard & Watkins*, 1961; 1965) but may result in a pronounced aspiration of odontoblasts (*Langeland*, 1957; *Hamilton & Kramer*, 1967). This also occurs when desiccation of the dentine is performed immediately after extraction of teeth (*Marsland & Shovelton*, 1957; *Brännström*, 1962).

The present *in vitro* study was designed to find out if removal of the surface layer of the cavities followed by rehydration of the dentine, after desiccation by drilling and air-cooling, could increase the centrifugal liquid movement in the dentinal tubules upon the application of some dehydrating and pain producing agents.

MATERIALS AND METHODS

The experiments were performed on 10 freshly extracted intact premolars from individuals 10—17 years of age. During the time elapsing from extraction to experiment the teeth were stored in saline. All experiments were made within one hour after extraction. The apical half of the root was cut off and the pulp was connected with a polyvinyl tube to a graduated glass capillary tube, 0.25 mm in inner diameter and filled with saline, as described elsewhere (*Brännström, Lindén & Åström*, 1967; *Brännström, Lindén & Johnson*, 1968).

A buccal and a lingual cavity, 2 mm in diameter and 1.5 mm in depth were prepared in each tooth at about 300.000 r.p.m., using only air for cooling. This procedure would give a pronounced aspiration of odontoblasts and also produce desiccation of the dentine surface in the cavities. Likely salts and organic substance may remain in the tubule apertures after the evaporation of water during drilling and air cooling. In order to remove

such plugs the superficial dentine layer in one cavity chosen by drawing lots was carefully removed using a fissure bur under water cooling. This was then followed by rehydration of the cavity by the application of saline in the cavity for 15 minutes. During this procedure the aperture of the opposite control cavity in the tooth was kept sealed with wax in order to keep this cavity dry until it was tested.

The tooth-glass capillary system was allowed to stabilize for 15 minutes before starting the test. A series of 3 tests were performed on the same cavity using 3 different agents. Between each test the cavity was rinsed thoroughly with saline, dried with cotton pellets and then filled with saline for 60 seconds.

As the first test a 4 molar solution of $CaCl_2$ was applied to the cavity for 100 seconds. The second test on the same cavity was ether applied in the same way and the third test was the application of a 5-second air blast. The position of the meniscus in the glass capillary was registered by a magnifying glass every 10 seconds. After these 3 tests were completed on the first rehydrated cavity this was covered with wax and the same tests were performed on the other cavity which had remained dry and untreated during the previous experiments.

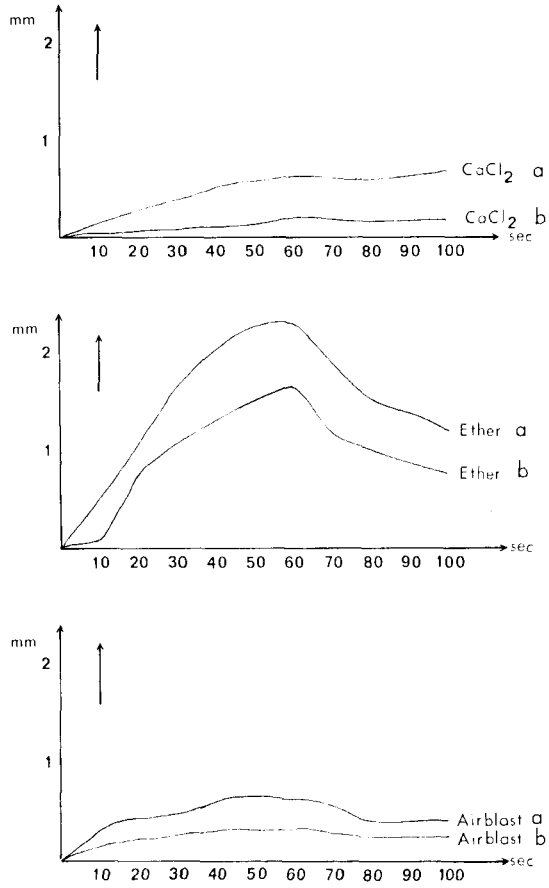
Table I.

Mean value for test on 10 teeth, a. cavity with dentine surface removed and rehydrated after original desiccation, b. untreated (desiccated) cavity

Seconds	$CaCl_2$ a	$CaCl_2$ b	Ether a	Ether b	Airblast a	Airblast b
10	0,15	0,03*	0,51	0,08*	0,31	0,15
20	0,28	0,06***	1,09	0,78*	0,42	0,21
30	0,38	0,08***	1,65	1,07**	0,49	0,26
40	0,52	0,1 ***	2,05	1,34*	0,59	0,30
50	0,57	0,14***	2,29	1,52*	0,64	0,32
60	0,63	0,2 *	2,3	1,66*	0,63	0,33
70	0,61	0,19***	1,9	1,17**	0,53	0,28
80	0,61	0,18***	1,53	1,01*	0,40	0,26
90	0,62	0,18**	1,41	0,88*	0,41	0,26
100	0,65	0,18***	1,21	0,79*	0,42	0,26

