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A parametric test to measure the cleaning power of toothpaste

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Synopsis—A sensitive *IN VIVO* method was developed to quantify the cleaning power of dentifrices. Volunteers built up natural STAIN on their TEETH over a period of 5 weeks by replacing their usual TOOTHPASTE with a non-abrasive paste. The estimated % area of the incisors covered by stained pellicle was observed to increase, especially towards the end of this build-up period. The natural stain was progressively removed by a series of 10 s BRUSHING periods using an electric TOOTHBRUSH and the pastes to be tested. The logarithm of the area of stain was plotted against the duration of brushing with the test paste and found to conform to a linear trace. Thus an equation for stain removal may be of the form $S=ae^{bt}$ with the coefficient b being an expression of the ability of the test paste to remove stain.

INTRODUCTION

Over thirty years ago, Manly (1) observed that the 'brown pellicle' which formed regularly on the teeth of some people who did not use dentifrice abrasives could be readily removed by one or two brushings with a dentifrice grade calcium carbonate or phosphate but not by brushing with a dry or moistened brush without a dentifrice.

Lobene (2), and later Van Abbé *et al.* (3) who slightly modified Lobene's technique, employed direct visual observation to assess the removal of stained material from teeth using a toothpaste under controlled brushing conditions. Wilkinson and Pugh (4) used both photographic recording and

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a photometric method to assess the extent of stain on teeth cleaned for 2 weeks with a test toothpaste, after an initial scale and polish.

These techiques detected differences in the stain-removing properties of toothpastes, but employed non-parametric data. Moreover, stain colour and intensity, and the presence of plaque complicated the assessment.

A technique has now been developed which uses quantitative measurement on a parametric basis, to generate a value of cleaning power for toothpaste. It is uncomplicated by stain colour and intensity or plaque and gives repeatable results.

EXPERIMENTAL

Formation of stain for study of cleaning power

When volunteers used a non-abrasive toothpaste for cleaning their teeth, a natural stain, not related to their smoking habits, developed visibly in approximately one-third of the subjects and increased in area during the course of 1 month. Satisfactory plaque removal and oral hygiene was achieved, however, with no adverse effect on the gingivae.

Quantitative assessment of stain

By examining the incisors of each volunteer through a horizontally mounted Nikon stereoscopic binocular microscope (model SMZ–2), fitted with double spotlight tungsten illumination, the stained areas were easy to identify.

Ektachrome X photographic transparencies of the teeth were taken with a Miranda Sensomat camera through the binocular microscope using crossed polaroid screens over the Multiblitz photographic flash* and objective lens. This method of illumination eliminated specular reflection and permitted clear identification of the stained areas, although giving a slightly out-of-focus effect.

Examiners were trained to estimate visually the percentage area of the labial surfaces of the eight incisors covered by stain and their estimates were found not to differ from the planimeter-derived measurements by more than one-sixth.

The percentage area of the labial surfaces of the eight incisor teeth covered by stain was calculated from planimeter measurements of boundary

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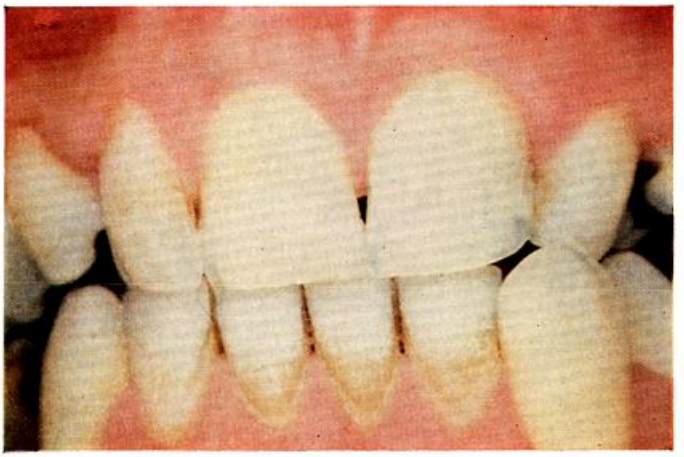

Figure 1. Naturally stained incisors. A cross-polarized photomicrograph of the stain built up on a volunteer's incisors after using a non-abrasive toothpaste for 1 month.

