REVISTA DE ODONTOLOGIA DA UNESP
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Original Article

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The influence of activated coconut charcoal-based abrasives on the surface of dental enamel

Influência de abrasivos a base de carvão de coco ativado sobre a superfície do esmalte dentário

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How to cite: Feitosa FA, Santos LC, Barbieri AA, Teixeira SC. The influence of activated coconut charcoal-based abrasives on the surface of dental enamel. Rev Odontol UNESP. 2024;53:e20240034. https://doi.org/10.1590/1807-2577.03424

Resumo

Introdução: Produtos a base de carvão ativado vem sendo comercializados como branqueadores dentais e amplamente utilizados pela população sem qualquer tipo de controle de qualidade ou estudo sobre suas repercussões sobre a estrutura dental. **Objetivo:** O objetivo desse estudo foi avaliar o efeito da escovação com produtos à base de carvão ativado sobre a rugosidade e cor de esmalte dentário. **Material e método:** Quarenta amostras de esmalte com 6mm de diâmetro foram manchadas com café durante 36 horas. Foram realizadas leituras iniciais de rugosidade (Ra e Rz) e cor (L*a*b*). Os espécimes foram divididos em 4 grupos (n=10): Grupo Controle: Creme dental Colgate Total 12; Grupo CBP: Pó de carvão de coco ativado Black Pearl Tooth Powder; Grupo CAC: Pó de carvão de coco ativado Activated Charcoal Teeth Whitening Powder; Grupo BS: Pó de Bicarbonato de sódio. Os espécimes foram então submetidos a ciclos de simulação de escovação (945, 4.050 e 49.275 ciclos), sendo que ao alcançar cada uma dessas marcas, novas medidas de cor e rugosidade foram tomadas. Para analisar os dados de variação de cor e rugosidade foi realizada a análise ANOVA 1-fator, seguida pelo teste de Tukey. **Resultado:** Não houve diferença estatística entre a rugosidade inicial e final em nenhum dos grupos estudados. Para os dados de cor, houve diferença estatística para as coordenadas a* e b* em todos os grupos entre o período inicial e os demais. **Conclusão:** Mesmo após a simulação de escovação referente ao período de um ano nenhum dos produtos estudados afetou a rugosidade superficial do esmalte. A cor do esmalte após realização dos ciclos abrasivos deu-se de forma semelhante nos grupos experimentais a base de carvão de coco ativado e com o creme dental convencional.

Descritores: Esmalte dentário; carvão vegetal; percepção de cores; escovação dentaria; abrasão dentaria.

Abstract

Introduction: Activated charcoal-based products have been marketed as teeth whiteners and are widely used by the population without any quality control or studies on their impact on dental structure. **Objective:** The objective of this study was to evaluate the effect of brushing with powdered coconut-based products on the roughness and color of human dental enamel. **Material and method:** To this end, 40 enamel samples with 6mm diameter were stained with coffee for 36 hours. Initial roughness readings (Ra and Rz) and color (L* a * b*) were performed. The specimens were divided into 4 groups (n = 10): Control Group: Colgate Total 12 toothpaste; CBP Group: Activated Coconut Charcoal Powder, Black Pearl Tooth Powder; CAC Group: Activated Coconut Charcoal Powder, Activated Charcoal Tooth Whitening Powder; Group BS: Sodium bicarbonate powder. The specimens were submitted to abrasive cycles for brushing simulation (945, 4.050 and 49.275 cycles), and upon completion of these cycles, new measurements of color and roughness were taken. A 1-factor ANOVA analysis was performed to analyze the color variation and roughness data, followed by the Tukey test. **Result:** There was no statistical difference between the initial and final roughness in any of the groups studied. For the color data, there was no statistical difference for the L* coordinate for any group. For the coordinates a * and b* there was a difference for all groups between the initial period and all the others. **Conclusion:** Even after the one-year period brushing simulation, the surface roughness of the enamel of none of the products studied was affected. The color of the enamel after the accomplishment of the abrasive cycles occurred in a similar way in the experimental groups based on activated coconut charcoal and conventional toothpaste.

Descriptors: Dental enamel; charcoal; color perception; toothbrushing; tooth abrasion.

