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STUDIES ON THE PERMEABILITY OF ACRYLIC FACING MATERIAL IN GOLD CROWNS. A LABORATORY INVESTIGATION USING Na^{22}

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Acrylic resin has increased in use as facing material for cast gold crowns during the last few years. Sometimes it is observed in clinical work that caries appears under an acrylic facing, where the underlying gold protection is perforated. It has therefore been recommended (*Yock,* 1953, and others) to have a complete casting protect the tooth in the buccal cut-out area of a gold crown prepared to receive an acrylic resin.

Provided that no leakage occurs at the cervical margin of an acrylic faced gold crown, there may be three possibilities for the mouth fluids to come into contact with the dentine, if the gold protection underlying the facing is perforated:

(1) penetration throughout the acrylic material
(2) leakage between acrylic material and gold
(3) combination of (1) and (2).

The theoretical backgrounds for these possibilities will be briefly discussed below.

Penetration through the acrylic material

It has been observed that polymers in contact with water absorb greater or smaller amounts of water depending on the number of polar groups in the polymer (*Kline, Martin, & Crouse,* 1940, *Baker,* 1952, and others). According to *Brauer & Sweeney* (1955) the

water presumably enters the acrylic resin between the macromolecules and forces them slightly apart. This action of the water is not unlike that of a plasticizer.

The most frequently used method for quantitative determinations of water absorption is to determine the weight increase of the resin per unit of surface area exposed to the water. In this way *Brauer & Sweeney* (1955) found that water absorption of polymethyl methacrylate is independent of the molecular weight in the 4 to 37°C range and that water absorption is constant and independent of the temperature in the 2 to 60°C range. The samples used in their investigation reached constant weights within 30 days. It has been reported (*Vernon-Benshoff*, 1955) that no further change in weight takes place even after storage for an additional 5 years. There seems to be no apparent difference in the water up-take between heat-curing and self-curing resins (*Caul, Stanford, & Serio*, 1952, *Stanford, Burns, & Paffenbarger*, 1955).

Thus, several authors have been interested in quantitative determinations of water absorption but, as far as is known, no extensive study has been published in the dental literature as to the question if a liquid can permeate through acrylic resins. Experiments by *Lamstein & Blechman* (1956) with acrylic faced gold crowns showed, however, that the facing material itself was not permeated by a diluted methylene blue solution or by microorganisms (*Micrococcus pyogenes var. aureus*). It might be thought, however, that the facing material is permeable to smaller particles.

Leakage between acrylic material and gold

The unrestricted linear curing shrinkage of acrylic materials has theoretically been calculated to be approximately 2 per cent if the volume proportions of polymer to monomer is three to one (*Skinner & Phillips*, 1960). The actual linear curing shrinkage observed in longitudinal direction, however, is much less; values have been reported varying from 0.2 to 0.5 per cent (*Skinner & Cooper*, 1943, *Sweeney*, 1939, *Peyton & Mann*, 1942).

Due to curing shrinkage there develops in an acrylic faced gold crown a minute space between the gold and the acrylic material, thus providing possibilities for leakage of mouth fluids into the construction. It has been discussed whether or not water imbibi-

tion compensates for curing shrinkage. *Skinner & Cooper* (1943) reported that measurements of strips of denture resin, presumably stress-free, have shown that the increase in dimension due to water absorption is, for all practical purposes, equal to the curing shrinkage of the specimens. Measurements of acrylic dentures indicate that such an absorption does not always compensate for curing shrinkage. This is proved to be dependent on the curing cycle (*Grunewald, Paffenbarger, & Dickson*, 1952).

The present investigation was undertaken in order to get more exact information concerning the permeability of acrylic facing material. It was decided to use a solution with small ions. Therefore a saline solution labelled with the radioactive isotope Na^{22} was used.

Following the above, the present study is divided in two parts: (1) permeation studies with Na^{22} ions through acrylic facing material and (2) permeation studies with Na^{22} ions through acrylic faced gold cups.

MATERIALS AND METHODS

Isotope used

The radioactive sodium isotope Na^{22} was supplied by the Radiochemical Centre, Amersham. In the present investigation Na^{22} was used in form of sodium chloride in isotonic solution.

Na^{22} disintegrates with emission of positrons of 0.54 MeV followed by one gamma ray of 1.28 MeV; 0.06 % of the positrons are of the energy of 1.83 MeV. The half-life of Na^{22} is 2.6 years.

Arrangements for studies of Na^{22} permeation through acrylic resin

The acrylic material used throughout the investigation was Justi's Dental Pearl, Crown and Bridge "S-R" Formula, and it was supplied by Ivoclar Schaan, Liechtenstein.

Fifty acrylic test cups were processed (See Fig. 1). The dimensions for all of them were equal, the wall thickness being 0.5 ± 0.1 mm. The test cups were processed in specially made brass molds.

