Chemical cleaning of oral appliances

By Professor Laurence J. Walsh

"digital image analysis can be used to assess the chemical cleaning capability of denture cleaning products, in particular to discriminate the direct chemical effect from the mechanical action added by the user after soaking the appliance..."

Dentures, removable orthodontic retainers, mandibular advancement and occlusal splints and other oral appliances develop extrinsic staining from a variety of sources, including components of the diet, and products used for oral hygiene. Biofilms of bacteria and fungi form on the surface of appliances and under appropriate conditions of pH and mineral concentration, these biofilms may serve as foci for the accumulation of calculus.

Denture cleaning products may utilise several modes of action:

- Physical abrasion;
- Surfactant effects to dissolve biofilms;
- Dissolution of calculus by acid erosion;
- Decolourisation of surface stains via oxidation reactions; and/or
- Removal of loose deposits by effervescence.

This short report illustrates how digital image analysis can be used to assess the chemical cleaning capability of denture cleaning products, in particular to discriminate the direct chemical effect from the mechanical action added by the user after soaking the appliance. Two commonly used denture cleaning products (Cal-Dent, Elbaford, West Chermide, Brisbane, Australia; and Steradent Extra Strength, Dentsply, UK) were compared in terms of their ability:

1. To remove stains (wine, tea, coffee, chlorhexidine) on maxillary complete dentures;
2. To alter the level of acidity of a solution (pH); and
3. To cause corrosion of metallic denture components in acrylic partial dentures.

Methodology

Effect on staining

A total of 41 identical full upper dentures were constructed from the same master cast (Figure 1), using the same batch of acrylic resin and identical

Figure 1. Control unstained denture. Note the calibration bars on the left side of the image.

Figure 2. Dentures immersed in one of the staining solutions (in this case, green tea).

Figure 3. Residual staining from wine on FU denture, after Steradent; occlusal view.

Figure 4. Residual staining from wine, after Steradent; buccal view, showing persisting stain in the gingival margin region.

Figure 5. Control unstained denture, beside a denture stained with red wine.

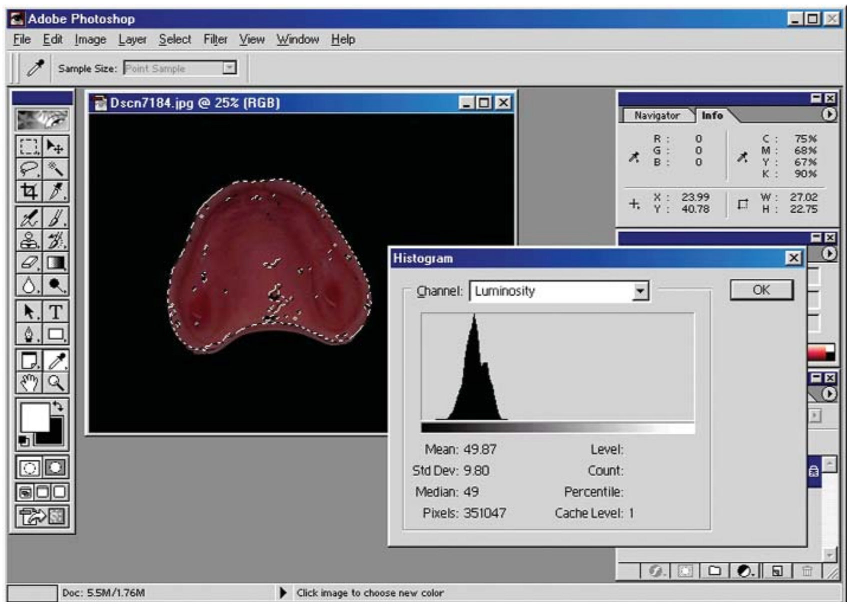


Figure 6. DOTCAM2 analysis showing selection of the denture after digital subtraction.

acrylic teeth. One denture was completely untreated and served as a control. The other 40 were divided randomly into 4 groups of 10 each and stained by immersion for 14 days at room temperature (22 degrees Celsius) in a sealed container containing 1 litre one of the following solutions (Figure 2):

1. Wine (Galway vintage Shiraz 2000, Yalumba Wineries, South Australia; 13.5% ethanol) (Figure 2);
2. Green tea (Dilmah, Sri Llanka, 5 tea bags in 1000 mL);
3. Coffee (Malongo café Moulo ground coffee (Zimbabwe), 5 heaped teaspoons in 1000 mL); and
4. Savacol (0.2% chlorhexidine in 11.5% ethanol; Colgate Oral Care, Australia).