INTRODUCTION

The number of self-portraits made by people brings a level of demand that looks even greater than what has been perceived previously[1]. Studies show that many Internet users use it as a source of health information, and sites such as YouTube are important sources for the dissemination and sharing of such information[2]. Headlining the “channels” available on YouTube are personalities who have gained notoriety for their reproduced content and advice. These personalities present reviews on, among other topics, products related to oral and general health, often without researching the accuracy and quality of the information and products presented[2].

Recently, several videos and reviews made available on the internet have been dealing with the use of powdered activated carbon as a “do-it-yourself” whitening method, i.e., without the guidance and supervision of a dental surgeon. These products, however, have not yet been sufficiently scientifically tested for this purpose.

The tooth is polychromatic and its structure has layers determining different reflections due to different planes[3] and the apparent color of teeth is formed by a combination of intrinsic and extrinsic pigmentations. Intrinsic staining may be due to genetic characteristics, such as: age (enamel wear over time, which exposes yellowish dentin), high levels of fluoride, and disorders that begin before the tooth erupts, whereas extrinsic staining is usually caused by environmental factors and habits, including smoking, drinks and food containing dyes and medications[4]. These pigments are adsorbed onto the acquired film or directly onto the tooth's surface, staining it[3,4].

Tooth-whitening techniques consist of a reduction in the pigmentation of these stains, and whitening performed in dental offices with substances such as hydrogen peroxide and carbamide act on intrinsic and extrinsic pigments, while extrinsic stains can be removed by chemical or mechanical methods, such as professional prophylaxis or brushing with pastes containing some level of abrasiveness[5].

Arising from the idea of whitening the dental structure in a more accessible way, companies have developed non-professional bleaching products, such as dentifrices and mouthwashes. Bleaching mouthwashes contain mostly hydrogen peroxide in low concentration as an active ingredient, while dentifrices help in the removal of stains by the incorporation of abrasives that act mechanically on the more pigmented surface of the enamel by the addition of hydrogen peroxide or optical whitening agents.

Abrasiveness is determined based on a method which provides the REA (the relative abrasiveness in the enamel), with reference values compared to a standard abrasive[6]. Studies have shown that increased abrasion of eroded enamel and dentine are directly proportional to the OER of toothpastes[7,8].

Activated charcoal is used in the medical environment as a neutralizer in cases of poisoning and is recognized for its great absorption capacity[9,10]. In the oral environment, however, it is currently being suggested as a natural method for tooth whitening, which can be found in the market as powder, or added to toothpaste formulas. The attractions highlighted by the manufacturers include the elimination of odors, calculus removal and the absorption of pigments that stain the teeth. However, data on abrasion, the possibility of tooth structure wear and the occurrence of dentin sensitivity, especially from continuous use, are not mentioned.

Based on the above, the objective of this study was to evaluate the influence of brushing with powdered coconut-based products on the roughness and color of human dental enamel, comparing them with conventional toothpaste and sodium bicarbonate powder.

MATERIAL AND METHOD

Adequacy of Teeth and Obtaining Specimens

The strength analysis of the sample for ANOVA 1 factor regarding color variation and roughness data was performed using the statistical software PIFACE Russ Lenth (Softpedia, Bucharest, Romania). For a sample size equal to 10 and standard deviation of 5.0 units, using Tukey's test (5%) to compare means, it was possible to detect a difference of 8 units with sample strength greater than 80%.

Twenty intact human third molars were scraped by low-rotation motor prophylaxis, Robinson brushes, pumice and water. The presence of cracks, cavities or defects in the structure of the teeth was evaluated with the help of a magnifying glass, and those with such defects were discarded and replaced.

The teeth were sectioned at cervical height in a precision cutter (LabCut) for complete removal of the root. Then, their crowns were sectioned in the mesiodistal direction until two halves were obtained, buccal and lingual (n = 40). The vestibular and lingual halves were cut in a circular format using a trephine-type diamond tip with 3 mm internal diameter adapted to a circular sample cutting device. The faces of each tooth were affixed to a hinged metal base, positioned perpendicularly to the diamond tip, and the clipping was performed under constant irrigation with water. The thickness of each specimen was standardized at 1 mm for the enamel and 1 mm for the dentin (Figure 1).

