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CLEANING POWER AND ABRASIVITY OF EUROPEAN TOOTHPASTES

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Abstract—For 41 toothpastes available to European consumers in 1995, the cleaning efficacy was evaluated in comparison with abrasivity on dentin (RDA value). For cleaning power assessment, a modified pellicle cleaning ratio (PCR) measurement method was developed. The method is characterized by a five-day tea-staining procedure on bovine front teeth slabs on a rotating wheel, standardized brushing of the slabs in a V8 cross-brushing machine, and brightness measurement by a chromametric technique. All tested products were in accordance with the new DIN/ISO standard 11609 for toothpastes in terms of dentin abrasivity. Not a single product exceeded an RDA value of 200. The majority of toothpastes (80%) had an RDA value below 100. Only three products surpassed the reference in cleaning power. Most products (73%) had a cleaning power (PCR value) between 20 and 80.

The correlation between cleaning power and dentin abrasion was low (r = 0.66), which can be explained with the different influence on dentin and stains by factors like abrasive type, particle surface and size, as well as the chemical influence of other toothpaste ingredients. Some major trends could be shown on the basis of abrasive types. The ratio PCR to RDA was rather good in most silica-based toothpastes. A lower ratio was found in some products containing calcium carbonate or aluminum trihydrate as the only abrasive. The addition of other abrasives, such as polishing alumina, showed improved cleaning power. Some active ingredients, especially sequestrants such as sodium tripolyphosphate or AHBP, also improve the PCR/RDA ratio by stain-dissolving action without being abrasive. The data for some special anti-stain products did not differ significantly from standard products. Compared with data measured in 1988, a general trend toward reduced abrasivity without loss of cleaning efficacy could be noticed on the European toothpaste market. This may be mostly due to the increased use of high-performance abrasives such as hydrated silica.

Key words: dental stain, dentin abrasivity, cleaning power method.

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One major function of toothpastes is the cleaning of all accessible tooth surfaces. This cleaning function involves most particularly the elimination of plaque and deposits originating from food residues as well as stains which primarily accumulate in the pellicle layer. Their main origin is the interaction of food and beverages with the oral milieu, especially with deeply colored liquids like tea, coffee, and red wine, but also with tobacco.

The mechanical removal of stains is accompanied by a certain abrasion on teeth. Several studies so far have showed that there need not be a direct relationship between cleaning power and abrasivity on teeth when the toothpastes differ in more than only the concentration of abrasive (Sturzenberger, 1978; Lobene, 1982; Stookey *et al.*, 1982; Klüppel *et al.*, 1986). The aim of this study was to evaluate the status of toothpastes on the European market in terms of abrasivity and cleaning power and to discuss the influence of certain raw materials on the efficacy of cleaning.

MATERIALS AND METHODS

Cleaning methods

Several laboratory and clinical methods have been developed to evaluate the cleaning potential of toothpastes and toothpaste ingredients (Lobene, 1968, 1982; Davis and Rees, 1975; Sturzenberger, 1978; Marcus and Ginzler, 1982; Stookey *et al.*, 1982; Klüppel *et al.*, 1986).

One of the best-known and most accepted laboratory methods worldwide for assessing the cleaning power of toothpaste was developed at Indiana University by Stookey *et al.* (1982). The Indiana cleaning method includes: (a) bovine front teeth surface conditioning, (b) staining, (c) mechanical toothbrushing for stain removal, and (d) visual assessment of stain removed.

In our laboratories, we developed a simplified model which allows us to work without bacteria at RT and results in dark-brown-stained teeth after one week of treatment with a staining solution. The assessment of the cleaning effect was done by means of a chromametric technique. The details of the method are described below.

Tooth mounting

Permanent bovine incisors were cut into 7 x 7 mm blocks. Each block was mounted on a plastic carrier with brown wax, and all the cut edges of the tooth were covered with the same brown wax. The bottom of the carrier was equipped with a female thread for mechanical attachment to removable plastic wheels of the staining apparatus (Fig. 1). The teeth were rubbed with abrasive paper for removal of surface stains and roughness before being conditioned and stained.

Staining apparatus

The individual tooth carriers were attached with a stainless steel bolt to the plastic wheels. The wheels could accommodate as many as 40 individual tooth mounts. The plastic wheels were then friction-fitted onto the rotating shaft of the staining apparatus. The shaft rotated very slowly at 2 rpm, so that the teeth were slowly rotated sequentially through the staining solution and air to build up a stable stain layer on the exposed tooth surface. These mounts and the staining apparatus were somewhat different from but functionally comparable with those used in the published Stookey method (Fig. 2).

