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Comparative stain removal properties of four commercially available denture cleaning products: an *in vitro* study

Abstract: Objectives: Formulations of commercially available denture cleaners vary widely. Unfortunately, comparative data to suggest which products are the most effective can become invalid as newer products are introduced or formulations are changed. The aim of this in vitro study was to measure the stain removal properties of four currently available denture cleaners. Methods: Stain was deposited on multi-well polystyrene saliva coated microplates using multiple chlorhexidine and tea solutions. Following drying, each stained well was exposed to a solution of denture cleaner, dried again and the amount of stain remaining measured using a microplate reader. The cleaning procedure was repeated with further multiple exposures of the wells to solutions of the denture cleaners. Results: All denture cleaners removed stain better than water used as a control. At five cleaning cycles only one of the cleaners (Superdrug Cleaning Powder) had removed 100% of the stain. At 30 cycles three of the cleaners had removed 100% of the stain. Conclusions: All the commercial denture cleaners removed stain. Superdrug Cleaning Powder, which contains sodium percarbonate and sodium lauryl sulphate, was particularly effective.

Key words: 3-10 MESH; chlorhexidine; cleaning; denture; staining

Introduction

Denture cleaning is necessary to remove extrinsic stain and soft and hard deposits from dentures. The microporous surface of an acrylic resin denture base material provides an environment that supports microorganisms. Microbial plaque on dentures has potential to be harmful to both the oral mucosa and to general health (1, 2). The cleaning and maintenance of denture prostheses are therefore important for the oral health of patients and to maintain an odour-free appliance.

Extrinsic staining of acrylic resin dentures can be a major problem for many individuals especially those who smoke tobacco products or drink tea, coffee, cola or red wine. A survey of patients with complete dentures showed that the drinking tea and coffee was the main cause of the denture staining (3).

There is a large number of denture cleansers supplied in different forms. Generally, cleansing agents can be described according to their mode of action (4):

Mechanical cleansing: with the aid of brushes, paste, powders and ultrasonic agitation.

Cleansing: such as the use of alkaline peroxides, alkaline hypochlorites, acids, disinfectants and enzymes.

Information on efficacy of the different types of cleaners and the effectiveness of individual additives in removing stain can be difficult to establish because alterations in formulations of existing products or introduction of newer ones (5, 6).

The aim of this study was to investigate *in vitro* the efficacy of four currently available commercial denture cleaners in the removal of extrinsic stain. The model used repeated applications of saliva, chlorhexidine and tea solutions to multi-well polystyrene plates resulting in a stained surface that could be treated by the denture cleaners. Subsequently, the removal of stain by the denture cleaners was measured using a UV/vis plate reader.

Materials and methods

The four commercially denture cleaners evaluated are described in Table 1. Additionally, a recognized tooth-whiten-

ing toothpaste which could be used for cleaning dentures was also assessed.

Preparation of denture cleaners and toothpaste

Powder denture cleansers

One gram of each product was placed in 20 ml of distilled water in a universal container and thoroughly mixed using a Whirlimixer until the product had dispersed completely in the distilled water. Three or four slurries for each product were prepared and placed in individual containers. The slurries were freshly mixed with a Whirlimixer before each treatment.

Tablet denture cleansers

About 0.65 g of each product was placed in 20 ml of distilled water in a universal container and thoroughly mixed using a

Denture cleansers	Manufacturer	Principal ingredients	Table 1. Details of cleaning materials
Superdrug Denture Cleansing Powder	Superdrug Store plc, Croydon, UK	Sodium chloride Sodium percarbonate Trisodium phosphate Magnesium carbonate	
Steradent Triple Action Powder	Reckitt Benckiser, Slough, UK	Sodium lauryl sulphate Sodium sulphate Potassium caroate Sodium bicarbonate Citric acid Sodium carbonate Sulphamic acid	
Steradent Three Minutes Tablet	Reckitt Benckiser, Slough, UK	Sodium lauryl sulphate Sodium bicarbonate Citric acid Sodium carbonate peroxide Potassium caroate Sodium carbonate Sodium sulphate Sulphamic acid Tetraacetylethylenediamine Malic acid Sodium chloride Hexamethylenetetramine	
Steradent Extra Strength Tablet	Reckitt Benckiser, Slough, UK	Cetyl pyridinium chloride Citric acid Potassium caroate Sodium sulphate Sodium bicarbonate Sodium carbonate Sulphamic acid Malic acid Sodium dodecylbenzenesulfonate Sodium chloride Hexamethylenetetramine	
Macleans Whitening Paste	GlaxoSmithKline Brentford, UK	Cetyl pyridinium chloride Pentasodium triphosphate Titanium dioxide Sodium lauryl sulphate Sodium hydroxide Hydrated silica	

Whirlimixer until the product had dispersed completely in the distilled water. The slurries were freshly mixed with a Whirlimixer before each treatment.

