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SOME OBSERVATIONS ON SILICATE CEMENT

by
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INTRODUCTION

Systematic studies on silicate cement have given rise to certain — mainly qualitative — observations on the properties of this material. It is considered that these properties are of general interest, and they will be described in the following pages.

MATERIAL AND METHODS

1. General description

Six different brands of silicate cement, all complying with F.D.I. Specification No. 5, were used throughout this study. The cements were normally mixed to standard consistency; to study the effect of thicker and thinner mixes upon the phenomena described below the cements were in some instances mixed with 10 % more or 10 % less powder than the amount required for standard consistency. The volume of liquid for all mixes was constantly 0.1 ml. The cements were mixed at a room temperature of $22 \pm 1°C$ according to the method described in the specification.

After mixing the cements were placed in cavities in extracted upper incisors by adapting small portions of the mix to the cavity walls. The cavities were normally slightly overfilled before the application of a celluloid matrix

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band. The matrix was tightened with a moderate pull in the free ends of the band: the matrix band was removed at the Gillmore initial setting time (Gillmore I time) of the different brands and mixes, whereafter the filled teeth were stored for two hours at room temperature in an atmosphere with a humidity of 100 % and then in demineralized water. In some cases the use of a matrix band was omitted, the cavities were not overfilled, and the surface of the filling was smoothened solely with the filling spatula. Immediately after filling the cavities the teeth were placed in a room temperature atmosphere with 100 % humidity for two hours and then transferred to demineralized water.

The extracted teeth used in the experiments had not been treated by any chemicals after extraction. They were cleaned mechanically and stored in demineralized water at room temperature over a period of minimum one month before cavity preparation. The cavities were prepared by means of smooth tungsten carbide fissure burrs under water spray. The teeth and the cavities were dried with an air blast immediately before the filling was commenced. The diameter of the cavities was two to three millimeters and the depth ca. two millimeters. The diametral dimensions of the cavities were found to be very stable, i.e. better than ± 1 micron throughout the experimental period.

2. Observations of marginal integrity of unpolished fillings

The marginal appearance of 60 fillings placed by the matrix band method was studied after initial setting by means of a stereo-microscope at 36 times linear magnification. 20 of the fillings were made from standard consistency mixes, 20 from mixes with 10 % more powder and 20 with 10 % less powder than at standard consistency. Selection of the cement brand was decided by lot for each individual filling. After finishing the observations the fillings were placed for two hours in a room temperature atmosphere with a humidity of 100 % and then in demineralized water for a period of minimum 48 hours. Later these fillings were used for the observations of surface roughness (see clause 4).

3. Fracturing of filling margins during polishing

Ten fillings were polished immediately after Gillmore I time, ten 24 hours and ten 48 hours after filling of the cavities. The cement brands used were selected by lot for each filling, all cements were mixed to standard consistency. The polishing was accomplished by means of Moyco extra fine finishing strips*.

* The J. Bird Moyer Co., Inc., Philadelphia, U.S.A.

The margins of the fillings were observed after the polishing under a stereo-microscope at 36 times linear magnification.

4. Surface roughness

The surface roughness of all fillings from the above clause (2) and (3) as well as of 20 fillings made without the use of a matrix band was measured by means of a Perth-O-Meter* surface measuring unit. When measuring the roughness of the polished fillings the diamond tracer of the Perth-O-Meter was travelling at right angles to the direction of the polishing streaks. On each filling only one profile line two millimeter long was measured. The surface of all the fillings was also studied in a stereo-microscope at 32 times linear magnification.

5. Setting contraction

20 fillings placed by means of a matrix band and 20 fillings placed only by the filling spatula were allowed to set for one week. All fillings were made from standard consistency mixes; selection of brands was done by lot for each filling. The fillings as well as a surrounding narrow rim of the enamel were ground plane under water on a no. 600 carborundum polishing paper. The width of the contraction gaps at two diametrically opposite points of each filling was measured in a metallographic microscope at 500 times linear magnification. The diameter of the fillings was measured at lower magnification and the setting contraction calculated.

Finally the possibility of displacing or rocking the fillings in the cavities under light unsymmetrical forces was investigated by means of the stereo-microscope at 72 times linear magnification. Light forces were applied on the fillings by means of a sharp dental probe.

During these measurements and observations the fillings were not allowed to dry up. The fillings were repeatedly dipped in water, and although a visible water film on the free surface of the fillings was not acceptable during the microscopic work, water was always visible in the contraction gaps surrounding the fillings.