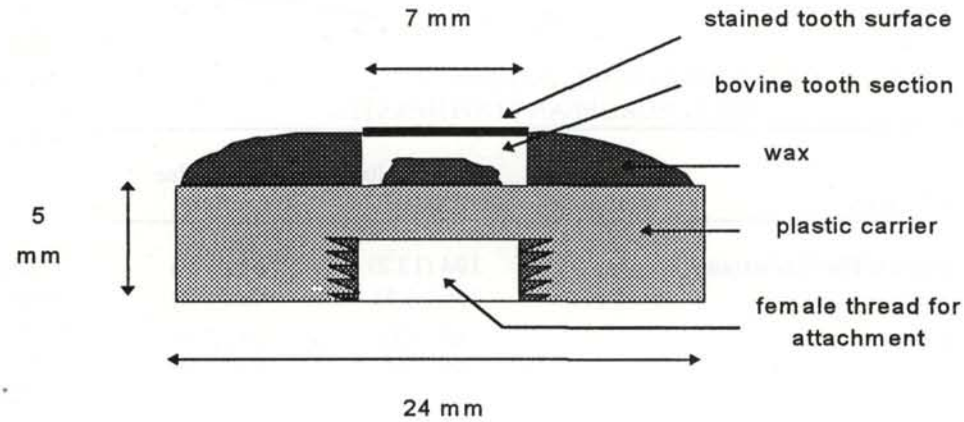

Fig. 1—Stained tooth on carrier.

Tooth conditioning and staining

The mounted teeth were immersed sequentially in 0.12 N hydrochloric acid for 60 sec, in a saturated solution of sodium carbonate for 120 sec, and in 1% phytic acid for 60 sec. The mounts were rinsed with de-ionized water between treatments and blotted dry with an absorbent tissue. The HCl-treated teeth were then placed in the staining apparatus and rotated through a black tea solution at room temperature for 5 days. The tea solution was prepared by the extraction of two 1.5-g tea bags of black tea with 300 mL of boiling water for 10 min. The tea solution in the staining apparatus was replaced twice each day.

Toothbrushing

The mounted teeth were then placed in a Grabbenstetter V-8 brushing machine and brushed by means of an Oral B soft toothbrush with a 150-g brushhead load. Calcium pyrophosphate, the ADA reference material, was used as a tooth surface cleaning reference. As in the Stookey method, the pyrophosphate reference was assigned a cleaning power of 100. As in the ADA method, 10 g of the pyrophosphate powder were mixed with 50 mL of a mixture of 0.5% carboxymethyl cellulose and 10% glycerine in water. The toothpastes were used as a slurry of 20 g of paste and 40 mL of de-ionized water.

Tooth brightness measurement

Measurements were made with a Dr. Lange Color Difference Measuring Instrument, Type Micro Color (DC8334), in accordance with the German Industrial Standard DIN 5033. A xenon lamp, which generated lighting conditions approximating those of standard illuminant D 65, was used. The color reference was barium sulfate. Duplicate color measurements were made of a 7-mm-diameter circular area of the tooth surface. A simple circular aluminum mask was placed over each tooth mount to position the chromameter head reproducibly.

For each toothpaste measurement, eight discolored mounted teeth were used. The brightness increment (Y - Yo), defined as the difference between brightness before brushing and brightness after 1000 double strokes, was measured individually for each tooth. The Pellicle Cleaning Ratio (PCR) was defined as the ratio of the increase in brightness of the tooth mounts brushed with the test paste divided by the increase of the calcium pyrophosphate reference:

$$\text{PCR (cleaning power)} = \frac{\text{mean Y increment of test paste}}{\text{mean Y increment of reference material}}$$

Abrasivity measurement

For measurement of the abrasivity on teeth, the radioactive dentin abrasion (RDA) method was used (Grabenstetter *et al.*, 1958; Hefferren, 1968; Marcus and Ginzler, 1982). The measurement was done in accordance with the Grabenstetter mode by Missouri Analytical Laboratories (St. Louis, MO).