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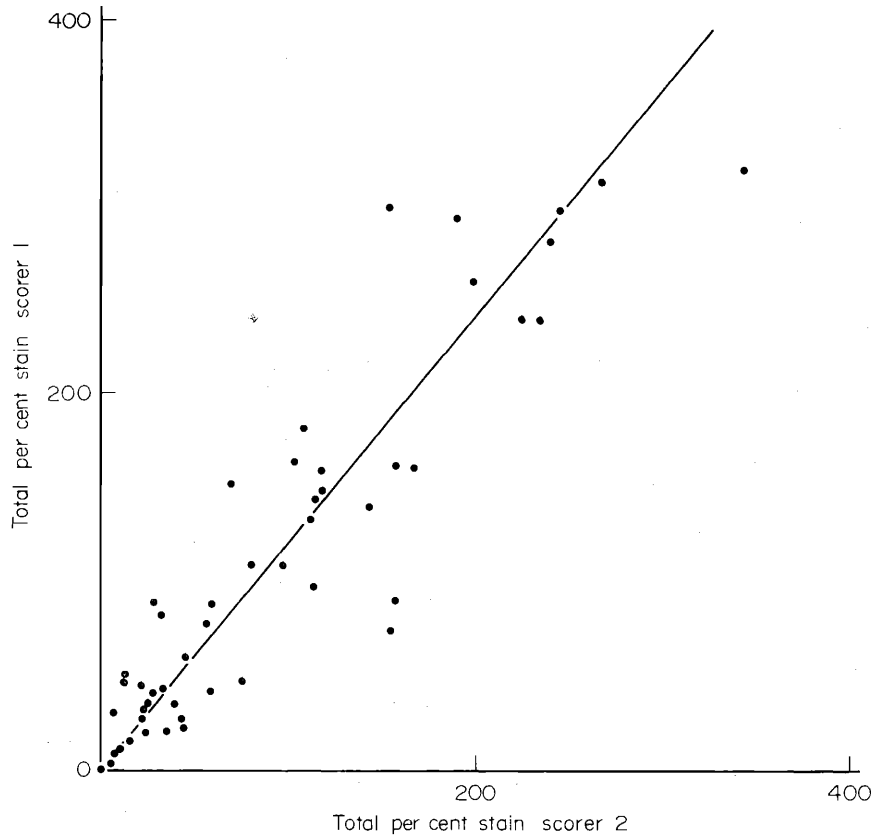

Figure 2. Scorers' concordance.

tracings drawn from projected images of the transparencies. After training examiners by repeatedly comparing their estimates with planimeter measurements of traces, good agreement was found between examiners' scores as shown in *Fig. 2*. The slope of line of best fit was 1.2 (complete agreement would be indicated by a slope of 1.0).

Measurement of stain removal on a single volunteer from a group

A hygienist removed fresh plaque by brushing for 15 s with a non-abrasive toothpaste applied with a Touch-Tronic electric toothbrush (Teledyne, Aqua-Tec, U.S.A.). After independent assessment of stain area on the labial surfaces of the eight incisors by two examiners, the hygienist brushed the incisors for 10 s, using a test toothpaste applied with the electric

toothbrush. The volunteer rinsed with a flavoured mouthwash to mask recognizable toothpaste aroma and stain was reassessed. The sequence was repeated for a further 10 s brushing and then followed by three periods of 20 s brushing with intervening assessments.

At each assessment interval, the percentage stained area on each of the eight incisors was recorded and totalled, giving a value S which represented *total* percentage stained area (maximum value of $S=800\%$).

Tables I and II present typical data using the technique described.

Cleaning power assessment

Those volunteers producing an appreciable amount of stain after 1 month's use of a non-abrasive toothpaste were allocated to groups in a way which approximately balanced the initial levels of stain. To each group of volunteers a test paste was randomly allocated, then subjects were presented to the examiners in a random order of treatment; neither the subjects nor the examiners knew which toothpaste was used on any individual.

In all these tests so far, when $\log_{10}S$ was plotted against brushing time, t, and the data were fitted to straight lines using the least squares method, Pearson correlation coefficients were found to be mainly in the range 0.75–0.99, confirming the $\log_{10}$/linear relationship found graphically.

The gradient of the mathematically-fitted straight lines, designated b, was a measure of the brushing time, in seconds, required with a particular toothpaste to remove a given portion of the initial stain. The reciprocal of the magnitude of the gradient, b, was the time in seconds required to remove 90% of the initial stain.

