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EFFECT OF TOOTHBRUSHING ON ACRYLIC RESIN VENEERING MATERIAL

II ABRASIVE EFFECT OF SELECTED DENTIFRICES AND TOOTHBRUSHES

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The abrasiveness of selected dentifrices and toothbrushes was studied with a toothbrushing machine. Test specimens of acrylic resin material were brushed for 60 minutes. The surface irregularities of the specimen were measured in a Talysurf instrument and the microwaves were studied in a scanning electron microscope. The weight reduction of the specimen was recorded and found to be correlated with a quality value of the irregularities in the test surface (CLA). — The abrasiveness of the dentifrices displayed a wide range, the lowest values being recorded for a dentifrice with methylmetacrylate as abrasive agent, the highest with calcium carbonate as abrasive agent. The abrasiveness of the toothbrushes likewise showed a wide range. Significant differences were recorded between »hard» and »soft» brushes with bristles of nylon, while the corresponding difference for natural bristle material was slight. All the toothbrushes and all but one of the dentifrices studied caused undesirable abrasive effects on the acrylic resin material during the brushing procedure.

The Council on Dental Therapeutics (1970) has pointed out that a dentifrice should not be more abrasive than is necessary to remove accessible plaque, debris and superficial stain. Tests on dentin have shown that commercial dentifrices vary greatly as regards abrasivity (*Council on Dental Therapeutics*, 1970; *Cordon, M.*, 1971).

Acrylic resin materials likewise undergo abrasive changes due to toothbrushing with dentifrices (*Sexson & Phillips*, 1951), the degree of abrasion reportedly correlating with the stiffness of the toothbrush bristles and the type of abrasive agent (*Viera & Phillips*, 1962). Other studies have indicated that abrasivity is not influenced by the hardness of the toothbrush but that abrasion increases with the number of bristles, brushing pressure and brushing time (*Flerlage & Marxkors*, 1969).

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While the effect of toothbrushing with dentifrice on acrylic resin materials has been characterized as mainly abrasive, a chemical influence has also been reported (*Sexson & Phillips*, 1951) and described as lustre changes and crackles (*Öberg & Nilsson*, 1970).

Studies of toothbrushing in vitro on acrylic resin veneering materials can be conducted with good reproducibility and the acrylic material has been shown to be a suitable medium for investigating the abrasivity of dentifrices (*Wictorin*, 1971). The purpose of the present study was to investigate:

1) The abrasivity of selected commercial dentifrices.
2) The abrasive effect of selected toothbrushes.

MATERIAL AND METHODS

The first part of the study concerned the abrasive properties of selected commercial dentifrices. The brushing procedure were performed with the same type of toothbrush for every dentifrice under standardized equivalent conditions.

The eight dentifrices most frequently used in Sweden were selected for the investigation (Table I). Information on the abrasive agents was obtained from the manufacturer. Some data on the size and shape of the abrasive particles were taken from *Gerdin* (1971). The abrasive agent consisted of calcium carbonate in five dentifrices and of sodium bicarbonate, dicalcium phosphate dihydrate and polymethylmetacrylate in one each. All these abrasive agents except sodium bicarbonate were relatively insoluble in water at 37°C.

The toothbrushes used were of prolon bristle (Pro double) with a bristle diameter of 0.012' in the inner rows and 0.009' in the outer rows.

Acrylic resin specimens were heat-cured according to ISO specification R 1567, using Meyersson's Crown & Bridge crosslinked copolymer (1168 A). For further information about the specimens, see *Wictorin* (1971).

The second part of the study dealt with the effect of brushing with selected toothbrushes of different brands, using the same kind of dentifrice in every case. Seven different kinds of toothbrushes were tested, with bristles of various materials (Table II). The bristles of prolon and nylon had a rather constant diameter within a toothbrush, while the natural bristles displayed a slight variation in diameter. The acrylic resin specimens were cured and the brushing procedure was performed in the same way as in the first part. The dentifrice used in this series of tests was Stomatol-Rosa ®.

The acrylic specimens were mounted in the toothbrushing machine described by *Wictorin* (1971). The brushing load was measured to 450 g.

Table I.