The tea and coffee solutions were prepared in the usual way using boiling water and the dentures placed in the solution when the water temperature had cooled below 60 degrees Celsius. Each of the 4 staining solutions was agitated gently every second day during the 14-day staining period.

Using a positioning jig, each denture was then photographed in a moist state, after shaking off excess staining solution (Figure 3). The images were captured using a 3.34 megapixel digital camera (Nikon Coolpix 995) mounted on a fixed stand with a constant camera-target distance of 45 cm, using an electronic flash under conditions of constant artificial ambient lighting. Each image included two colour calibration bars to serve as internal reference points. Checking of these internal controls by animating the photographs in sequence, and by digital image analysis, did not reveal any detectable variation in the lighting conditions during the study.

After the baseline photographs were obtained, the 10 dentures in each group were then allocated into 2 subgroups of 5 each.

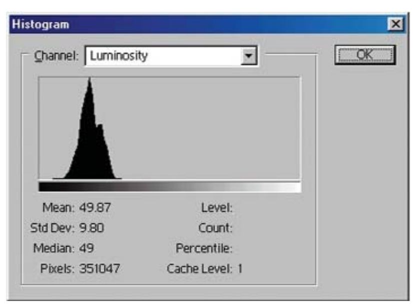
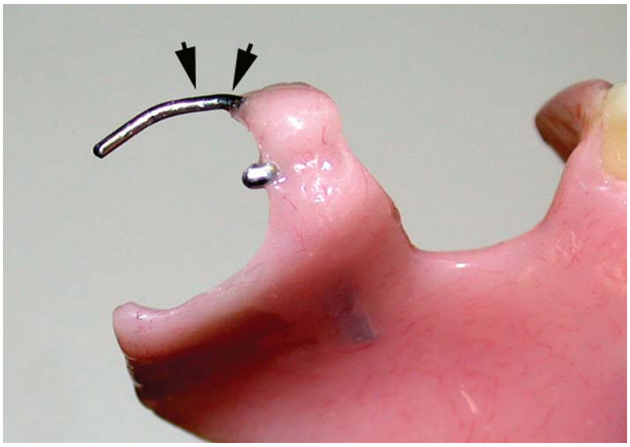


Figure 7. Histogram analysis of luminosity using Adobe Photoshop software.



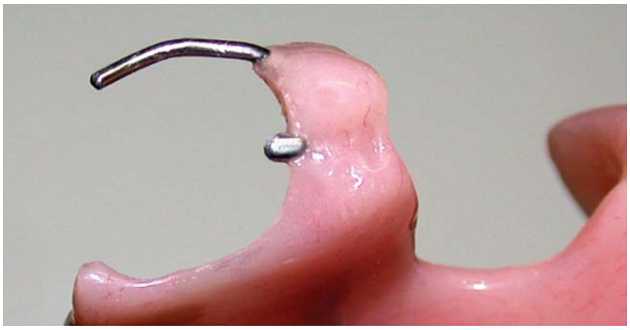


Figure 8. Small areas of surface corrosion on clasp from 20 minutes in Steradent (arrows).
Figure 9. Sample kept for 30 minutes in Cal-Dent does not show corrosion.

Two sachets of Cal-Dent™ powder were added to 500 mL of hot (60 degree Celsius) water in a 2-litre plastic container, and 5 dentures placed in the solution to fully submerge them, with the tissue fitting surface placed toward the bottom of the container. After 30 minutes, the dentures were removed one at a time, the Cal-Dent solution rinsed off for 5 seconds, and photographs taken as before. Each denture was then brushed lightly with a wet Oral B 30 soft toothbrush without any paste, for 20 seconds in total (10 seconds each on both the tissue and oral surfaces), to remove loosened material. The dentures were then re-photographed.

This sequence was followed for dentures stained with wine, tea, coffee and chlorhexidine.

Two tablets of Steradent™ (UK) were added to 500 mL of hot (60 degree Celsius) water in a 2-litre plastic container and 5 dentures placed in the solution to fully submerge them, with the tissue fitting surface placed toward the bottom of the container. After 10 minutes, the dentures were removed one at a time, rinsed, photographed, bushed and re-photographed as before. This sequence was followed for dentures stained with wine, tea, coffee and chlorhexidine.