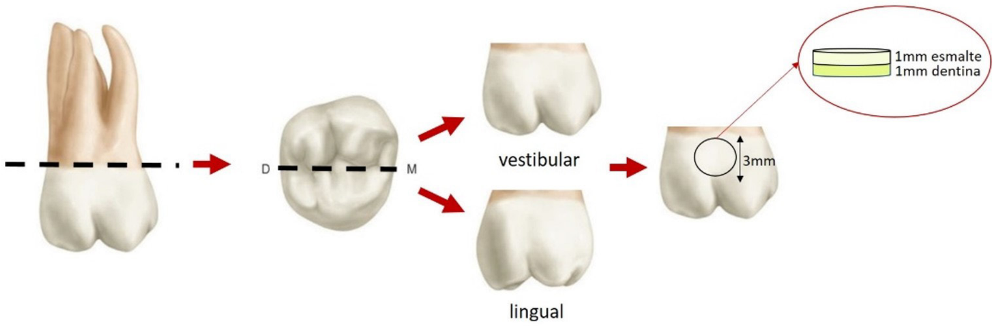

Figure 1. Sample preparation scheme from human third molar.

After preparation of the specimens, polishing of the inner face (dentin) in a circular polishing machine (DP-10, Panambra, São Paulo, SP, Brazil) was performed to standardize the thickness and regularization of the specimen. Then the specimen was placed with the enamel face facing the outer surface of the device, to carry out the planning and polishing also in a circular polisher, allowing alignment between the polished surfaces and the metal base on which the specimens were to be fixed.

After polishing the specimens, they were stored in distilled water in a bacteriological oven at 38ºC for 7 consecutive days before continuing the study.

Initial Readings of Color and Roughness

A Vita EasyShade® spectrophotometer (VITA-Zahnfabrik H. Rauter Gmbh & Co. KG, Bad Säckingen-Germany) was used to record the initial color of the enamel specimens, which provided the values of the color coordinates L *, a * and b * in accordance with the instructions of the Commission Internationale de l'Éclairage (CIE)[11]. The spectrophotometer was properly calibrated following the manufacturer's specifications and constant illumination (illuminant D65, which corresponds to daylight) was maintained and standardized throughout the measurement procedure.

The quantitative roughness analysis (Ra and Rz) was performed using a Mitutoyo SJ 400 rugosimeter (Mitutoyo, Tokyo, Japan) by a single trained examiner using the following parameters: Ra (mean roughness), which corresponds to the mean arithmetic of the absolute values of the spacing ordinates (peaks and valleys) in relation to the midline within the measurement path; and Rz (mean depth roughness) that corresponds to the arithmetic mean of the absolute values of the ordinates of the points of greatest distance, above and below the midline. Three measurements were performed on the surface of the samples. An average value for each sample was obtained from the measurements and then the mean of each group was obtained.

Distribution of Experimental Groups

The specimens were divided into 4 experimental groups (n = 10) (Table 1), as follows:

- Control Group: Brushing with Colgate Total 12 toothpaste.
- CBP Group: Brushing with activated coconut charcoal powder Black Pearl Tooth Powder.
- CAC Group: Brushing with activated coconut charcoal powder Activated Charcoal Teeth Whitening Powder.
- Group BS: Brushing with sodium bicarbonate powder.

Table 1. Composition, presentation, manufacturers and composition of the products used

Product	Presentation	Manufacturer	Composition
Colgate Total 12 Clean Mint	Toothpaste	Colgate Palmolive, São Bernardo do Campo, São Paulo, Brasil	Water, sorbitol, hydrated silica, sodium lauryl sulfate, PVM / MA copolymer, carrageenan, sodium hydroxide, sodium fluoride, triclosan, sodium saccharin, titanium dioxide (CI 77891), limonene / dipentene
Activated Charcoal Teeth Whitening Powder	Powder	Moody Zook, Trend Dragon Limited, Hong Kong, China	Activated Coconut Charcoal, sage Activated Coconut Charcoal, bentonite clay, mint, clove, cinnamon. Water, sorbitol, hydrated silica, sodium lauryl sulfate, PVM / MA copolymer, carrageenan, sodium hydroxide, sodium fluoride, triclosan, sodium saccharin, titanium dioxide (CI 77891), limonene / dipentene
Black Pearl Tooth Powder	Powder	Living Earth, Estados Unidos	Activated Coconut Charcoal, sage Activated Coconut Charcoal, bentonite clay, mint, clove, cinnamon
Sodium Bicarbonate	Powder	Biodinâmica, Ibiporã, Paraná, Brasil	Sodium bicarbonate