The monomer was placed in a mixing jar and polymer was added until all the monomer was taken up. The mixing jar was then vibrated to bring excess monomer to the surface, and more polymer was added until the monomer was saturated. The dough-forming

time was 30 minutes. The acrylic material was then inserted in the brass mold. Trial closures with a damp cloth were repeated until no flash was observed. The brass mold was then allowed to rest in a clamp during 30 minutes before curing. Thereafter, the brass mold was placed in a water bath of 20—22°C. The temperature was raised to 100°C during 30 minutes and kept there for another 30 minutes. The brass mold was then removed from the bath and allowed to cool slowly before the test cup was taken out of the mold.

The test cups were allowed to remain in the radioactive solution (Na^{22} labelled saline solution) for 100 days (see Fig. 1). Before being placed in this bath, 15 of the acrylic cups were allowed to stand with their outer surfaces in an ethyl alcohol bath for five minutes.

Arrangements for studies of Na^{22} permeation through acrylic faced gold test cups

Eight test cups in C-gold were processed. As shown in Fig. 1, they were provided with a 3.0 mm thick, acrylic facing in a bottom cut-out. These facings were cured in the gold cup according to the

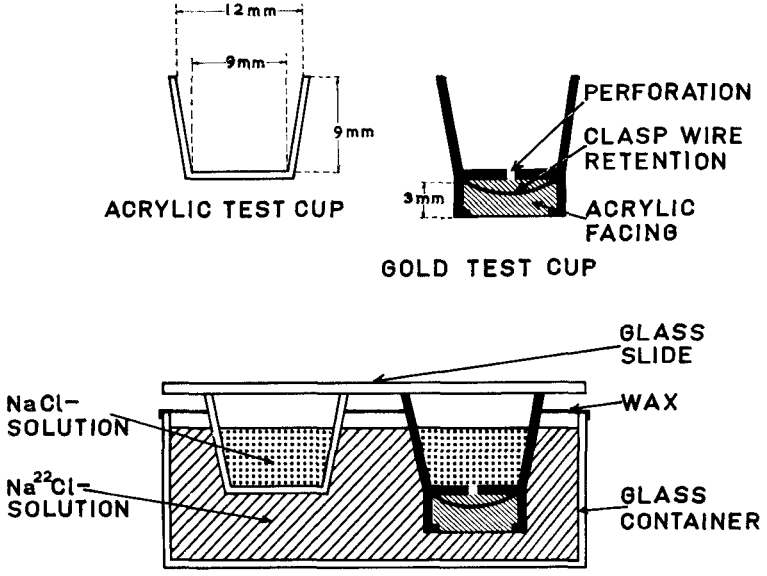

Fig. 1. Test arrangements.

procedure described above. The facings varied in size, four having a diameter of 10 mm and the other four a diameter of 5 mm. The gold material in the bottom of the cups was perforated in the centre with a hole one mm in diameter.

As was done with the acrylic test cups, these gold cups also were put into the radioactive solution and were allowed to be in this solution for 50 days.

Every acrylic test cup was, before use, finely scrutinized microscopically to ascertain that it actually did not show any crack. The same was done with the gold castings and their facings.

Measurement of the permeation of Na^{22} ions

Into every test cup inactive saline solution was pipetted so that the inner and outer solution surfaces were equal in height. The cups were covered with glass slides to prevent evaporation. However, a small evaporation of water occurred from the solution in the cups. In order to keep the inner solution surface level constant distilled water now and then was added.

Every fifth day 0.5 ml of the saline solution in the test cups was taken for measuring the radioactivity. The activity was measured in a well-type scintillation crystal. The size of this NaI (Tl) crystal was $2'' \cdot 1^7/_8''$ with a well of $^5/_8'' \cdot 1^1/_2''$. The operating voltage was 1200 V. At least 10,000 counts were recorded. After measuring, the solution was poured back into the test cup.

RESULTS

No radioactivity was found in the inner solution of any of the 35 acrylic test cups which were immersed in the Na^{22} labelled saline solution for 100 days.

All of the 15 acrylic test cups that before immersion in the radioactive solution were exposed to ethyl alcohol showed a very low activity in the inner solution. This activity tended to rise during the period of 100 days in the Na^{22} labelled saline solution.

In all gold test cups with acrylic facings the inner solutions were contaminated with Na^{22} after only a few hours. The activity increased rapidly in intensity. The influx of Na^{22} from the outer solution to the inner one was more rapid in gold cups with the larger acrylic facings than in those with the smaller acrylic facings.

The rate of permeation was approximately four times more rapid in the cups with the facings having a diameter of 10 mm than in those having a diameter of 5 mm.

DISCUSSION

Sodium ions are very small, the radii being 0.95 Å. The present study did not show any permeation of these small ions through 0.5 mm-thick acrylic facing material.