The matched images were analyzed using DOTCAM2, an image analysis method which is not affected by variations in lighting between images of the same object under different conditions (See The Cutting Edge in this edition). The non-denture component of each image was subtracted digitally and a histogram analysis performed of the approximately 500,000 pixels representing the denture surface, using Adobe Photoshop™ version 6 software (Figsures 6 and 7). Histogram analysis was performed with data for the luminosity (brightness) channel. The possible range of luminosity values is 0 to255, with zero representing black, and 255 representing white. Thus, a higher luminosity value indicates a brighter denture surface and thus corresponds to better removal of staining.

Luminosity data for the 5 samples per group were pooled. Variations within each group were very small and typically the standard deviations were less than 6% of the mean. Image analysis was performed in a blinded fashion using coded images to obviate any concerns regarding bias regarding particular products. Statistical analysis employed the two-tailed unpaired Student's t test with Welch correction for unequal standard deviations, using the software package GraphPad Instat version 3.01.

Changes in pH over time

A temperature-corrected digital pH meter (Dick Smith Electronics) was calibrated using a pH 7.0 standard. One sachet of Cal-Dent powder was added to 250 mL of hot (50 degree Celsius) tap water and the pH recorded (to an accuracy of 0.01 pH units) using a digital pH meter at time zero, at 30 seconds and 60 seconds, and then at each minute up to 10 minutes. The same method was used with Steradent (1 tablet added to 250 mL).

Corrosion assessment

Five identical partial acrylic dentures were constructed from a master cast. Each denture had a wrought stainless steel circumferential clasp and an occlusal rest. Two dentures were immersed in either Cal-Dent or Steradent solution (freshly prepared as described above), and the remaining denture used as a control. The dentures were removed and photographed using a macro lens after 10, 20 or 30 minutes (Figures 8 and 9).

Results

Staining: Qualitative results

Because the greatest intensity of staining was achieved using wine (Figures 4 and 5), detailed digital analysis of the images was undertaken for the wine samples only.

Lesser staining occurred with tea, coffee and chlorhexidine and in each of these three sub-groups, the combination of soaking and gentle brushing gave complete stain removal when assessed visually. Cal-Dent visibly gave more effective stain removal from soaking alone than Steradent, and thus was confirmed subsequently by digital image analysis.

With wine, a visibly noticeable difference was that intense staining of teeth and gingival margin regions was not removed completely with either cleaning agent, with Steradent performing much worse in this regard.

Staining: Quantitative results

Luminosity data for wine staining are presented in Figures 10 and 11. The main points can be stated as follows:

1. There was no difference in the groups at baseline. As expected, the groups are comparable before stain removal was undertaken.
2. With both products, there was a significant increase in luminosity with either soaking alone, or soaking followed by brushing ($P<0.001$ in all cases).
3. With both products, soaking followed by brushing gave better stain removal than soaking alone. Nevertheless, a significant benefit was gained by soaking alone, thus confirming the concept of "chemical cleaning" of appliances.

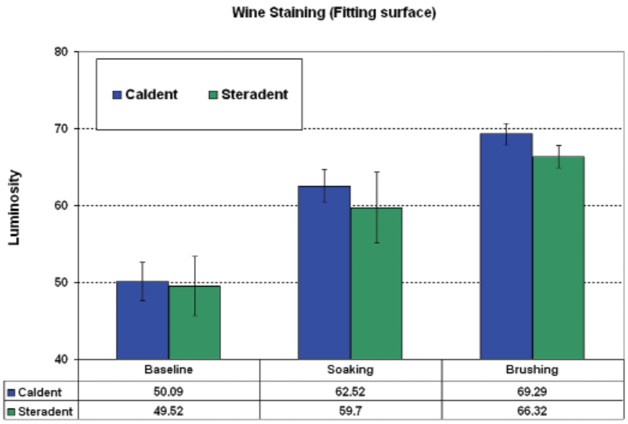


Figure 10. Luminosity data for the fitting surface for the wine group. The higher the luminosity, the better the stain removal and the brighter the surface.