Evaluation of Abrasion Wear

After reading the initial roughness and color, the specimens were submitted to the abrasive challenge with brushing simulation equipment (MEV-2T, Odeme Equipamentos Médicos e

Odontológicos Ltda. - Joaçaba, SC, Brazil) where they were submitted to 945, 4.050 and 49.275 cycles, corresponding respectively to 1 week, 1 month and 1 year of brushing[12]. The abrasion was carried out with a load of 200 gms., according to ISO 11609[13], with the specimens immersed in the tested products corresponding to each group in the proportion 2:1 weight / weight[14]. When transferring the samples to the brushing machine, a similar number of samples from each group was positioned, aiming at evenly distributing the errors resulting from the process. During the night waiting period, the specimens were stored in a closed container with 100% relative humidity. The abrasion of the samples was carried out in a continuous way, and when they reached the number of cycles corresponding to 1 week, 1 month, and 1 year, new measurements of color and roughness were performed.

To analyze the data of color variation (L * a * b *) and roughness, 1-factor ANOVA was used, followed by the Tukey's test (p <5%).

RESULT

Color Variation (CIE Coordinates L * a * b *)

The 1-factor ANOVA results showed that for the L * coordinate there was no significant difference between the periods studied for any of the experimental groups. For the coordinates a * and b * the Analysis of Variance showed a significant difference in all the experimental groups. The averages for the coordinates L *, a * and b *, as well as the p-value for the ANOVA 1-factor test are shown in Table 2.

Table 2. Mean and standard deviation of the coordinates L *, a * and b * for each group and number of abrasive cycles and p-value for 1-factor Variance Analysis

GROUP		ORIGINAL	945 CYCLES	4,050 CYCLES	49,275 CYCLES	Value of P
Control	L	78.3 (3.11)	77.3 (2.59)	77.7 (2.55)	77.7 (2.9)	P=0.6689
	a	8.5 (1.54)	3.5 (1.11)	4.4 (1.24)	5.1 (1.38)	P=0.0004
	b	42.8 (2.89)	30.8 (1.95)	31.7 (1.58)	34.0 (1.83)	P=0.0006
CBP	L	81.2 (3.77)	81.2 (4.58)	81.8 (3.51)	82.2 (3.1)	P=0.6621
	a	7.8 (2.43)	3.4 (2.09)	4.1 (2.17)	4.6 (2.48)	P<0.0001
	b	40.6 (1.07)	32.0 (2.24)	32.7 (2.14)	32.9 (3.01)	P=0.0084
CAC	L	77.9 (4.08)	79.0 (3.30)	77.6 (3.83)	72.1 (4.1)	P=0.8594
	a	8.8 (4.63)	2.9 (2.57)	3.7 (3.43)	6.4 (2.86)	P=0.0011
	b	43.0 (2.39)	27.8 (2.97)	27.7 (3.5)	34.9 (2.46)	P=0.0015
BS	L	81.4 (5.25)	79.4 (3.36)	79.1 (5.12)	73.4 (3.9)	P=0.0803
	a	8.7 (1.41)	3.1 (1.48)	3.7 (1.07)	8.6 (2.1)	P<0.0001
	b	43.8 (3.89)	29.4 (4.69)	29.9 (4.23)	32.3 (3.22)	P<0.0001

The Tukey test showed that for the coordinates a * and b * the difference was between the initial period and all the others (945, 4.050 and 49.275 cycles).

Surface Roughness

For the analysis of the surface roughness data Ra and Rz, 1-factor Variance Analysis was performed to verify the difference of each of the groups between the studied periods. The analysis did not indicate significant differences in any of the experimental groups. The averages for Ra and Rz, as well as the p-value for the ANOVA 1-factor test are shown in Table 3.