RESULTS

Marginal integrity

After removal of the matrix band a separation of the cement liquid in an irregular zone along the cavity margin was frequently observed (Fig. 1). The separation was the more pronounced the thinner the cement was mixed;

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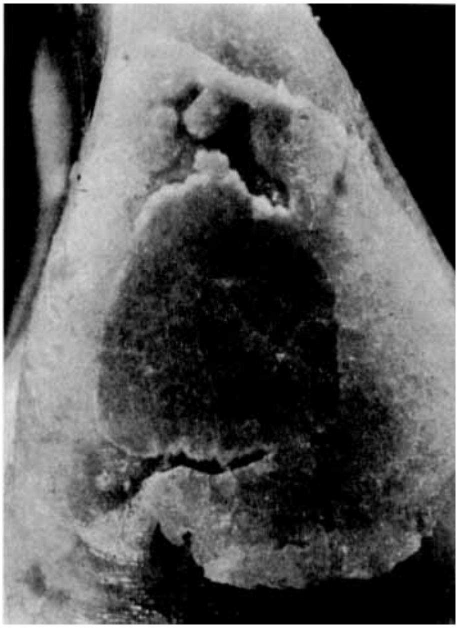

Fig. 1. Marginal separation of cement liquid incisally and gingivally in a Class III silicate cement filling. Ultraviolet photography.

cement mixed to standard consistency showed only a slight tendency to marginal liquid separation and with the thicker mixes there were no signs of liquid separation at all. After the initial observation 20 more fillings were made from thin mixes. The following findings were based mainly on the totally 40 fillings made from thin mixes. The separated cement liquid was most frequently observed in the marginal area of the filling and thus involved the quality of the fillings. In a few cases the liquid was localized on the unprepared surface of the tooth; it was observed here that the matrix was not tightened in toward the cavity margin and that the narrowest fissure between the matrix and the tooth was situated outside the margin immediately adjacent to the expressed liquid.

Separation of liquid was never recorded in cases where the surface of the tooth in the cavity area made it locally impossible for a narrow fissure to form between matrix and tooth (e.g. gingival concavity on proximal surfaces, or very extended cavities); in other words, liquid separation was confined to fillings in small or medium cavities on flat or convex surfaces.

There was no difference between brands as regards the separation of liquid.

Fig. 2. Marginal fracture in a silicate cement filling. The gap occurring between the filling and the cavity wall due to contraction during setting is clearly visible in the lower right of the marginal area. × 65.

Fracturing of filling margins during polishing

A study of the polished fillings revealed that in every instance the margins had been fractured. The width of the fractured area frequently extended to between 100 and 150 μ (Fig. 2) but depended on the direction of polishing action. In the case of local polishing action restricted to a movement parallel with the filling margin, the width of the fracture was slight, often less than 20 μ; when polishing was at a certain angle to the margin of the filling, the width of the fracture often exceeded 100 μ. No connection could be found between on the one hand the age of the filling and on the other hand the size of the marginal fracture; nor had the brand of cement any influence upon the size of the marginal fracture. The enamel margin of the cavity was also damaged by the polishing, frequently showing irregular fractures of a width of between 25 and 50 μ; before the cavities were filled the enamel margins were normally quite smooth and without any defects.

Surface roughness

The surface produced by a matrix band on a silicate cement filling is often described as very smooth, shining or mirror-like, and it is claimed that this surface is more desirable than that which results from polishing with strips. The microscopical study of the cement surfaces produced by the matrix

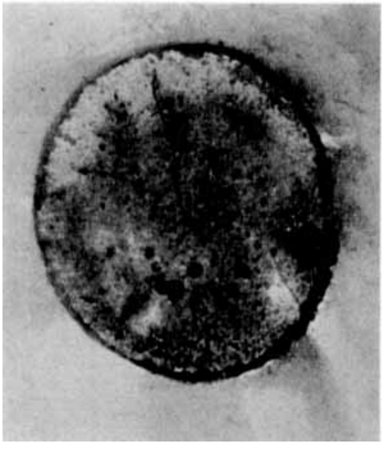

Fig. 3. Typical surface of a silicate cement filling after the removal of the matrix. The surface defects take the form of irregular hemispheres and were caused by air bubbles trapped under the matrix band. The filling has been dyed with methylene blue. The periferal gap was caused partly by contraction during setting, partly by drying. In a macroscopic examination the filling appeared shiny and smooth, and the marginal defects were difficult to see. × 20.

band revealed however that claims of smoothness are based mainly on an optical illusion. When the surface of the fillings were magnified and examined in reflected light, large numbers of surface defects of a considerable size (Figs. 3 and 4) could be observed. The defects apparently arose because the

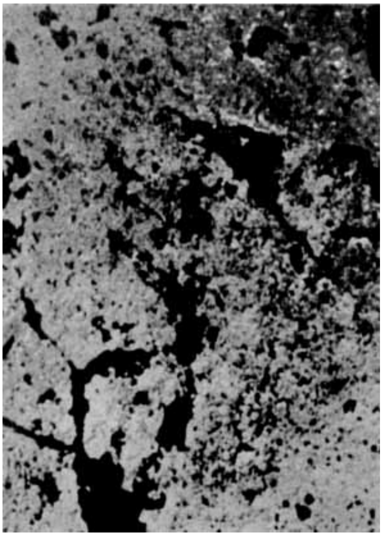

Fig. 4. Irregular defects in the surface of a silicate cement filling after the removal of the matrix. × 50.

