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A New Approach for Dental Bleaching Using Violet Light With or Without the Use of Whitening Gel: Study of Bleaching Effectiveness

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Clinical Relevance

Violet light produced clinically significant chromatic changes without the use of bleaching gel and potentiated the bleaching effect obtained with a gel containing 17.5% hydrogen peroxide (HP). However, the use of violet light with a gel containing 35% hydrogen peroxide did not affect the final result.

SUMMARY

The objective of this study was to evaluate the effectiveness of violet light-emitting diodes (LEDs) in dental bleaching treatment when used in conjunction with bleaching gels containing different concentrations of hydrogen peroxide (HP). Here, 90 bovine teeth (n=15) were randomly assigned to the following groups: GI, placebo without light; GII, 35% HP without light; GIII, 17.5% HP without light; GIV, placebo with violet LED; GV, 35% HP with violet LED; and GVI, 17.5% HP with violet LEDs. Three bleaching sessions of 45 minutes were conducted; 21 cycles involving one minute of irradiation by violet LEDs with 30-second intervals were performed during each session of bleaching (GIV, GV, and GVI). Color changes (ΔE, ΔL, Δa, and Δb) were analyzed using a visible ultraviolet light spectrophotometer 7 days after each bleaching session.

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The mean ΔE, ΔL, Δa, and Δb values were compared between groups by analysis of variance and Tukey tests, with a significance level of 5%. The groups treated with 35% HP had higher ΔE and ΔL and lower Δb values, regardless of whether violet light was used. The group that received only violet LED differed from the control group in terms of ΔE, and the group treated with 17.5% HP and violet LED presented higher ΔE values than the group treated with 17.5% HP only. Thus, violet light did not influence bleaching efficacy when using 35% HP, but when used in conjunction with 17.5% HP, it increased the bleaching efficacy. Moreover, use of the violet LED only also prompted a bleaching effect, although it was less marked.

INTRODUCTION

The search for the perfect smile has led to considerable advances in cosmetic dentistry. A marked proportion of patients seeking to enhance the appearance of their smile choose dental bleaching, which can provide significant esthetic improvements in a relatively short time and at low cost.

In 1989, Haywood and Heymann proposed a home-based dental bleaching technique; it involved application of low-concentration carbamide peroxide-based products, which are used in acetate trays.[1] When properly applied and supervised by a dentist, this technique provides highly satisfactory esthetics.[2] However, to accelerate the results of bleaching, new techniques and products have been developed, including the adoption of more concentrated products for use in in-office procedures.

Teeth can be lightened due to the permeability of the dental structure to the active compounds present in bleaching gels.[3-5] Reactive oxygen species (ROS) permeate the tooth structure and oxidize the chromophore molecules that are present in dentin and that are the main cause of tooth pigmentation. Oxidation of these substances results in their breakdown, resulting in lighter shades of the treated teeth.[6,7]

To accelerate and increase the effectiveness of bleaching treatment, products with high concentrations of hydrogen peroxide have been developed and are used in conjunction with different light sources, such as halogen light, light-emitting diodes (LEDs), and laser.[8,9] The use of light is based on the hypothesis that light projected onto a bleaching product is absorbed and partially converted to heat, increasing the release of ROS and the efficacy of bleaching. In this way, the light source acts as a catalyst for the degradation of the bleaching product, facilitating its diffusion into the dental structure.[2,10] However, although this technique is preferred by many practitioners and patients, the use of highly concentrated peroxides may result in exaggerated penetration of peroxide into the pulp tissue, which may further lead to poor health of the pulp.[11,12]

Moreover, the action of ROS is not limited to oxidation of pigment agents, and reports of excessive concentrations of peroxide in the pulp chamber after application of bleaching gels to the dental enamel are not uncommon.[11-13] This may be associated with mild and transient hypersensitivity, until an inflammatory process that irreversibly affects the pulp develops,[14-18] which can lead to substrate morphologic changes[19,20] and decreased mitochondrial respiration rate of MDPC-23 odontoblast cells, according to in vitro studies.[19] In vivo studies in human teeth have reported a discreet disturbance in the odontoblastic layer of the pulp tissue of premolars after in-office bleaching treatment,[15] in addition to areas of coagulative necrosis in the lower incisors subjected to bleaching treatment.[18]