Table 3. Mean and standard deviation of the surface roughness values Ra and Rz (µm) for each group and number of abrasive cycles and p-value for 1-factor Variance Analysis

GROUP		ORIGINAL	945 CYCLES	4,050 CYCLES	49,275 CYCLES	Value of p
Control	Ra	0.19 (0.19)	0.18 (0.17)	0.15 (0.04)	0.24 (0.15)	P=0.0522
	Rz	1.07 (1.49)	1.12 (0.57)	1.14 (0.44)	1.17 (1.57)	P=0.8004
CBP	Ra	0.20 (0.09)	0.14 (0.05)	0.14 (0.04)	0.17 (0.04)	P=0.7271
	Rz	1.13 (0.74)	1.05 (0.40)	1.14 (0.40)	1.42 (0.89)	P=0.6899
CAC	Ra	0.16 (0.08)	0.12 (0.03)	0.14 (0.05)	0.13 (0.38)	P=0.0187
	Rz	0.95 (0.72)	0.81 (0.31)	0.86 (0.40)	0.94 (0.25)	P=0.2827
BS	Ra	0.14 (0.06)	0.12 (0.05)	0.14 (0.04)	0.16 (0.1)	P=0.3811
	Rz	1.31 (0.97)	0.90 (0.30)	0.92 (0.30)	1.31 (0.87)	P=0.7139

DISCUSSION

Coconut charcoal powder-based products used in this study have added to their formulation Salvia, bentonite clay, mint, clove and cinnamon. Bentonite clay has industrial applications and in the composition of cosmetic products, dentifrices and medicines[15]. The use of bentonite clay is still not considered safe because studies associate crystalline silica present in its composition with the development of cancer in humans[15].

Sage is an herb with antibacterial, antiviral, antifungal and antioxidant therapeutic properties. When added to oral rinses it promotes antibacterial action linked to the bacterial plaque Streptococcus Mutans[16]. Mint extract, as well as cinnamon extract, have a known antimicrobial factor, while clove oil has antioxidant, antifungal and antibacterial properties linked to the inhibition of Staphylococcus spp[17,18]. One factor to be considered is the absence of data on the concentration of these components in the formulation of the products, which hinders the judgment of their therapeutic properties.

The absence of fluoride should be emphasized since the general population may not know about the effects of its disuse. Fluorides have a key role in reducing the number of cavities in the population and, although they are present in the water supply in most cities of the world, their concentration is much more pronounced in toothpaste formulations[19]. Therefore, the continuous use of pure activated charcoal powder in all brushing is restricted due to the lack of added benefits to its formulation when compared to traditional toothpastes. Colgate Total 12 toothpaste (Control Group) also has Triclosan which, associated with fluorides, is able to reduce the formation of bacterial plaque, bleeding and gingival inflammation when compared to toothpaste that does not contain it[20].

In this study, the BS group, when subjected to simulated toothbrushing with sodium bicarbonate, did not present any increase in their surface roughness (Ra and Rz) during any of the studied periods. These results corroborate with that described by Hara, Turssi[21], 2017, in a literature review in which they concluded that the use of sodium bicarbonate-containing toothpastes is safe for continuous use, since the hardness of their particles is inferior to both enamel and dentin, therefore not causing any damage.

The Control group, subjected to simulated toothbrushing with Colgate Total 12 dentifrice, also did not present significant surface roughness difference for any of the evaluated periods ($p > 0.05$). The same was observed in the study by Turssi et al.[22], 2005, in which the enamel was subjected to simulated brushing for 5.000 cycles with toothpaste of the same composition and stored in distilled water. This result can be supported by the study by Newbrun[23], 1997, which classifies hydrated silica at 2.5 in the Moh's hardness scale while tooth enamel is classified as 3.5 to 4.5[24-27].

Experimental abrasive groups with activated coconut charcoal also did not show differences of surface roughness between the initial and final periods. This result corroborates the one found by Palandi et al.[28], who evaluated products containing activated charcoal with conventional toothpastes and observed that there were no changes in the perception of color[28]. In this same direction, Franco et al.[29], in a laboratorial randomized study carried out with the goal of assessing the whitening properties of a charcoal-based powder, observed, regarding superficial roughness measured by the rugosimeter, there was no significant difference. There are large differences in the hardness of activated carbon depending on its raw material, and no scientific validation data regarding coconut charcoal was found for comparison with the components of the other groups studied, or even with the dental enamel structure. Activated charcoal-containing toothpastes have not yet been classified on the toothpaste abrasive scale for Relative Dentin Abrasion (RDA) by the American Dental Association (ADA). By contrast, another study has assessed, via Optical Coherence Tomography, the wear of tooth enamel after using different toothbrushes and brushing materials containing abrasive components, including activated charcoal and the authors stated that the whitening toothpastes and the activated charcoal can promote intense wear in dental enamel[29]. However, the authors emphasize the need for more research on the topic.