Whitening paste

Three gram of whitening paste was placed in 10 ml of distilled water in a universal container and thoroughly mixed using a Whirlimixer until the product made a homogenous consistency in the distilled water. The slurries were freshly mixed with a Whirlimixer before each treatment.

Preparation of the microplates

A 96-well microplate as supplied by the manufacturer (Corning, VWR International Ltd, Lutterworth, UK) was used as the stain surface.

Pre-staining of the microplates

Fresh human stimulated saliva (stimulated by chewing a plastic film) was collected from one individual after breakfast in the morning. Saliva (100 µl) was dispensed into each chamber of a flat bottom polystyrene plate using fine point multi-channel tips and left for 2 min in order to build an initial pellicle laver and facilitate the uptake of the stain. Each well was then rinsed with water and dried. Each chamber of the plate was subsequently filled with 100 µl of 0.2% chlorhexidine mouthwash (Corsodyl, Glaxo SmithKline, Brentford, UK) for a period of 2 min. The liquid was removed by tipping and the wells were rinsed with water and dried. The plate was then filled by pipette with freshly prepared tea solution and left for a period of 1 h. The plate was then rinsed in water and allowed to dry. This process was repeated until an optical density of 0.40-0.60 was recorded for the plate in a plate reader using a wavelength range of 340-900 nm.

Removal of established stain by denture cleaning products

The baseline optical density of the previously stained plates was recorded (range 0.40–0.60) and a column of eight rows in the plate was allocated for each cleaning product. The freshly prepared slurries were dispensed into the each column for individual denture cleansers by multi-channel pipette and left for 2 min, rinsed with water and dried. The optical density of the plate was measured by the plate reader after every treatment and continued until the optical density reached 0.00 for three of the denture cleaners.

Two columns of eight rows on the plate were exposed with whitening paste and water as controls.

Statistical analysis

The statistical system package used was Stat Graphics plus V5.0 (Manugistic Inc, Rockville, MD, USA).

The maximum to minimum SD ratio was tested and was found to be >3:1 indicating that non-parametric analysis should be used.

The data were compared using a Kruskal–Wallis test that indicated if differences existed between the groups' median values. Where differences were established, Box and Whisker plots (a graphical significant difference) were used to determine significant difference between groups.

Results

The mean percentage of stain removal after each cycle is given in Fig. 1. It can be seen that Super Drug Denture cleaner removed most stain within a short period of time. All of the denture cleaners except Steradent Extra Strength had removed 100% stain from the microplate after thirty cycles.

Mean percentage stain removals at 1, 6, 11 and 30 cycles are given in Table 2.



Fig. 1. Graph showing mean % stain removal.

Table 2. Mean % stain removal at one, six, 11 and 30 cleansing cycles

Cleansers	Cycles	Mean % stain removal	SD
Maalaana Wikitaning Daata	4		45.7
Macleans whitehing Paste		45.7	15.7
Steradent Extra Strength	1	47.9	2.0
Steradent Three Minutes	1	44.0	3.6
Steradent Triple Action	1	34.8	7.0
Superdrug Powder	1	95.9	2.2
Water	1	17.6	19.0
Macleans Whitening Paste	6	66.7	12.0
Steradent Extra Strength	6	61.7	1.7
Steradent Three Minutes	6	71.0	2.6
Steradent Triple Action	6	65.0	1.7
Superdrug Powder	6	100.0	0.0
Water	6	19.6	19.6
Macleans Whitening Paste	11	48.8	22.6
Steradent Extra Strength	11	67.9	1.6
Steradent Three Minutes	11	100.0	0.0
Steradent Triple Action	11	79.0	1.9
Superdrug Powder	11	100.0	0.0
Water	11	19.6	19.9
Macleans Whitening Paste	30	66.7	7.6
Steradent Extra Strength	30	78.0	2.3
Steradent Three Minutes	30	100.0	0.0
Steradent Triple Action	30	100.0	0.0
Superdrug Powder	30	100.0	0.0
Water	30	22.3	18.7

Box and Whisker plots comparing stain removal capacities between cleansers at 1, 6, 11 and 30 cycles are given in Fig. 2a–d. Removal of stain by all cleaners was significantly better than the water control at all cycles. It can be seen that at one cycle and six cycles, Superdrug was statistically significantly more effective than the other cleansers. At 11 cycles Superdrug and Steradent Triple Action were significantly more effective than others. At 30 cycles Superdrug, Steradent Triple Action and Steradent Three Minutes were significantly more effective than Steradent Extra strength.