The dentifrices and their abrasive agents

No.	Dentifrices	Manufacturer	Chemical composition	Solubility in H_2O,20°C	Mean size 10^{-3} mm	Per cent abrasive agent in the dentifrice
1.	Bofors® No 02635	AB Bofors	Polymethyl metacrylate	Insoluble	0.5	41
2.	Colgate-Gardol® No 0244	Colgate Palmolive AB	$CaCO_3$ $CaHPO_4.2H_2O$	Insoluble	5	8 40
3.	Dentosal® No 7008	AB Dentosal	$NaHCO_3$	Soluble	95*	57
4.	Jod-Kaliklora® No 1528	AB Jodka	$CaCO_3$	Insoluble	3	31
5.	Menthy® No 136 A	Barnängens T.F. AB	$CaCO_3$	Insoluble	8.3	33.5
6.	Pepsodent® No 0233	Gibbs AB	$CaHPO_4.2H_2O$	Insoluble	17	46
7.	Signal® No 0163	Gibbs AB	$CaHPO_4.2H_2O$ $CaCO_3$	Insoluble	14	40
8.	Stomatol® No 0145	Grummebolagen	$CaCO_3$	Insoluble	8.3	36

*) values according to *Gerdin* (1971).

The cylinder was partly filled with a 1:1 slurry of distilled vater and dentifrice. The three brushes in the holder passed through the slurry before coming into contact with the specimen. In this way the bristles were kept wet throughout the procedure and particles were prevented from sedimenting to the bottom of the cylinder. Each specimen was brushed for 60 minutes, which corresponded approximately to the number of strokes in one year's toothbrushing.

Table II.

The toothbrushes, their material and bristle diameter

Toothbrush	Bristle material	Number or bristles per bundle	Bristle diameter (mm) Mean
Pro-Double	Prolon	23 32	0.22 0.29
Jordan — Hard (H)	Nylon	16	0.34
Pepsodent — Hard (H)	Nylon	20	0.30
Pepsodent — Soft (S)	Nylon	51	0.20
Jordan — Soft (S)	Nylon	32	0.22
Pro—Vuxna	Prolon	17	0.22
Lactona — Hard (H)	Natural	34	0.24
Lactona — Soft (S)	Natural	40	0.22

MEASURING METHODS

A. Weight differences. The specimens were weighed before and after the brushing procedure, using a digital analytical balance (Sartorius 2400) with a sensitivity of 0.1 mg. The precision calculated from ten weighings of one specimen amounted to 0.05 mg. Before being weighed the specimens were dried for one hour at room temperature (20°C) in order to reduce the effect of water evaporation of the polymethylmetacrylate.

B. Recording of surface irregularities. In order to study the effects of brushing on the microgeometry of the test surface, the brushed specimens were analysed in a Taylor-Hobson Model 3 Talysurf instrument (*Wictorin*, 1971).

An area in the centre of each specimen was selected for analysis and a graphic recording of the scratch marks was obtained with selected horizontal and vertical scales. The length (L) and height (H) of a wave was determined from direct measurements on each recording. The L-value of a wave was defined as the horizontal distance from one top of the wave to the next top. The H-value of a wave was defined as the vertical distance from the highest to the lowest part of the wave (Fig. 1).

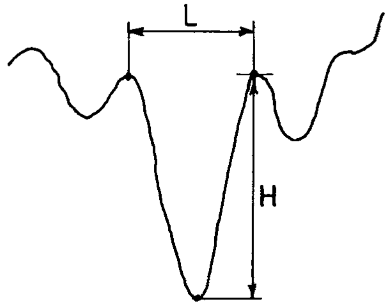

Fig. 1. The definition of the length (L) and the height (H) of a wave in the graphic profile.

The average meter of the Talysurf instrument recorded the centre line average index (CLA-value or Ra-value). This value, obtained by integration of the profile curve, is a qualitaty value of the irregularities in the test surface. A previous study (*Wictorin*, 1971) has shown the Ra-value to be a reliable measure of these irregularities. A calculation of the correlation between the weight differences and the Ra-values recorded in a series of 21 specimens gave r = 0.91 (Fig. 2), thereby confirming that the two methods give comparable values for abrasion. This agreement can be taken as an indication of the reliability of the two methods in this respect. A similar correlation was found between H-values and Ra-values, which is not so surprising as the Ra-value

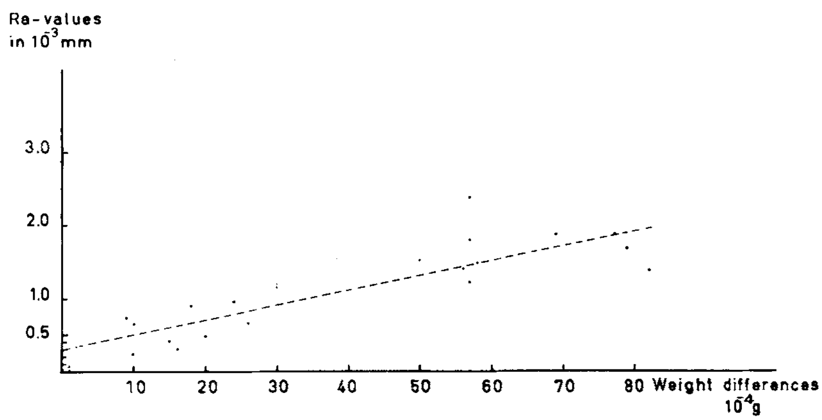

Fig. 2. Correlation of Ra-values and Weight reductions for 21 specimens testing abrasiveness of dentifrices (r = 0.91).