The absorption reported when polymers are in contact with water is probably concentrated in the surface layer. Anyhow, this seems to be the case with the absorption of Na^{22}. This was confirmed by the following experiments: eight thin acrylic sheets were allowed to stand with half of their heights in a bath of Na^{22}-labelled saline solution for 60 days. Autoradiograms of these sheets revealed location of sodium ions just in the region of the sheet that had been in contact with the radiosodium solution. Thus sodium ions were not drawn up into the part of the sheet above the level of the bath. The acrylic sheets were then washed in water for one minute and again placed in contact with emulsion for two weeks' exposure. The autoradiograms showed no sodium ions in the sheets at all. Consequently, all sodium ions had been washed out by the water.

It seems, however, that the acrylic material exposed to ethyl alcohol probably is permeable to sodium ions. This permeability is probably due to cracks in the acrylic material produced by ethyl alcohol. Solvent crazing effects by alcohol and certain other liquids have been observed by *Spreng* (1943) and others, and were described in detail by *Russel* (1950) and by *Hsiao & Sauer* (1950). The phenomenon of crazing of acrylic material has been defined as "fine cracks which may extend in a net-work over or under the surface of or through a plastic" (*Simonds, Ellis, & Bigelow,* 1943).

The permeation of sodium through the gold cups with the acrylic facing material on the perforated gold windows seems therefore normally not to take place through the acrylic facings but through the gold—acrylic resin margin. It is also evident that this leakage is more pronounced the greater the margin is. Theoretically, it also seems that this leakage will be greater during temperature changes, because the thermal expansion coefficient of the acrylic material is about six times as great as that of gold.

It has also been reported (*Nelsen, Wolcott, & Paffenbarger,* 1952, and *Spreter v. Kreudenstein,* 1953) that when acrylic fillings are chilled and warmed, fluids are imbibed and exuded at their margins. This pumping action has been termed "percolation".

Lamstein & Blechman (1956) concluded that the use of acrylic faced cast gold veneer crowns with perforated gold windows is contra-indicated. *Hedegård* (1957) also suggested that the marginal fit of cold-polymerized acrylic fillings and acrylic crowns is the site of penetration of mouth fluids into the dentine. The results from the present study do not contradict their opinions.

SUMMARY

The permeability of acrylic facing material was studied with a Na^{22}-labelled saline solution. It was shown that during a period of 100 days the small sodium ions did not permeate through 0.5 mm thick acrylic test cups. However, it was demonstrated that when acrylic test cups were exposed for five minutes to ethyl alcohol before immersion in the radioactive solution a very low activity could be demonstrated in the solutions in the test cups. Permeation of sodium ions through gold cups with acrylic facing material on perforated gold windows could be demonstrated within only a few hours. This permeation seems to be due to leakage in the minute space between acrylic resin and gold.

RÉSUMÉ

ÉTUDES SUR LA PERMÉABILITÉ DES FACETTES ACRYLIQUES DANS LES COURONNES D'OR. ÉTUDE DE LABORATOIRE AU MOYEN DE Na^{22}

La perméabilité des matières acryliques des facettes a été étudiée avec une solution saline physiologique marquée au Na^{22}. On a montré que pendant 100 jours les petits ions de sodium n'ont pas pénétré à travers des cupules acryliques d'épreuve d'une épaisseur de 0.5 mm. Cependant on a prouvé que lorsque des cupules acryliques d'épreuve ont été exposées pendant 5 minutes à l'alcool éthylique avant l'immersion dans la solution radioactive, une activité très faible pouvait être mise en évidence dans les solutions contenues dans les cupules d'épreuve. La pénétration d'ions de sodium à travers des cupules d'or avec comportant

de la résine à facette acrylique dans des fenêtres d'or perforées pouvait être mise en évidence en l'espace de quelques heures seulement. Cette pénétration paraît provenir d'un écoulement par la fente minime entre la résine acrylique et l'or.

ZUSAMMENFASSUNG

UNTERSUCHUNGEN ÜBER DIE DURCHLÄSSIGKEIT VON AKRYLAT-FAZETTEN BEI GOLDKRONEN. EINE LABORATORIUMSUNTERSUCHUNG UNTER BENUTZUNG VON Na^{22}

Die Durchlässigkeit von Akryl-Fazetten wurde mit Hilfe einer Na^{22} enthaltenden physiologischen Kochsalzlösung untersucht. Es wurde gezeigt, dass während einer Periode von 100 Tagen die kleinen Na^{22}-Ionen die 0,5 mm dicken Akryl-Testhütchen nicht zu durchdringen vermochten.

Indessen konnte eine geringe Aktivität der im Inneren der Testhütchen befindlichen Lösung nachgewiesen werden, wenn die Testkörper vor dem Einsetzen in die radioaktive Lösung 5 Minuten lang Äthylalkohol ausgesetzt wurden.

Die Durchwanderung von Na^{22}-Ionen durch Gold-Akrylhütchen mit Fenstern in der Goldschicht konnte bereits innerhalb einiger Stunden nachgewiesen werden. Diese Durchlässigkeit scheint auf Undichtigkeit an dem feinen Zwischenraum zwischen Gold und Akryl zu beruhen.

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