The data could be presented mathematically in the form of an equation.

$$\log_{10}S=\log_{10}a+bt \qquad (1)$$

where 'a' is the constant representing the interpolated initial level of stain.

Cleaning Power (B) for a dentifrice is defined as $-\bar{b}.\ 10^3$ for the subjects allocated to this preparation, $\bar{b}$ being the average gradient.

Results

Data accumulated from several tests appear in *Fig. 3* and *Table III*. From these results it can be seen that the cleaning powers of the dentifrices were dependent on the mineral used as the polishing agent.

Table I. A typical raw data sheet for stain removal

Test Product Code Number .....*P*.....
Volunteer..... *Mr Smith* .....

Oral Hygiene..... *Brushes twice daily* .....
Usual Toothpaste* .....
Date of Last Scale & Polish... *Not known* ...
Next Dental Appointment ..... *None* .....

Smoking Habits..... *20 daily* .....

Cleaning time (s)		0				10				20				40				60				80			
Scorer (1)	Upper stain (%)	45	60	25	15	45	10	18	10	45	5	15	5	40	0	5	5	35	0	3	3	35	0	2	3
	Lower stain (%)	75	80	70	65	70	45	65	60	50	60	55	50	40	55	60	40	30	45	50	15	50	45	48	20
Scorer (2)	Upper stain (%)	80	20	15	30	40	15	10	50	40	10	8	25	35	10	5	20	35	5	5	15	30	5	5	10
	Lower stain (%)	50	50	50	50	50	40	40	40	40	40	40	25	35	40	35	35	35	35	30	15	35	40	30	15

* The brand name or other identifying name is entered here.

Table II. Summation of stain area on Mr Smith

	Brushing time (s)					
	0	10	20	40	60	80
Examiner 1	435	323	285	250	181	203
Examiner 2	345	285	228	215	175	170

Each score was total recorded stain for eight incisors.

Because, in any cleaning experiment, the examiners would expect a progressive decline in scores, some volunteers were returned at random to examiners for a repeat scoring, without a further brushing. By doing this, the expected tendency of the observers to record lower scores could be quantified. Of 58 repeat observations, 36 were lower and 22 higher than the previous reading and a 9% mean fall in estimated stain area was recorded. This proved to be of the same order as the assessment made when cleaning throughout was done with a non-abrasive gel toothpaste.

The initial tests reported here, carried out to prove the technique, used only ten to twenty subjects per group. Despite such small group sizes coefficients of variation for cleaning power were nevertheless within the range 0.4–0.7, except for the non-abrasive paste which had the lowest cleaning power. Even with these small groups of volunteers, differences between the cleaning powers for non-abrasive and chalk-based toothpastes could still be detected.

Chalk-based toothpastes were generally the best cleaning agents and as effective as a highly abrasive pumice-based prophylaxis paste. A silica-based toothpaste was almost as efficient with respect to cleaning power as the least effective chalk-based toothpaste. The non-abrasive toothpaste was significantly lower in cleaning power, especially if the quantified expectancy element was taken into account.

Discussion

The development of the parametric test for dentifrice cleaning power was aimed at producing a test that was quantitative, realistic and reproducible while also being capable of detecting small differences between products. By using this technique on small groups of volunteers, the technique appears of fulfil all these requirements. Furthermore, the training of new operators was a simple process; since the expectancy of the scorers could be quantified,

