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The Cleaning and Whitening Ability of Charcoal Containing Toothpastes and Homeopathic Remedies on Human Tooth Enamel

La Capacidad de Limpieza y Blanqueamiento de las Pastas Dentales que Contienen Carbón y los Remedios Homeopáticos en el Esmalte Dental Humano

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ABSTRACT: The purpose of this research was to determine the cleaning and whitening ability of two charcoal containing toothpastes compared with baking soda, activated charcoal and a hydrogen peroxide containing whitening toothpaste. Tea-stained enamel/dentin slices were mounted dentin side down in cylinders of auto-polymerizing acrylic and subjected to simulated brushing. Total color, ΔE, and stained area were measured using a reflectance spectrophotometer and ImageJ software using a Hue, Chroma, and Brightness color threshold method; respectively, at prescribed brushing intervals of baseline, months 1, 6 and 12. A two- way repeated measure analysis of variance was performed, with included factors being toothpaste group and time. Statistical analysis revealed the included factor of brushing time interval was significant ($p<0.05$) for both ΔE and stained area. There was significant interaction for both main effects ($p<0.05$) for the dependent variable of stained area alone. Significant reduction in ΔE values occurred in all groups except Optic White at the 1-month interval. Statistically significant reduction in stained area occurred at 1-month for the baking soda group only. Post-hoc Tukey HSD tests revealed there was significant group*time interaction for baking soda at month 1 for the variable stained area. The charcoal containing (Crest 3D with Charcoal and Colgate Essentials) and non-charcoal containing toothpastes (Optic White) only produced a significant stain removal at the 6-month interval.

KEY WORDS: charcoal containing toothpastes, human enamel, stain removal.

INTRODUCTION

Increasingly, patients desire cosmetic procedures to enhance their smiles (Torres *et al*., 2013). Vital tooth bleaching has become a common and standard procedure in many dental offices, however many consumers also try over the counter products to enhance the appearance of their teeth (Torres *et al*., 2013). The standard for bleaching teeth are gels containing carbamide peroxide (Carey, 2014); while toothpastes with a mix of abrasive particles such as sodium bicarbonate or silica can be used of the removal of extrinsic stain caused by dietary factors or habits such as smoking (Torres *et al*., 2013). Toothpaste however have been reported to have little effect on the intrinsic color of teeth (Demarco *et al*., 2009). Overall, tooth color is a combination of both intrinsic color; determined by the color of dentin and modified by overlying enamel thickness; and the deposition of extrinsic surface stain (Joiner & Luo, 2017). Any product marketed for whitening teeth should target both intrinsic and extrinsic stain (Sharif *et al*., 2000) while mitigating excess change in the macro or micro structural changes of dental hard tissue.

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Brushing with, or application of charcoal as an oral hygiene aide remains popular in many countries of Asia, South-East Asian and Africa (Brooks *et al*., 2017). Recently charcoal has been incorporated and marketed as promoting whitening of teeth due to either the abrasive or chelating effect of charcoal. Use of charcoal or charcoal containing toothpastes are increasingly being touted on homeopathic online fora, even though there is insufficient scientific evidence to suggest that charcoal offers any cosmetic advantages in regard to tooth whitening (Brooks *et al*., 2017; Greenwall *et al*., 2019).

Recent research on the whitening ability of one brand of charcoal containing toothpaste seems to conclude that its efficacy at whitening is lower than that of other whitening toothpastes brands that have varied mechanisms of action (Vaz *et al*., 2019). This same study, however, examined only changes in the intrinsic color of tooth samples after brushing with various toothpaste brands and did not measure changes in area of extrinsic stain (Vaz *et al*., 2019).

The aim of this study was to ascertain the changes in both intrinsic and extrinsic color after simulated brushing with both charcoal and charcoal containing toothpastes. This study was comparative in nature, since the stain removal effect of charcoal and charcoal containing toothpastes were compared against a positive control of a 'whitening' toothpaste and sodium bicarbonate (baking soda). Our null hypothesis stated that would be no statistically significant differences in terms of extrinsic or extrinsic stain removal in any of the groups.

MATERIAL AND METHOD

Prior to the start of the study a waiver to ethical review was granted by the Ethics Committee of the University (CREC-SA.0495/09/2020) given the in vitro nature of this research. A power analysis (G Power 3.0.10, Universität Kiel, Germany) was completed to determine the optimum number of samples to attain statistically significant results given an effect size of 0.5 power of 0.8 and number of groups of 5. A total of 55 specimens were required with 11 specimens per group.