Table III.

Mean ($\bar{x}$) and standard error (S.E.) of the weight reduction, Ra-, H- and L-values for the specimens testing dentifrices.

	Weight reduction x 10^{-3} g		Ra-values x 10^{-3} mm		H-values x 10^{-3} mm		L-values x mm		
Denti-frice No.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	Ranking Index
1.	0.2	0.2	0.11	0.48	—*	—*	—*	—*	32
2.	7.7	0.9	2.16	0.35	6.5	1.0	0.54	0.08	8
3.	1.9	0.2	0.60	0.12	1.7	0.2	0.21	0.01	28
4.	2.0	0.1	0.71	0.04	3.2	0.1	0.48	0.02	23
5.	9.1	0.6	1.94	0.22	7.8	0.7	0.67	0.01	5
6.	4.9	0.4	0.87	0.05	4.4	0.1	0.50	0.01	19
7.	2.9	0.2	1.09	0.07	3.8	0.3	0.43	0.02	20
8.	8.4	0.6	1.64	0.05	6.3	0.6	0.51	0.04	11
Water	0.5	0.1	0.18	0.15	*)	*)	*)	*)	—

*) *not measurable.*

of the Talysurf instrument is based in part upon the vertical dimension of the wave.

C. Scanning electron microscopy (SEM). The central part of the acrylic specimens was analysed by scanning electron microscopy. After the specimen had been covered by vaporization with a gold layer — 200 Å — to conduct off the secondary electrons from the acrylic material, with an accelerating voltage of 20 kVp and a pressure of 10^{-4} torr.

RESULTS

I. Data on the abrasive effect of the dentifrices tested are presented in Table 3 under four headings — weight reduction, Ra-value, H-value and L-value — denoting different aspects of abrasiveness. Weight reduction expressed the total loss of material; the Ra-, H-, and L-values provided information about the characteristic abrasive effect. The ranking index, finaly, summarized the four abrasive values for each specimen. The index figures

Fig. 3. Graphic profile of a specimen brushed with a dentifrice of low abrasive effect, no. 1.

indicated that the dentifrices studied could be devided into three classes of abrasiveness — high, medium and low. The high class comprises dentifrices nos. 2, 5 and 8 (Table III) with ranking values below 15, the medium class consisted of nos. 4, 6 and 7 and the low class of nos. 3 and 1. — Taken separately the four aspects of abrasiveness agreed with this ranking order except in the case of no. 3, for which the values were closer to the medium class than to the extremely low values of no. 1. The abrasive agent of dentifrice no. 1 was polymethylmetacrylate, which gave very low abrasion (Fig. 3), lower even than brushing with water. The abrasive agent of no 3 was soluble sodium bicarbonate, which resulted in rather low abrasiveness. The other dentifrices contained calcium carbonate, in some together with calcium

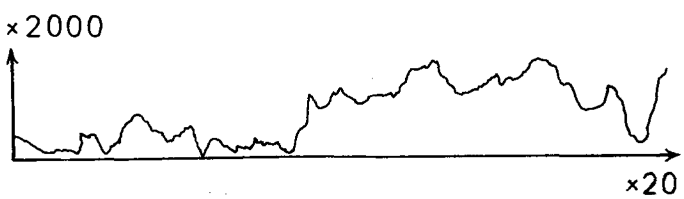

Fig. 4. Graphic profile of a specimen brushed with a dentifrice of medium abrasive effect, no. 6.

Fig. 5. Graphic profile of a specimen brushed with a dentifrice of high abrasive effect, no. 5.

Fig. 6. Acrylic surface brushed with dentifrice no 1. No scratch marks noticed (SEM-photogram × 500).