Fig. 5. Surface of an unpolished silicate cement filling placed by means of the spatula only. Ultraviolet photography.

smooth matrix at the moment of application trapped air bubbles between itself and the uneven rough surface of the cement, pressing the bubbles into the cement; the defects thus took the form of irregular hemispheres (Fig. 3). It could occasionally be noted that the trapped air had been in the process of flowing out from under the matrix band; in such circumstances the surface defects became quite irregularly shaped (Fig. 4). Fig. 5 shows the surface of an unpolished filling which was placed solely by means of the spatula.

The results of the surface roughness measurements are presented in Table 1.

The differences in roughness between the various experimental groups are relatively small. It is particularly noticeable that polishing at Gillmore 1 time did not result in a greater roughness than polishing 24 or 48 hours later, and that filling solely with a spatula did not result in a significantly greater roughness than when a matrix band was used. Fig. 6 shows sections of some typical surface roughness curves.

Setting contraction

The setting contraction after one week of fillings made by the matrix method was 0.18 ± 0.05 % and of fillings made by the spatula method 0.20 ± 0.06 %.

Table I.

Surface roughness (R_a in μ) of unpolished and polished fillings.

Powder/liquid ratio	Matrix band	Polishing	Age of filling when polishing	n	R_a $\bar{x}$	S.D.
Standard consistency	+	−	Min. 48 hours	20	3.7	0.9
+10 % powder	+	−	» » »	20	3.8	0.9
10 % powder	+	−	» » »	20	3.6	0.7
Standard consistency	+	+	Gillmore I	10	3.4	0.5
» »	+	+	24 hours	10	3.3	0.8
» »	+	+	48 hours	10	3.5	0.8
» »	−	−	Min. 48 hours	20	4.0	0.8

The difference between the two groups is not statistically significant. No difference in setting contraction between the various brands was detectable.

The microscopic observations showed repeatedly that very light asymetric forces would make the fillings rock in the cavities, whith the result that the contraction gap at one point closed completely while at the diametrically opposite point it opened to its maximum width. At the same time the water in the gap was alternately pressed out of the gap or sucked into it.

DISCUSSION

The marginal separation of liquid described in the section on marginal integrity can be explained as a filtration process of the same type as described

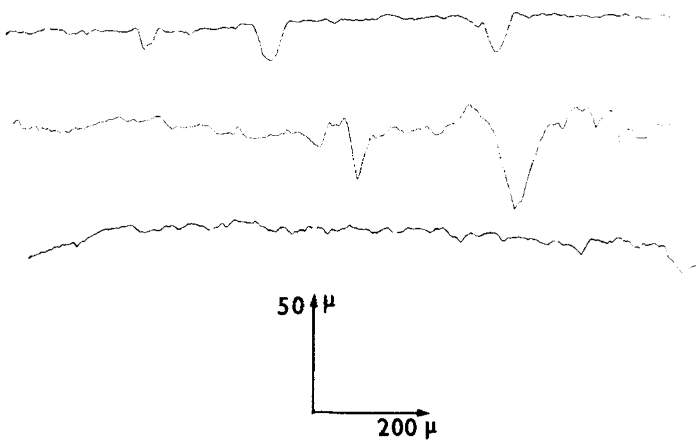

Fig. 6. Surface relief of silicate cement fillings. Top curve: filling placed with matrix band. Middle curve: filling placed by means of spatula alone. Bottom curve: filling polished with an extra fine polishing strip.

in connection with phosphate cement (*Jørgensen,* 1960): the powder particles are pressed closer together in a region in which the cement is forced through a narrow fissure, and it is thus difficult for them to pass through the fissure. Liquid on the other hand will be able to pass through the agglomerated bridge of powder particles and to wash away cement which in relation to the direction of flow lies in the periphery of the fissure. This bridge formation and filtration process is known from many other fields, both dental and non-dental.

Fracturing of silicate cement filling margins during polishing is probably due to the fact that the margins of this brittle material are to a great extend unsupported because of the setting contraction of the cement. The contraction gap may also explain the fracture of the enamel margin.

It is generally assumed that silicate cement fillings are not to any great extend subject to thermal percolation because of the great similarity between the thermal conductivity and the coefficient of thermal expansion of silicate cement and hard dental tissues, respectively (*Nelsen et al.*, 1952); the position does not however appear to be fully clarified (*loc. cit.* p. 289).