The buccal and lingual surfaces of lower molars were sectioned to give a sample of both enamel and dentin that was 2-3 mm thick. Samples falling outside of this thickness threshold were discarded. Tooth samples were then subjected to staining in a cooled solution of black tea (RedRose, Unilever, Canada) in a ratio of 250 mL distilled water to 8 g tea for 4 cycles. Each cycle consisted of immersion in the staining solution for 18 hours and drying for 6 hours at room temperature. Samples were then mounted, dentin side down, in clear autopolymerizing acrylic resin (Orthoresin, DeguDent, GMBH, Germany) (in polyvinylchloride (PVC) cylinders using a salt and pepper technique.

Baseline color measurements- ΔE^*- total color were taken using the Vita EasyShade V (Vita Zahnfabrik, Germany) clinical spectrophotometer on a white background. A total of 3 readings were taken at random areas on each tooth surface, to give an individual mean sample reading, followed by mean group readings.

Standardized photographs of each sample, together with a gradated scale bar, were taken using digital photography in a 1:1 ratio and a focal length of 4.2 mm. ImageJ software (National Institutes of Health, Maryland, USA) was used to measure areas of exogenous stain on the enamel surface of each sample. Initially the edges of tooth structure were identified and demarcated compared to the embedding acrylic. A threshold color method was used to calculate stained areas of each specimen in square millimeters using a default HSB (Hue, Chroma, and Brightness) color space and a threshold color of red (Fig. 1).

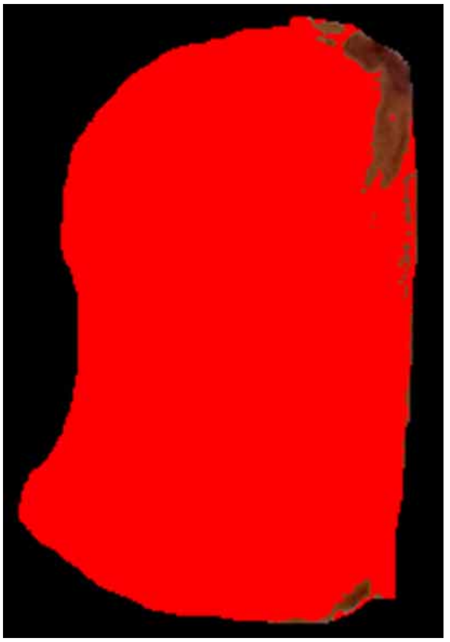

Fig. 1. Sample of Color Threshold Method used to calculate stained area.

Table I. Experimental groups, ingredient lists and manufactures' information.

Group	Brushing Agent	Ingredients	Manufacturer
1	Baking Soda	Sodium Bicarbonate	Church & D wight CO., Inc., NJ USA
2	Activated Charcoal	Activated charcoal	Aldrich Chemical Company, Missouri USA
3	Colgate Optic White	Sodium Monofluorophosphate 0.76 % (0 .12 % w/v fluoride ion), Propylene Glycol, Calcium Pyrophosphate, PVP, PEG/PPG-116/66 Copolymer, PEG-12, Glycerin, Flavor, 2 % Hydrogen Peroxide, Sodium Lauryl Sulfate, Silica, Tetrasodium Pyrophosphate, Sodium Saccharin, Disodium Pyrophosphate, Sucralose, Phosphoric Acid, BHT, Water	Colgate-Palmolive Company, New York, NY, USA
4	Colgate Essentials with Charcoal	Sodium Monofluorophosphate 0.76 %, Wat er, Hydrated Silica, Sorbitol, Calcium Pyrophosphate, Glycerin, PEG-12, Pentasodium Triphosphate, T e trapotassium Pyrophosphate, Flavor, Sodium Lauryl Sulphate, Cellulose Gum, Sodium Saccharin, Charcoal Powder, Xanthan Gum, Cocamidopropyl Betanine, Blue 1, Red 40, Yellow 5	Colgate-Palmolive Company, New York, NY, USA
5	Crest 3D White with Charcoal	Sodium Fluoride 0.243 %, Water, Sorbitol, Hydrated Silica, Disodium Pyrophosphate, Sodium Lauryl Sulphate, Flavor, Cellulose Gum, Sodium Hydroxide, Sodium Saccharin, Carbomer, Charcoal Powder, Polysorbate 80, Mica, Titanium Dioxide	Procter & Gamble, Cincinnati OH, USA