In medical terms, among other purposes, activated charcoal is used in cases of drug poisoning and overdosing[29]. The terminology "activated carbon" refers to its processing at high temperature, which "activates" it, making it more porous and therefore efficient in the adsorption of certain substances like dyes, phenols, organic matter, among others. Activated coconut-based powder products promise to adsorb tooth stains on contact, a factor not yet proven by the literature. Thus, in this study the results for color considering the abrasive challenge through the simulated brushing by 945, 4.050 and 49.275 cycles are considered.

Many factors influence the degree of abrasiveness on the dental structure, such as the use of an abrasive product, the pressure exerted during brushing, brushing frequency and the softness of the brush bristles, for example.

For the coordinate L * (black (+) to white (-)) there were no changes for any of the experimental groups. This means that there was no whitening effect on the color of the teeth after coffee staining when exposed to brushing with the tested products. Franco et al.[29] (2020) stated, based on their research, that the charcoal-based powder had shown ineffective as a tooth-whitening method. Still, corroborating the results of this paper, Palandi et al.[28] (2020) have assessed the effects of activated charcoal-based powder coupled with both conventional and tooth-whitening toothpastes in color and in the surface of enamel in comparison to urea hydrogen peroxide and observed that although the charcoal powder hadn't increased the enamel's superficial roughness when coupled with toothpastes, the activated charcoal powder did not show increase in the change in color when compared to both conventional and tooth-whitening toothpastes[27].

In this study, all groups presented differences in their coloration for the a * coordinate between the initial period and the others. The coordinate a * refers to the variation between green (-) and red (+) colors and, for all groups, there was a decrease in the amount of red and an approximation of the green color between the initial color and the first abrasive cycles (945). Among the other periods, the coordinate a * did not change significantly for any of the groups. For the coordinate b * (yellow (+) to blue (-)) there was also a statistical difference between the initial period and the others for all the experimental groups. The decrease of the values of the coordinates a * and b * means an approximation of the center and decrease of the saturation of the colors. This data reinforces the idea that carbon removes extrinsic stains by abrasion and, after this initial removal, does not have any adsorption reaction with the other pigments deposited in the dental enamel structure.

In a literature review published in the year 2017, Brooks et al.[15], the authors found advertisements on the Internet that were misleading or lacking scientific evidence for the therapeutic use of coconut charcoal as a, antibacterial, antifungal, antiviral and detoxifying agent in the oral environment. In 2022, despite the increase in studies about the topic, in a literature review done by Gimenes et al.[30], the authors report that adverse effects arose due to toothpastes containing activated charcoal such as increase of superficial roughness of enamel and dental wear and concluded that the whitening action of these toothpastes is still questionable and their frequent use may negatively impact oral health.

Further studies must be carried out with the aim of verifying the relationship between the use of activated carbon charcoal abrasives and the removal of oral odors and the adsorption of pigments, characteristics highlighted by their manufacturers, but not scientifically based. In this study, the behavior of the dental enamel structure subjected to brushing with activated coconut powder was evaluated for a period of up to 1 year[12]. For a more thorough evaluation, a longer period of brushing could be evaluated for a closer proximity to situations to which the teeth are exposed in daily reality.

CONCLUSION

The surface roughness of the enamel was not significantly altered by simulated brushing with products containing activated coconut charcoal in any of the periods tested. The coloration of the enamel after the abrasive challenge showed similar results in the experimental groups based on activated coconut charcoal and conventional toothpaste.

AUTHORS' CONTRIBUTIONS

Fernanda Alves Feitosa: Formal analysis, Methodology, Project administration.
Laura Chaves Santos: Conceptualization, Data curation, Formal analysis, Investigation, Writing - original draft.
Ana Amélia Barbieri: Conceptualization, Data curation, Investigation, Writing - review & editing.
Symone Cristina Teixeira: Data curation, Funding acquisition, Project administration, Validation.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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Received: October 21, 2024
Accepted: October 30, 2024