RESULTS

Table 1 shows the results of the cleaning power measurements and the RDA assay for 41 European toothpastes. All toothpastes were available in the indicated European countries in 1995. Fig. 3 shows the relationship between cleaning and abrasivity in a two-dimensional diagram. The diagram shows clearly that there is no strong correlation for the total of measured values. The Pearson correlation factor is low (r = 0.66). All toothpastes are within the range accepted

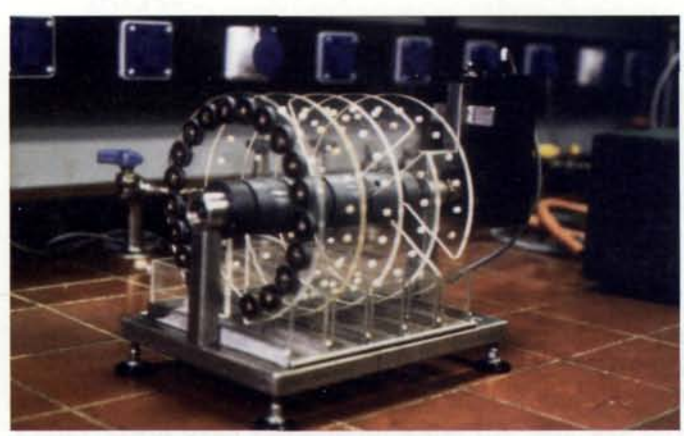

Fig. 2—Staining apparatus.

TABLE 1

CLEANING POWER AND DENTIN ABRASIVITY OF 41 EUROPEAN TOOTHPASTES

Country	(s = smoker's toothpaste)	RDA Value (SD)	PCR Value (SD)
Belgium/The Netherlands	(s)	194 (13.2)	59 (3.7)
	(s)	146 (6.5)	72 (4.2)
Germany		45 (4.0)	24 (2.0)
		89 (3.5)	76 (7.6)
	(s)	76 (4.0)	21 (2.4)
	(s)	52 (1.3)	58 (5.1)
		74 (5.9)	52 (5.5)
		47 (3.0)	44 (3.4)
	(s)	72 (2.8)	67 (4.8)
		76 (2.5)	71 (4.6)
		39 (1.5)	56 (3.5)
		52 (2.4)	81 (4.4)
		43 (1.5)	56 (2.9)
		29 (0.9)	54 (3.3)
Spain		38 (1.7)	25 (2.2)
		61 (2.5)	45 (3.8)
	(s)	49 (1.5)	37 (3.6)
France	(s)	47 (1.6)	59 (3.6)
		100 (2.1)	88 (4.7)
		40 (1.9)	29 (2.6)
		72 (1.8)	58 (3.0)
Italy		193 (11.9)	119 (6.6)
		56 (1.8)	38 (5.5)
		49 (1.5)	39 (3.3)
	(s)	183 (4.9)	122 (4.9)
	(s)	91 (7.3)	122 (7.0)
Norway		102 (5.4)	38 (2.7)
		61 (2.9)	98 (18.4)
		70 (1.3)	44 (2.3)
		42 (2.1)	19 (1.8)
		89 (2.9)	82 (15.5)
		64 (1.7)	47 (4.2)
		33 (1.4)	13 (2.2)
		43 (2.3)	24 (3.3)
		44 (1.7)	20 (3.2)
Sweden	(s)	53 (1.0)	36 (3.8)
		60 (2.8)	38 (3.8)
		71 (4.1)	65 (4.6)
Finland		58 (4.1)	33 (4.2)
United Kingdom	(s)	129 (4.0)	91 (6.4)
		133 (4.5)	94 (5.9)

for the abrasivity of toothpastes by the new international DIN/ISO standard 11609 (maximum 2.5x reference value). Only 20% of the toothpastes have an RDA value between 100 and 200. All other toothpastes have lower values, indicating the low-risk level of market toothpastes.

The cleaning value for most products (73%) is between 20 and 80. Only three products exceed the pyrophosphate standard. Only one product out of these three has an RDA lower than 100.

DISCUSSION

Today, tooth cleaning with toothpaste is still done mainly by mechanical means. Tooth bleaching by peroxides, which could chemically interact with stains, is very restricted for consumer products in the EU, due to the regulations of the European Cosmetics Directive. Nevertheless, all toothpastes showed that they are able, more or less, to reduce strong stains such as the tea stain used in the abovementioned staining method. Also, for toothpastes with a mechanical cleaning effect, to be better in cleaning does not necessarily mean higher abrasivity on teeth. This was again demonstrated by this study. Usually, the toothpaste abrasives have the highest impact on abrasivity as well as cleaning, which also means that a difference between them has the strongest influence on the effects.

It is known that not only can chemically different types of abrasives have different cleaning/abrasivity patterns (Barbakow *et al.*, 1987), but also chemically identical abrasives such as hydrated silica or calcium carbonate can differ distinctively in these effects and can also have different cleaning/abrasivity ratios. The mixture of chemically different abrasives can result in effects which differ distinctively from those of the individual components.

In a prior study that we conducted with different abrasives in the same toothpastes, we obtained not only rather different RDA and PCR values but also very characteristic cleaning/ abrasivity ratios, especially for the mixture of different abrasives, such as silica and aluminum oxide (Table 2).