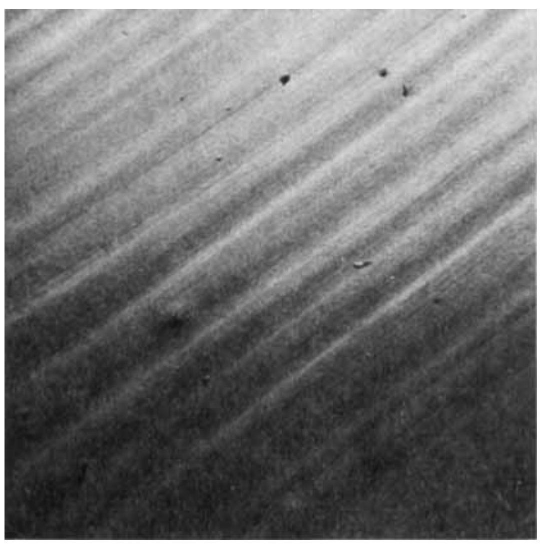

Fig. 7. Acrylic surface brushed with dentifrice no 5. Macro scratch marks observed (× 20).

Fig. 8. Same area and specimen as in fig. 4. Micro scratch marks noticed between and in the macro marks (× 1000).

Fig. 9. An irregularity of the polymerized acrylic surface can be developed to a pit with a ridge. (dentifrice no. 2, × 500).

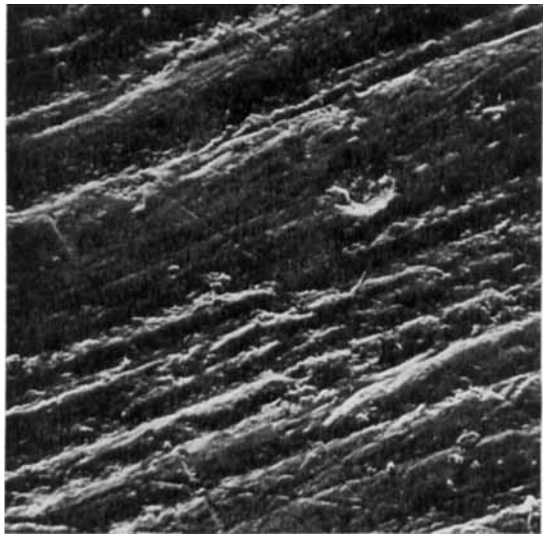

Fig. 10. The scratch marks of a dentifrice, no. 7 (× 2000) ranked in the medium class of abrasiveness.

phosphate dihydrate (Table I). No correlation could be found between the size or percentage content of the abrasive agent and the abrasiveness of these dentifrices. Photomicrographs from the SEM-study are presented in Figs. 6—10. A difference could be observed between dentifrice no. 1 and the others. Scratch marks from brushing with dentifrices nos. 2—8 were detectable at both macro- and micro-level (Figs. 7 & 8). Irregularities on the acrylic surface may cause a pit, with a subsequent ridge or groove due to toothbrushing (Fig. 9).

Data on the abrasive effect of the toothbrushes are given in Table IV. A ranking-index value was calculated for each toothbrush. The high class, i.e. toothbrushes with a low ranking index and a high abrasive property, comprised Jordan-H, Pepsodent-H and Pro-V (nylon or prolon bristles). Brushing with Lactona-H and Lactona-S (natural bristles) resulted in a ranking index in the medium class, Pepsodent-S and Jordan-S (nylon bristles) in the low class. The differences between the groups — high, medium, low — were significant, indicating a very large range in the abrasive quality of the toothbrushes. The differences between hard (H) and soft (S) brushes with nylon bristles were highly significant whereas those between brushes with natural bristles were not so pronounced, though they were significant for some measurements (Ra-values, H-values).

Table IV.

Mean ($\bar{x}$) and standard error (S.E.) of the weight reduction, Ra-, H- and L-values of the acrylic specimens testing 7 different — toothbrushes

Tooth-brush	Weight reduction $\times 10^{-3}$ g		Ra-value in 10^{-3} mm		L-value in mm		H-value in 10^{-3} mm		Ranking Index
	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	$\bar{x}$	S.E.	
Pepsodent—H	4.8	0.3	4.43	0.57	0.34	0.04	13.4	1.3	8
Pepsodent—S	4.2	0.1	1.18	0.12	0.28	0.04	2.4	0.1	24
Jordan—H	5.0	0.3	5.00	—	0.43	0.10	16.0	3.8	4
Jordan—S	2.8	0.2	1.68	0.31	0.28	0.03	4.4	0.8	25
Lactona—H	3.4	0.2	3.66	0.24	0.31	0.03	9.0	0.8	18
Lactona—S	3.3	0.2	2.54	0.06	0.34	0.03	7.1	0.5	19
Pro vuxna	3.8	0.3	4.16	0.30	0.33	0.03	10.6	0.5	14

DISCUSSION

The various methods for recording irregularities on the test surface of the specimen gave mutually consistent values. The data on weight reduction might represent a real loss of material but some error could arise because of the property of water sorption of the specimen material, polymethylmetacrylate. It was therefore satisfactory to be able to establish a correlation between weight reduction and the Ra-value for irregularities on the test surface. This confirmed the reliability of the measuring methods used. The standard errors reported in Table 4 indicate the reproducability of the method and the possibility of evaluating abrasive property. Acrylic resin may offer advantages over biological materials such as enamel and dentine in view of the uniformity of its physical properties.