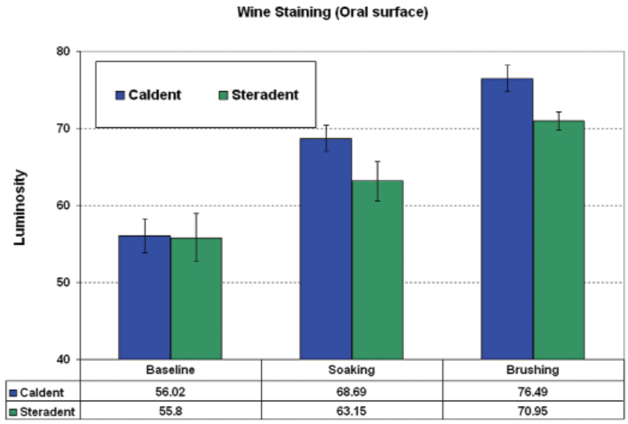


Figure 11. Luminosity data for the polished oral (palatal) surface for the wine group.

4. Comparing the two products, for the oral surface of dentures, Cal-Dent gave greater stain removal (higher luminosity) both with soaking alone, and with soaking followed by brushing.
5. For the fitting (tissue) surface of dentures, there was a clear trend for better stain removal by soaking alone, however this did not reach statistical significance. Cal-Dent gave greater stain removal than Steradent for the combination of soaking and brushing.

Changes in pH

Following mixing, effervescence was noted immediately with both Cal-Dent and Steradent. In both cases, no further effervescence was seen after approximately 60 seconds. Both products were highly acidic when dissolved; there was a rapid drop in pH during the first minute, and this drop was more pronounced with Cal-Dent, which maintained a lower pH by more than 1 pH unit across the period of measurement (Figure 12).

Corrosion assessment

When the five partial acrylic dentures were examined, the following observations were made. After 10, 20 or 30 minutes, no corrosion could be seen when the metal components of dentures soaked in Cal-Dent were examined (Figure 9). With Steradent, no visible corrosion was seen at 10 minutes, however after 20 minutes of immersion, subtle brown coloured surface reaction products were seen on the clasp surface (Figure 8). These were easily removed by gentle brushing, and no visible surface pitting was seen.

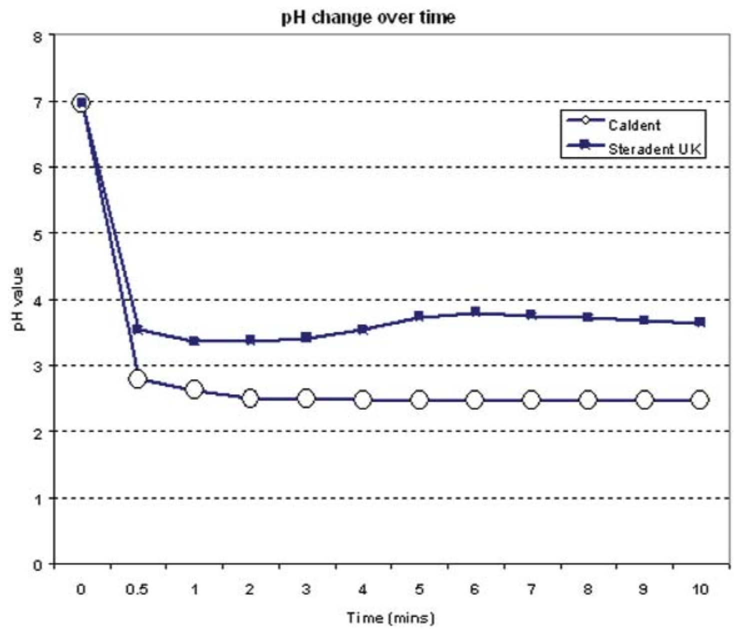


Figure 12. Changes in pH over time.

Conclusions

1. Chemical cleaning (removal of external stains) from oral appliances can be effective with common types of stains.
2. Staining from red wine is more difficult to remove by chemical cleaning.
3. With common stains (tea, coffee and chlorhexidine), both commercial products assessed achieved complete stain removal when dentures were soaked and then brushed gently.
4. Brushing using a wet toothbrush (without any paste) facilitated stain removal by dislodging material loosened by the denture cleaning solutions.
5. For more difficult and resistant stains (i.e. red wine), Cal-Dent (for 30 minutes) gave better stain removal than Steradent (for 10 minutes).
6. Cal-Dent was more acidic (lower pH) than Steradent.
7. Cal-Dent did not cause visible corrosion of wrought stainless steel clasps when used for 30 minutes. Mild corrosion occurred with Steradent.

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