The hydrated silica toothpaste was the best of all the mono-abrasive toothpastes tested, in terms of the most effective cleaning with the highest ratio. As a mono-abrasive in toothpaste, aluminum oxide was not very effective, even when used in a concentration of 10%. The addition of only 1% of aluminum oxide to a silica-based toothpaste, on the other hand, distinctly improved its efficacy without being considerably higher in dentin abrasivity. With respect to abrasivity not only on dentin, but also on enamel, the silica toothpastes again showed their superiority in terms of cleaning efficacy compared with the other abrasives. It is obvious that the addition of aluminum oxide, which had rather high enamel values, resulted not only in a value only gradually higher than the low value of the hydrated silica component but also in an improved cleaning value, better than those of the mono-abrasive pastes (Klüppel *et al.*, 1986).

For the toothpastes with known abrasives, the types are indicated on the diagram in Fig. 3. It is apparent that hydrated silica toothpastes are now favored on the European market. Most of them have good or very good cleaning values combined with low to moderate dentin abrasivity.

Other abrasives used are calcium carbonate, aluminum trihydrate, and aluminum oxide (polishing alumina), as well as dicalciumphosphate dihydrate. For most toothpastes with known composition, there is no indication of a strong additional chemical potential to reduce stains. For sequestrant substances such as tripolyphosphate or phosphonates like AHBP, a stain-solving effect which adds to the mechanical cleaning effect could be found with the above-described staining method.

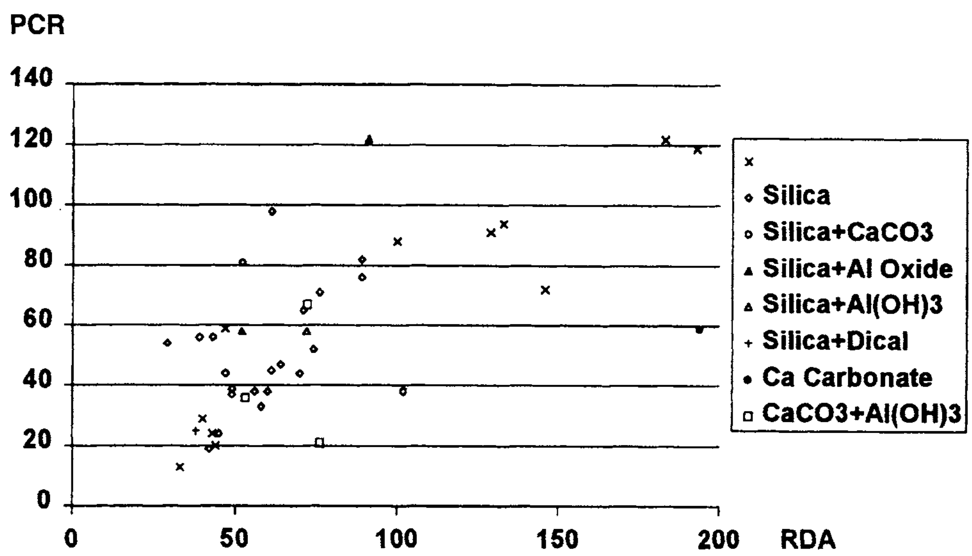

Fig. 3—Cleaning power and RDA value diagram of 41 European toothpastes.

CONCLUSIONS

The following conclusions can be drawn regarding the status of the cleaning efficacy of toothpastes on the European market: The major anti-stain effects of toothpastes are still due to mechanical action (abrasivity). Bleaching does not play a role, due to the regulatory situation in the EU. The dentin abrasivity status is acceptable in terms of safety, because most of the toothpastes range far below the upper limits given by DIN/ ISO standard 11609. Compared with data we collected in 1988 on the European market, the trend in recent years has been more toward hydrated silicas and improved cleaning power of toothpastes. The mean dentin abrasivity of the toothpastes on the market did not rise. This may be explained by a trend toward the use of more high-quality abrasives in toothpastes.

Dentin abrasivity should not be the only safety criterion for the abrasivity of toothpastes. The comparison in Table 2 shows that enamel abrasivity values can differ substantially without major changes in RDA for some abrasive types.

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TABLE 2

CLEANING AND ABRASIVITY PARAMETERS
OF TOOTHPASTES CONTAINING DIFFERENT ABRASIVES

Abrasive Type	RDA Value	REA Value	PCR Value	PCR/RDA
Hydrated silica	35	11	92	2.6
Al oxide, 1%	20	80	26	1.3
Al oxide, 10%	38	197	60	1.6
Silica + Al oxide, 1%	37	27	110	3.0
Dicalciumphosphate dihydr.	49	4	76	1.6