* The mean values for the untreated (desiccated) cavities (b) differed significantly from the corresponding mean values for the cavities with dentine surface removed and rehydrated after orginal desiccation (a)

* = $0{,}05 > p > 0{,}01$;
** = $0{,}01 > p > 0{,}001$;
*** = $0{,}001 > p$



RESULTS

The results are summarized in Table I with the mean values for all tests and are graphically illustrated in Fig. 1. The results showed that the pulpal movement of the liquid in the glass capillary (which tubules beneath the cavity) was larger for the rehydrated cavity than for the untreated cavity. The meniscus started to move immediately upon the application of ether while a slight delay was observed with the application of $CaCl_2$ and an air blast. The movement stopped immediately when the cavity was rinsed with saline, then started to return toward its original position if ether had been the test agent. However, this return movement was observed only to a slight extent following an air blast but not at all after the application of $CaCl_2$.

DISCUSSION

The results seem to support the concept that the reduction in sensitivity after dehydration of dentine may be due to a blocking of the cavity end of the dentinal tubules with salts and organic substances rather than to blocking of the pulpal end by the aspiration of odontoblasts. The present observations also support the view presented by *Anderson*, *Matthews* and *Shelton* (1967) that variations in dentine sensitivity are partly due to changes in the dentine rather than in the pulp. It is reasonable to believe that the situation at the outer apertures of the tubules plays an important role in the sensitivity of the dentine. This has also been indicated in replica studies in which it was found that a hypersensitive dentine surface had tubule apertures more easily affected by mechanical disturbances (*Brännström*, 1965). If the hydrodynamic transmission theory for pain stimuli is true it is conceivable that dry substances plugging the outer apertures of the tubules may essentially reduce the possibility for different types of mechanical and chemical stimuli to produce a rapid capillary flow in the tubules.

The possibility that aspiration of odontoblasts would result in a blocking of the connection between the nerve ending and odontoblasts in the dentinal tubules and thus result in reduction in sensitivity, is contradicted in experiments showing that the dentine may still be sensitive — even to dry absorbent paper — in areas in which the odontoblasts have been removed (*Brännström & Åström*, 1964).

The more extensive movement produced by ether compared with the other stimuli is in accordance with previous observations and due to the low thermodynamic water activity for this solution combined with its cooling effect during evaporation (*Lindén & Brännström*, 1967). The distinct return movement after the interruption of the application of ether may to some extent be due to the cooling of the dentine during evaporation. The liquid in the tubules contracts during the test period and expansion will follow when the temperature returns to the starting points. Such a return movement can not be expected to any appreciable extent for pure dehydrating stimuli such as $CaCl_2$. The hydrodynamic effect of dehydrating stimuli and temperature changes have been illustrated and discussed in previous studies (*Brännström, Lindén & Åström*, 1967).

SUMMARY

Buccal and lingual cavities were prepared in ten freshly extracted premolars with high speed, using air-cooling thus desiccating the cavities. By random

selection one cavity on each tooth was chosen for removal of the surface layer of the cavity followed by rehydration. Half of the root was cut off and the tooth pulp was apically connected to a graduated glass capillary filled with saline. Ether, calcium chloride solution, and an airblast were applied to both cavities on each tooth. The movement of the liquid meniscus in the glass capillary, was recorded for each test. It was found that this movement was more pronounced when testing the rehydrated cavity.

It is known that the test agents used in this study may produce pain when applied to exposed dentine but that the sensitivity is strongly reduced after desiccation. The results indicate that one reason for this reduction in sensitivity might be due to blocking of the dentinal tubules at the floor of the cavity with salts and organic substances thus reducing the outward movement of the contents of the dentinal tubules. This outward movement might be the usual pain producing stimulus.

RÉSUMÉ

DÉPLACEMENT DE LIQUIDE PROVOQUÉ DANS LA DENTINE APRÈS DESSICCATION ET RÉHYDRATATION IN VITRO PAR DES AGENTS PRODUISANT UNE DOULEUR

Des cavités versibulaires et palatines ont été préparées dans dix prémolaires récemment extraites en utilisant des instruments à grande vitesse avec refroidissement par air, ce qui déterminait une dessiccation des cavités. Un prélèvement au hasard a permis de choisir pour chaque dent une cavité dans laquelle l'ablation de la partie superficielle a été suivie d'une réhydratation. La moitié de la racine a été amputée et la pulpe dentaire a été mise en communication du côté apical avec un tube capillaire gradué en verre rempli d'une solution saline. De l'éther, une solution de chlorure de calcium et un jet d'air ont été appliqués aux deux cavités dans chaque dent. Le déplacement du ménisque dans le tube capillaire a été enregistré pour chaque essai. Ce déplacement s'est révélé être plus marqué lors de l'essai dans la cavité réhydratée.

On sait que les agents utilisés dans cette étude pour les essais sont susceptibles de produire une douleur lorsqu'on les applique à la dentine, mais que la sensibilité est fortement réduite après dessiccation. Les résultats de cette étude indiquent qu'une des raisons de cette réduction de la sensibilité peut résider dans un blocage des canalicules dentinaires par des sels et des substances organiques au niveau du plancher de la cavité, réduisant ainsi le déplacement vers l'extérieur du contenu des canalicules dentinaires. Ce déplacement vers l'extérieur serait peut-être le stimulus produisant habituellement la douleur.