Samples (n=11) were equally distributed to one of 5 groups (Table I) with the aid of randomizing software (Random.org) and temporarily stored in distilled water until brushing occurred. Information on the agents/toothpastes used in this study are included in Table I. Specimens were mounted in an automated tooth brushing simulator (Toothbrushing Simulator MEV 4X-3D, Odeme Dental Research, Brazil) and brushed with a soft, nylon-bristled toothbrush (Wisdom Sensitive, Suffolk, England, UK) and a slurry of toothpaste and distilled water in a 1:2 ratio, at 2 strokes per second with a load of 200 g in intervals of 420, 2520 and 5040 cycles to simulate 1 month, 6 month and 12 month brushing intervals. At the end of each brushing interval, specimens were washed with distilled water, blotted and total color and area measurements repeated.

Data was analyzed using Statistical Software for Social Sciences, SPSS Version 24 (IBM, Chicago). Dependent variables of ΔE and area (mm^2) were verified for normality using the Shapiro Wilk test. A 5*3 two-way repeated measure analysis of variance, using a significance level of $p \leq 0.05$, was used to determine significances for each of the tested parameters. Included factors were toothpaste type and time interval. Post-hoc Tukey HSD tests were used for pairwise comparisons.

RESULTS

The mean values together with standard deviations and significances for both ΔE and area at each of the time intervals is presented in Tables II and III, respectively. Statistical tests revealed the included factor of brushing time interval was significant ($p<0.05$) for both ΔE and stained area. There was significant interaction for both main effects ($p<0.05$) for the dependent variable of stained area alone.

All the tested toothpastes/agents showed a significant reduction in ΔE values between baseline and 1 month, except Optic White. There was, however, a

Table II. Mean (ΔE) for DE (Different case letters (a) show significances within groups at various time intervals).

Toothpaste	Total Color Baseline ΔE	1 Month ΔE	6 Months ΔE	12 Months ΔE
Baking Soda	20.04 (4.72)[a]	11.73 (6.83)[A]	9.43 (4.68)[A]	8.67 (5.73)[A]
Activated Charcoal	17.56 (4.37)[a]	7.09 (2.24)[A]	7.02 (2.04)[A]	6.06 (3.50)[A]
Colgate Optic White	18.55 (6.45)[a]	10.55 (10.61)[a]	5.95 (2.11)[A]	4.95 (2.39)[A]
Colgate Essentials with Charcoal	16.55 (6.25)[a]	8.92 (4.73)[A]	5.75 (2.38)[A]	5.04 (2.44)[A]
Crest 3D White with Charcoal	18.24 (8.51)[a]	11.49 (5.30)[A]	6.14 (2.69)[A]	6.20 (2.63)[A]

significant reduction in ΔE values between baseline and the 6-month interval ($p<0.001$) for the specimens brushed with Optic White. Comparison between subsequent brushing intervals revealed no significant change between ΔE values for any of the tested agents/ toothpastes at any of the paired time intervals.

A statistically significant reduction in stained surface area, from baseline to 1-month was noted for specimens brushed with baking soda only. Neither activated charcoal nor any of the charcoal containing toothpastes resulted in reductions from baseline to 1-month. Crest 3D with Charcoal, Colgate Essentials with charcoal and Optic White at the 6-month interval, however, produced significant reductions in stained area compared to baseline. This baseline to 6-month interval reduction was not noted with activated charcoal. Charcoal produced a significant reduction in stained area compared to baseline at the 12-month interval only.

Since there was a significant group* time effect post hoc tests were done between groups using Tukey HSD. Comparison between groups at the specified time intervals demonstrated the following observations. At one month there were significant differences between baking soda and all the other tested toothpastes and charcoal only. No other pairwise comparisons produced significant results. At 6-month and 12-month intervals there were no significant pairwise comparisons for any of the tested toothpastes, charcoal or baking soda.

Table III. Mean (ΔE) for stained area (Different case letters(a) show significances within groups at various time intervals. B,b- show significances only at 1-month between groups.