The flow of liquid around and under loose and rocking fillings as demonstrated in the present study may be called mechanical percolation since the causing factor is of mechanical nature. Another mechanical factor that will cause percolation is uneven pressure of the liquid at the opening of the setting contraction gap. The mechanical factors in the oral environment which produce asymmetric pressure on fillings and on the liquid in the gap openings are, for example, biting and chewing, drinking, and tongue and labial pressure.

Mechanical percolation around loose fillings probably may be relatively intense. Under the influence of weak forces a filling can, for example, be displaced from contact with one cavity wall to contact with the opposite wall in a fraction of a second while fluid surges through the gap. Thermal percolation, which is often produced by relatively small and brief changes in temperature in materials with low thermal conductivity, must undoubtedly by comparison be considered slight and perhaps almost negligible.

If this view is correct, the precision characteristics of a dental filling material (expansion and contraction during setting, expansion as a result of absorption of water etc.) must be regarded as considerably more important material properties than its thermal characteristics (coefficient of expansion, conductivity, specific heat). Clarification of the position must be awarded importance in the laboratory assessment of both existing and new restorative materials such as silicate cement and compositie and non-composite plastic filling materials.

SUMMARY

A description is given of several, mainly new, technological properties of silicate cement considered to be of importance in assessing the quality of this material.

1. Marginal defects can occur as a result of a filtration process between the matrix band and the cavity margin.

2. Polishing of a silicate cement filling normally results in marginal fractures up to approx. 0.15 mm in width. After the Gillmore 1 time the age of the cement at the polishing stage has no effect on the appearance of the polished filling.

3. The belief that the use of a matrix band produces a mirror-like, smooth filling surface is based mainly on an optical illusion. The surface roughness is approximately the same when a matrix band has been used as when the filling has been placed solely by means of a spatula.

4. The term mechanical percolation is introduced as a new concept parallel to the well-known phenomenon, thermal percolation. In many cases mechanical percolation can be assumed to be considerably more damaging to the quality of filling than thermal percolation.

RÉSUMÉ

QUELQUES OBSERVATIONS SUR LE CIMENT AU SILICATE

Cet article présente quelques propriétés technologiques du ciment au silicate, dont la plupart n'ont pas encore été prises en considération, et qui seraient importantes lorsqu'on veut juger des qualités de ce matériau.

1. Il peut exister au niveau des bords des défectuosités qui sont la conséquence d'un processus de filtration entre la matrice et le bord de la cavité.

2. L'apparition de fractures des bords, d'une largeur allant jusqu'à 0,15 mm environ, est une conséquence normale du polissage de l'obturation. L'aspect de l'obturation après le polissage est indépendant du moment, précoce (Gillmore 1) ou tardif (48 heures après l'exécution de l'obturation), où l'on effectue le polissage.

3. L'aspect brillant de la surface de l'obturation, obtenu en utilisant une matrice, est surtout dû à une illusion optique. La rugosité de la surface est sensiblement la même, que l'obturation soit placée en utilisant seulement une spatule, ou à l'aide d'une matrice.

4. L'auteur introduit la notion d'infiltration d'origine mécanique, parallèlement à la notion d'infiltration d'origine thermique connue depuis longtemps. Les infiltrations d'origine mécanique pourraient dans de nom-

breux cas compromettre la qualité de l'obturation de façon bien plus décisive que les infiltrations d'origine thermique.

ZUSAMMENFASSUNG

EINIGE BEOBACHTUNGEN AN SILIKATZEMENT

Es werden einige in der Hauptsache neue technologische Eigenschaften des Silikatzements besprochen, die für die qualitative Beurteilung dieses Materials von Bedeutung sein dürften.

1. Infolge eines Filtrierprozesses zwischen Matrize und Kavitätenrand können Randdefekte auftreten.

2. Randfrakturen einer Breite von bis zu etwa 0,15 mm sind eine normale Folge des Polierens von Füllungen. Das Aussehen der polierten Füllung ist davon unabhängig, ob das Polieren sehr früh (Gillmore-I-Zeit) oder spät (48 Stunden nach der Herstellung der Füllung) stattfindet.

3. Eine spiegelblanke Füllungsoberfläche nach der Benutzung einer Matrize ist vor allem eine optische Täuschung. Die Rauheit der Oberfläche ist etwa die gleiche, ob die Füllung lediglich mit dem Spatel gelegt oder eine Matrize benutzt worden ist.

4. Mechanische Perkolation wird parallel mit dem längst bekannten Begriff der thermischen Perkolation als neuer Begriff eingeführt. Es ist anzunehmen, dass die mechanische Perkolation für die Qualität einer Füllung in vielen Fällen wesentlich diskriminierender ist als die thermische Perkolation.

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