ZUSAMMENFASSUNG

FLÜSSIGKEITSBEWEGUNGEN IM DEHYDRIERTES UND REHYDRIERTES DENTIN IN VITRO

Buccale und linguale Kavitäten wurden an 10 eben gezogenen Premolaren mit dem Hochfrequenzbohrer präpariert. Mittels Luftkühlung trocknete man die Kavitäten aus. Nach dem Zufallsprinzip wurde einer Kavität pro Zahn ausgewählt. An dieser Kavität wurde dann das periphere Lager enfernt; eine Rehydration folgte. Die Hälfte der Wurzel wurde abgeschnitten, und die Zahnpulpa apikal mit einer Skala versehenen Kapillare verbunden, die mit einer Kochsalzlösung gefüllt war. Äther, Kalziumchlorydlösung und Luftbläser verwendete man bei beiden Kavitäten an jedem Zahn. Die Bewegung des Flüssigkeitsmeniskus in der Kapillare wurde bei jedem Test registriert. Man kam dabei zu dem Ergebnis, dass die Bewegung immer dann, wenn rehydrierte Kavitäten getestet wurden, besonders ausgeprägt war.

Man weiss, dass die Testagenzien, die bei diesen Versuchen zur Anwendung kamen, Schmerz hervorrufen, wenn sie aus freigelegtes Dentin appliziert werden; dass aber die Sensibilität nach der Austrocknung stark herabgesetzt ist. Die Resultate deuten darauf hin, dass ein Grund für diese Reduktion der Sensibilität in einer Blockierung der sich auf dem Grund der Kavitäten befindlichen Dentinkanäle durch Salz und organische Substanzen gesucht werden könnte; auf diese Weise könnte das Nachaussen-Fliessen des Inhalts der Dentinkanäle reduziert werden. Die angeführte Bewegung (das Nachaussen-Fliessen) könnte die Ursache für die Zahnschmerzen sein.

REFERENCES

Anderson, D. J., B. Matthews & C. Gorretta, 1967: Fluid flow through human dentine. Archs oral Biol. *12:* 209.

Anderson, D. J., B. Matthews & L. E. Shelton, 1967: Variations in the sensitivity to osmotic stimulation of human dentine. Archs oral Biol. *12:* 43.

Anderson, D. J. & G. A. Ronning, 1962: Osmotic excitants of pain in human dentine. Archs oral Biol. *7:* 513.

Berggren, G. & M. Brännström, 1965: The rate of flow in dentinal tubules due to capillary attraction. J. dent. Res. *44:* 408.

Brännström, M., 1960: Dentinal and pulpal response. II. Application of an air stream to exposed dentine. Acta odont. scand. *18:* 17.

» 1962: Dentinal and pulpal response. VI. Some experiments with heat and pressure illustrating the movement of odontoblasts into the dentinal tubules. Oral Surg. *15:* 203.

—»— 1963: Dentine sensitivity and aspiration of odontoblasts. J. Amer. dent. Ass. *66:* 366.

Brännström, M. & A. Åström, 1964: A study on the mechanism of pain elicited from the dentine. J. dent. Res. *43:* 619.

Brännström, M., 1965: The surface of sensitive dentine. Odont. Revy *16:* 293.
—»— 1966: Sensitivity of dentine. Oral Surg. *21:* 517.
Brännström, M., L. Å. Lindén & A. Åström, 1967: The hydrodynamics of the dental tubule and of pulp fluid. Caries Res. *1:* 310.
Brännström, M., 1968: The effect of dentine desiccation and aspirated odontoblasts on the pulp. J. prosth. Dent. *20:* 165.
Brännström, M., L. Å. Lindén & G. Johnson, 1968: Movement of dentinal and pulpal fluid caused by clinical procedures. J. dent. Res. *47:* 679.
Frank, R. M., 1968: Attachment sites between the odontoblast process and the intradentinal nerve fibre. Archs oral Biol. *13:* 833.
Hamilton, I. & I. Kramer, 1967: Cavity preparation with and without watersprav. Brit. dent. J. *123:* 281.
Langeland, K., 1957: Tissue changes in the dental pulp. Odont. Tidskr. *65:* 239.
Lindén, L. Å. & M. Brännström, 1967: Fluid movements in dentine and pulp. Odont. Revy *18:* 227.
Marsland, E. A. & D. S. Shovelton, 1957: The effect of cavity preparation on the human dental pulp. Brit. dent. J. *102:* 213.
Miller, W. D., 1898: Behandlung des hypersensitiven Zahnbeins. p. 114. Lehrbuch der Conservierenden Zahnheilkunde. Verlag, Leipzig.
Schuchard, A. & C. E. Watkins, 1961: Temperature response to increased rotational speeds. J. prosth. Dent. *11:* 313.
—»— 1965: Thermal and histologic response to high-speed and ultra-high-speed cutting in tooth structure. J. Amer. dent. Ass. *71:* 1451.

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