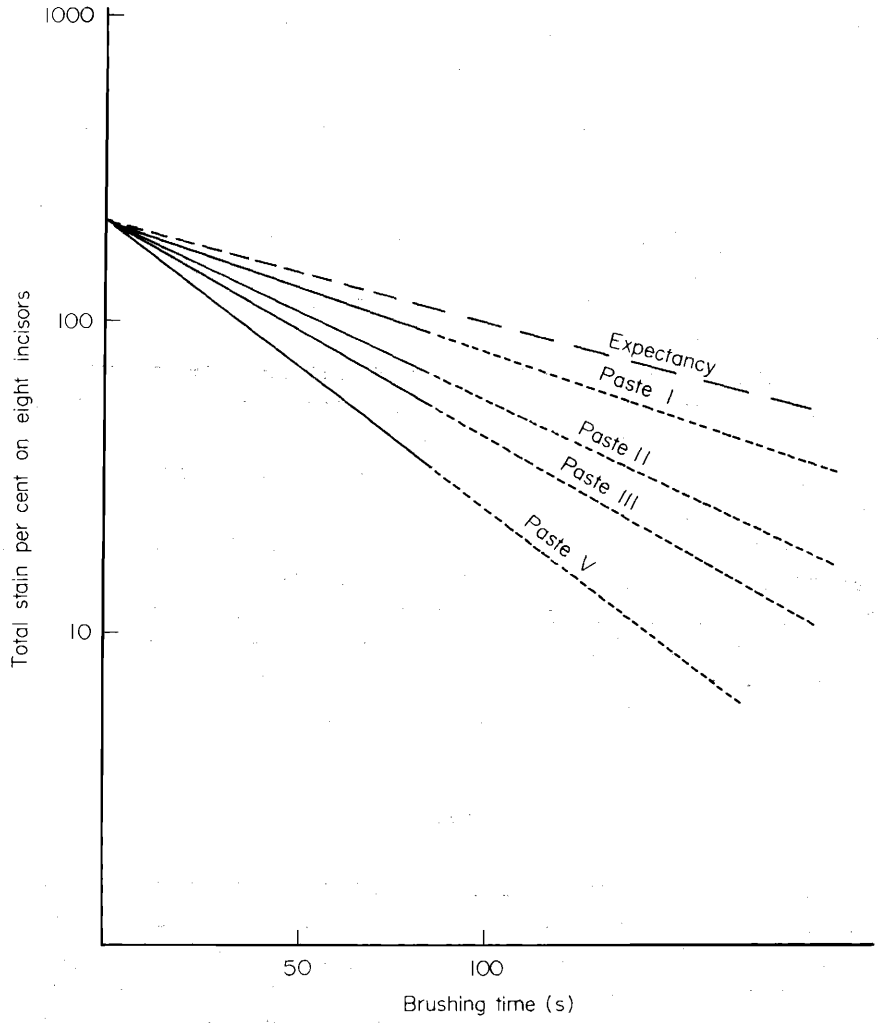

Figure 3. Total stain/brushing time. The straight lines represent the average least squares fit lines for stain reduction with the dentifrices tested. The broken line indicates the scorers' expectancy. (Paste IV is not shown as the line almost coincides with that for Paste II.)

Table III. Cleaning powers B of six pastes

Paste type	Non-abrasive I	Silica II	Chalk III	Chalk IV	Chalk V	Pumice VI
Cleaning power	2.8	5.5	6.1*	5.6*	8.0	6.0

* These data are from two separate tests and confirm the reproducibility of the technique using the same toothpaste.

influence of the unavoidable human elements in the trials could be minimized and the test could be used to compare scorers one with another, as well as for comparing different products in numerical terms.

As the basis of measurement was parametric in this series of tests, the number of volunteers required to permit statistical differentiation of the cleaning powers of test dentifrices could be estimated before starting the test. The information required for this calculation was (a) typical test data variance deduced from earlier tests, (b) the marginal difference in cleaning powers that the test was required to detect, and (c) the approximate cleaning powers of the pastes to be tested.

The reproducible quantitative form of the data generated by this method permits statements such as Paste A is two to three times better in cleaning power than Paste B with statistically-reinforced confidence. The quality of toothpastes may also now be directly related to the duration of brushing required to remove stain.

The current status of investigations on abrasivity/cleaning power relations does not suggest any numerical relationship between these functions at present, although the evidence shows that stains build up when a subject's normal dentifrice is replaced with a non-abrasive toothpaste and that the cleaning power of a non-abrasive toothpaste is probably less than one-quarter of that of a typical chalk-based dentifrice.

Summary

A reliable *in vivo* method of quantitatively measuring the cleaning power of toothpastes has been developed. Natural stain is allowed to build up over a period of 1 month by volunteers using a non-abrasive toothpaste.

The stain is progressively removed by a hygienist using an electric toothbrush and the test pastes for 10 or 20 s periods. The progress of stain removal is quantified by measuring the percentage areas of stain remaining on volunteers' incisors. When the logarithm of this parameter is plotted against the total brushing time, a series of straight lines are produced, the gradients of which are a numerical measure of the cleaning power of each specific test paste.

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