The dentifrices tested differed considerably in abrasiveness, which partly agreed with *Frostell & Lindström* (1964). Dentifrice no. 1 showed an extremely low abrasive effect, somewhat less than that obtained by brushing with water. For cleaning purposes in the mouth, this dentifrice might be considered most favourable for acrylic resin material, the polished surface of which can be preserved, thereby maintaining the hygienic benefits of this material. Whether dentifrice no. 1 was sufficiently abrasive to remove plaque and debris in the oral cavity could not be determined from this investigation. *Moss* (1971) considered that the removal of plaque and debris depended more on brushing technique and time than on the composition of the dentifrice.

Dentifrices nos. 2—8 produced abrasive effects that were visible as scratch marks and recordable as continuous waves (Figs. 7 & 8). They differed considerably in abrasiveness, however, the highest values being three times greater than the lowest. The abrasive effect of dentifrices nos. 2, 5 and 8 resulted in severe scratches on the acrylic resin material. Thus it is questionable whether these dentifrices are suitable for cleaning this material. Patients wearing a prosthetic appliance made from acrylic resin should be recommended to avoid dentifrices with such a high abrasiveness. Further studies may give more adequate information about the most suitable abrasiveness of a dentifrice.

It seemed that microdefects in the surface of the acrylic specimen may lead to scratch marks on the macro level. These microdefects consisted of porosities resembling pits or small eminences, which brushing may turn into a ridge or a groove (Fig. 9). Microdefects of this type may be regarded as a property of acrylic resin material and can hardly be avoided.

Once an acrylic surface has lost its polished smoothness as a result of incorrect cleaning or toothbrushing, it becomes more and more difficult to remove plaque, debris etc. This vicious circle may be broken by repolishing the damaged surface.

The seven toothbrushes displayed considerable differences in abrasive effect. The material and dimension of the bristles clearly had a great effect on the abrasion of acrylic resin material. The »hard» (H) brushes were more abrasive than the »soft» (S) brushes of the prolon bristle material. As the hard brushes had fewer bristles per bundle but a larger bristle diameter, it was conceivable that a larger bristle diameter was responsible for the higher abrasiveness of the hard nylon brushes. A greater number of bristles per bundle did not seem to have any effect. Similar though not so pronounced differences were observed with natural bristles, the mean bristle diameter here being approximately the same for the »hard» and the »soft» brush but the latter having six bristles per bundle (15 percent) more than the »hard» brush.

REFERENCES

Cordon, M, 1971: Method for measuring the abrasion of dentin by dentifrices. J. dent. Res. *50:* 491.

Council on Dental Therapeutics, 1970: Abrasivity of Current dentifrices. J. Amer. dent. Ass. *81:* 1177.

Danielsson, A., 1970: Svepelektromikroskopet. Kosmos, Almqvist & Wiksell, Uppsala.

Flerlage, Th. & R. Marxkors, 1969: Abrasion des Verblend-Kunststoffes durch Zahnpflegemittel. Deutsch. Zahn. bl. *23:* 106.

Frostell, G. & G. Lindström, 1964: Undersökningar av några av den svenska marknadens tandkrämer. Del I. — O.F.T., *28:* 211.

Gerdin, P. O., 1971: Studies in dentifrices IV Size and shape of particles in commercial dentifrices. S.T.T. *64:* 447.

Moss, A., 1971: Kliniske undersögelser over nogle tandpastaers og tandpulveres virkning over for plaque forekomst. Tandlaegebladet, *75:* 197.

Sexson, J. & R. Phillips, 1951: Studies on the effects of abrasives on acrylic resins. — J. Prosth. dent. *1:* 454.

Viera, D. F. & R. Phillips, 1962: Influence of certain variables on the abrasion of acrylic resin veneering material. — J. prosth. dent., *12:* 720.

Wictorin, L., 1971: Effect of toothbrushing on acrylic resin veneering material. S.T.T. *64:* 247.

Öberg, G. & B. Nilsson, 1970: Tandpastor och dentala akrylat. In vitro studier av tandpastors kemiska inverkan på några dentala akrylat. — Sverig. Tandl. förb. Tidn. *63:* 320.

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