Discussion

The purpose of the present *in vitro* study was to measure and compare the ability of a number of commercially available denture cleansers to remove chlorhexidine- and tea-derived stain. Significant differences in efficacy of stain removal were noted. Superdrug Denture powder, which contains sodium lauryl sulphate, trisodium phosphate, sodium chloride and magnesium carbonate, proved most effective.

Previous *in vitro* studies on denture cleaners have used clear Perspex specimens as the surface for deposition of stain (5). In this study, polystyrene microplates were chosen as a standard surface to build up stain. These microplates have excellent optical clarity and are relatively inexpensive. Numerous samples can be assessed simultaneously in a short period of time. The chlorhexidine/tea stain used in the study relates to denture stain seen commonly *in vivo* with this antiseptic and has been used as a model previously for assessment of efficacy of tooth and denture cleaning products (5, 7). The specimen surfaces were pre-treated with saliva to build up an initial pellicle layer and facilitate the uptake of the stain in order to more closely mimic the clinical situation.

The selected denture cleansers were readily available in shops and their compositions varied widely. Superdrug powder included sodium percarbonate and the detergent sodium lauryl sulphate that has been shown to have stain removal properties via a chemical action (8). Two other cleansers, both in a tablet form, also included the oxygenating agent sodium percarbonate (sodium carbonate peroxide). These cleansers also contained citric acid that may also help to remove stain in combination with sodium bicarbonate, which is a recognized tooth-whitening agent. Interestingly, Steradent Extra Strength contained cetylpyridinium chloride which is a cationic antiseptic similar to chlorhexidine. This chemical is also purported to produce staining both in vitro and in the mouth (9). Unfortunately, the concentrations of chemicals in the formulations are not stated in the packaging. It is not possible to determine whether the inclusion of the antiseptic is of relevance to the findings of this study.

As a possible reference to stain removal the whitening toothpaste Macleans Whitening was used. One of its whitening ingredients is pentasodium triphosphate that also may help reduce staining independent of stain removal by the contained abrasive, hydrated silica.

Because of the complexity of formulations, the exact mechanism of stain removal by the denture cleansers cannot be determined. It should be noted that the stained microplate surfaces were exposed to slurries or solutions of the denture cleansers. Stain reduction in this study was obtained therefore by means of a chemical effect, independent of any mechanophysical effect such as produced by application with a denture cleaning brush.

This stain removal study compared the ability of the denture cleaners to remove stain to varying degrees. Increasing exposure cycles generally showed an increase in stain removal. The major stain removal appeared to occur during the first few exposure cycles to the denture cleaner. Particularly effective was Superdrug denture cleansing powder which was significantly better than all the other denture cleansers and water control. Generally as the number of exposure cycles to the denture cleansers increased, less effective denture cleansers reached the level of efficacy of the more efficient one such as Steradent Extra Strength.

There is little other information on comparative efficacy of the different types of cleaners and the effectiveness of individual additives in removing stain. One previous study demonstrated particular efficacy of alkaline hypochlorite denture soak solutions (3). No hypochlorite was included in this study. It would be of interest in future work to compare a broader range of formulations with potentially different modes of action. Similarly it would be of interest to investigate the ability of individual ingredients to remove stain from denture base materials.

In addition to the potential value of denture cleaners, several harmful effects have been noted with the use of these products (10). However, the side effects of the active ingredi-



Fig. 2. (a) A Box and Whisker plot showing differences in % stain removal for stain removal on smooth surfaces after one cycle. (b) A Box and Whisker plot showing differences in % stain removal for stain removal on smooth surfaces after six cycles. (c) A Box and Whisker plot showing differences in % stain removal for stain re

ents or products used in this study were not evaluated (and could be the subject of further research). Examples of these effects include the following:

Peroxide cleansers can cause bleaching of acrylic resin and deterioration of the surface of denture soft lining materials.

Hypochlorites may tarnish and corrode metal denture components such as CoCr frameworks. They can also bleach acrylic resin. Commercial solution cleansers with bases of dilute hydrochloric acid or phosphoric acid can also cause corrosion of the metal components of dentures.

Conclusions

All the denture-cleaning products removed staining.

Superdrug denture cleaning powder containing sodium percarbonate and sodium lauryl sulphate was particularly effective.

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