Toothpaste	Area Measurements (mm2)			
	Baseline	1 Month	6 Months	12 Months
Baking Soda	19.81 (10.09)^{a}	11.92 (6.16)^{Ab}	8.55 (5.90)^{A}	4.75 (3.53)^{A}
Activated Charcoal	11.62 (5.44)^{a}	6.11 (2.79)^{aB}	4.67 (2.22)^{a}	3.02 (1.75)^{A}
Colgate Optic White	11.92 (5.11)^{a}	5.80 (3.04)^{aB}	2.30 (0.91)^{A}	1.81 (0.76)^{A}
Colgate Essentials with Charcoal	15.16 (8.87)^{a}	8.55 (5.69)^{aB}	5.56 (4.74)^{A}	3.50 (4.21)^{A}
Crest 3D White with Charcoal	12.51 (6.42)^{a}	7.22 (3.40)^{aB}	4.32 (2.76)^{A}	3.34 (1.85)^{A}

DISCUSSION

The staining protocol used in this study was previously used by Vaz *et al*. (2019). *In vivo* staining normally occurs due to the presence of acquired pellicle promoted by tannin rich foods such as black tea or red wine (Addy *et al*., 1995). While tea staining is a widely used method to produce exogenous stain on dental hard tissues, the intensity and extent of such stain may be limited compared to *in vivo* situations. The use of buccal and lingual slices of enamel with underlying dentin, stained and mounted acrylic side down was intended to simulate intrinsic dentin staining in this experimental design.

Relative changes in ΔE of more than 3.3 is normally associated with clinically, visually perceptible changes in color (Kohli *et al*., 2017). All the specimens showed changes is ΔE that would be considered clinically perceptible. Except for Optic White, this study also demonstrated that these month-1 changes in DE from baseline were statistically significant for all the tested toothpastes, activated charcoal and baking soda. This was unexpected since the Vita Easyshade, a reflectance spectrophotometer, ignores light reflected from the enamel and depends on light scattered from the dentin (Kholi *et al*., 2014). The authors expected no change in the ΔE values, as a result of abrasive toothpaste use on the surface of enamel which was expected to work on surface stain alone. Drastic reduction in ΔE values could be explained by either one or two methodological limitations. Absorbed tea stain on the surface of teeth could also cause scattering of light. An associated reduction in extrinsic stain could cause a variance in the amount of scattered light with accompanying reductions in ΔE. The authors posit that total color measurement, as measured by the instrumentation used, were the sum of both intrinsic (dentin) and extrinsic staining. A concomitant reduction in extrinsic staining, while notable, but not significant also resulted in improved ΔE values. This argument could further be supported by both the color and area measurements obtained from all brushed samples.

Secondly the interface between the acrylic and dentin may have allowed fluid movement during brushing. Fluid acting as a carrier for chelating charcoal particles (Mohan & Karthikegan, 1997) of the charcoal containing toothpastes or the pentasodium triphosphate and tetrapotassium pyrophosphate of the Optic White could interact with and break down chromophore molecules within the stained dentin substrate, resulting in reductions of ΔE. This led the authors to conclude that both activated charcoal and charcoal containing toothpastes had a significant chelating effect on the stained dentin that was mounted acrylic side down. This hypothesis would need to be explored with a robustly designed study to ascertain the effect of charcoal containing toothpastes on stained dentin surfaces.

Despite the inclusion of 2 % hydrogen peroxide in the formulation of Optic White, this was insufficient for a change of ΔE values in the short term (1 month). This finding is somewhat in agreement with that of Carey (2014) who stated that whitening toothpastes can lighten teeth by one or two shades. Even though there was a reduction in ΔE values that would be clinically perceptible, this was not statistically significant until month-6. These findings could be a product of either the low hydrogen peroxide concentration or the contact time with the enamel substrate during simulated brushing.

The results of this study revealed that activated charcoal by itself does not act as an effective abrasive agent in the removal of extrinsic tooth surface stain in the short (month-1) or medium (month-6) term. Extrinsic stain removal depends primarily on the abrasive potential of toothpastes. This calls into question the inclusion of charcoal incorporated into toothpastes containing known abrasives. The fact that toothpastes with (Crest 3D with Charcoal, Colgate Essentials with Charcoal) and without charcoal (Optic White) both produced significant changes at the 6- month interval lends strength to an argument that extrinsic stain removal was most likely due to known abrasives such as silica within the formulations and not charcoal. Hydrated silica is a known abrasive (Singh *et al*., 2016), that is angular in profile and known to abrade surface stain effectively via known tri-biological mechanisms (Ashcroft & Joiner, 2010). Ratios of charcoal to other abrasives such as silica in the tested toothpaste formulations may have affected the abrasive cleaning ability of these toothpastes, with an effect only being noted with longer and cumulative brushing times.

The stain removing ability of any toothpaste, however, depends on the concentration of the abrasive available at the brush-tooth interface (Wright, 1969). The authors postulated that the concentration of silica in the formulations of the tested charcoal containing toothpaste are insufficient for stain reduction after one month of use. This could also account for the efficient stain removal with baking soda. The formulation of baking soda in this current study contained 100 per cent of sodium bicarbonate, making the saturation of abrasive at the brush-tooth interface sufficient to abrade away surface stain in the short term. Li (2017) in a review article, discussed the increase in stain removal ability of toothpastes as concentrations of sodium bicarbonate were increased from 45 % to 65 %. Additionally, dissolved sodium bicarbonate is alkaline in nature. Constant interaction with a basic solution over an interval of simulated brushing could have resulted in this basic solution interacting with and reducing oxidized surface tea stain on enamel surfaces and within dentin, as discussed previously.

The chelating effect of activated charcoal, by itself, on surface stain may be useful if used for long periods of time. Charcoal, however, may lead to an unaesthetic appearance of brushed teeth. Throughout the experiment visual observation of the specimens brushed with activated charcoal revealed charcoal debris in anatomical grooves and any roughened areas of specimens. Charcoal debris could have influenced the calculation of stained area using the color threshold method, with charcoal contributing to the appearance of stain using this method. Furthermore, the use of this Hue, Chroma, and Brightness color threshold method for measuring stained area would further need to be validated since large sample variance was noted and there are no reported instances of its use in the literature for measuring extrinsic stain on human teeth.

CONCLUSIONS

Within the limitations of this study the results indicate that baking soda used as a tooth powder has excellent extrinsic stain removal ability on enamel surfaces that have been stained by tea, in the shortest possible time when compared to charcoal or any of the tested toothpastes. Charcoal by itself is not useful in removing surface staining on tooth enamel. All tested toothpastes/agents, except for Optic White may have some role in improving overall color of dentin surface in the short term once such dentin is exposed. Based on the findings of this study the null hypothesis was rejected.

MARCHAN, S. M.; BASCOMBE, K. & SMITH, W. A. J. La capacidad de limpieza y blanqueamiento de las pastas dentales que contienen carbón y los remedios homeopáticos en el esmalte dental humano. *Int. J. Odontostomat., 16(3)*:435-440, 2022.

RESUMEN: El propósito de esta investigación fue determinar la capacidad de limpieza y blanqueamiento de dos pastas dentales que contienen carbón en comparación con bicarbonato de sodio, carbón activado y una pasta dental blanqueadora que contiene peróxido de hidrógeno. Los cortes de esmalte/dentina teñidos con té se montaron con el lado de la dentina hacia abajo, en cilindros de acrílico autopolimerizable y se sometieron a un cepillado simulado. El color total, ΔE y el área teñida se midieron usando un espectrofotómetro de reflectancia y el software ImageJ usando un método de umbral de color de tono, croma y brillo; respectivamente, en los intervalos de cepillado prescritos al inicio, los meses 1, 6 y 12. Se realizó un análisis de varianza de medidas repetidas de dos vías, con factores incluidos como el grupo de pasta de dientes y el tiempo. El análisis estadístico reveló que el factor incluido del intervalo de tiempo de cepillado fue significativo ($p<0,05$) tanto para ΔE como para el área manchada. Hubo interacción significativa para ambos efectos principales ($p<0,05$) para la variable dependiente del área teñida sola. Se produjo una reducción significativa en los valores de ΔE en todos los grupos excepto Optic White en el intervalo de 1 mes. Se produjo una reducción estadísticamente significativa en el área manchada al mes solo para el grupo de bicarbonato de sodio. Las pruebas post-hoc Tukey HSD revelaron que hubo una interacción significativa entre grupo y tiempo para el bicarbonato de sodio en el mes 1 para el área manchada variable. Las pastas dentales que contenían carbón (Crest 3D con Charcoal y Colgate Essentials) y las pastas de dientes que no contenían carbón (Optic White) solo produjeron una eliminación significativa de las manchas en el intervalo de 6 meses.

PALABRAS CLAVE: pastas dentales con carbón, esmalte humano, eliminación de manchas.

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