To ameliorate these side effects, some researchers have recently proposed dental bleaching using violet light (λ: 405-410 nm), with or without concomitant use of bleaching gels.[21] The wavelength range of violet light coincides with the absorption peak of pigment molecules, interacting selectively with them and causing their breakdown into smaller, colorless components.[21] However, because this technique has recently been introduced, studies on its actual bleaching effectiveness, as well as its possible side effects are lacking. Several methods have been introduced for analyzing chromatic changes,[22-27] but the Commission Internationale de l'Eclairage (International Commission on Illumination [CIE]) system (L*, a*, b*) is one of the most commonly used color analysis methods,[12,19,28] and surface color analysis is commonly performed in studies analyzing bleaching efficacy.[10-12,19,26,29]

Thus, there is a need to investigate the possibility of bleaching teeth by exposing them to lower amounts of oxidizing agents. Therefore, this study aimed to evaluate the *in vitro* effectiveness of different bleaching treatments, with or without use of a violet light source. The null hypothesis was that 1) the various bleaching treatments used with or without a violet light source would not vary in their effect on color changes and 2) use of violet light

Table 1: *Division of experimental groups according to whitening therapy adopted*

Groups	Light	Wavelength	Bleaching Product
No light			
GI	—	—	Placebo
GII			HP 35%
GIII			HP 17.5%
Violet LED			
GIV	Violet LED[a]	405-410 nm	Placebo
GV			HP 35%
GVI			HP 17.5%

[a] *Fotoclareador Bright Maxx Whitening, MMOptics Ltda.*

would not promote a color change when used without a bleaching gel.

METHODS AND MATERIALS

Experimental Design

This factorial randomized study included the following factors: three different bleaching gels (placebo [control], 35% hydrogen peroxide [35% HP], and 17.5% hydrogen peroxide [17.5% HP]); two different light conditions (no light and violet light); and four evaluation times (T0 [before bleaching]; T1 [seven days after the first bleaching session]; T2 [seven days after the second bleaching session]; T3 [seven days after the third bleaching session]).

A total of 90 bovine permanent incisors were randomly divided into six groups (n=15 per group), as shown in Table 1, for use in the study.

Specimen Preparation

Initially, 200 bovine teeth were obtained. All teeth were cleaned with periodontal curettes followed by prophylaxis with pumice and water using a Robinson brush (KG Sorensen Ind. E Com. Ltd, São Paulo, Brazil) at low speeds. To prevent bacterial proliferation, the cleaned teeth were stored in physiologic saline containing 0.1% thymol and kept in a refrigerator at approximately 4°C until the start of the experiment. Dentin and enamel discs measuring 5.7 mm in diameter were obtained with diamond burs used for glass cutting (Dinser Ferramentas Diamantadas Ltd, São Paulo, Brazil). Then, all the discs were subjected to wear by planing of the dentin surface by means of manual rotation on 400 and 600 granulating aluminum oxide polishing discs scales (T469-SF-Noton, Saint-Gobain Abrasives Ltd, São Paulo, Brazil). Discs were planed until they had a thickness of 3.7 mm (1.3 mm of enamel and 2.4 mm of dentin ± 0.2 mm), measured using digital calipers (model 500-144B, Mitutoyo Sul América Ltda, São Paulo, Brazil).

Selection and Pigmentation of Samples

After obtaining the discs, they were subjected to an initial reading of the value of L*, using the Visible Ultraviolet Reflection Spectrophotometer apparatus, Model UV-2450 (Shimadzu, Kyoto, Japan). The mean of all samples was determined. We selected 180 dental blocks with L* values closest to the mean value, in accordance with a 5% tolerance level. These 180 enamel/dentin disks were stored in Eppendorf tubes containing a 1-mL infusion of black tea (Matte Leão Tea, The Coca-Cola Company, São Paulo, Brazil) and were monitored for six days, with daily changes of infusion solution. After the pigment treatment, a second color measurement was performed, as described above. Thereafter, 90 pigmented dental blocks were selected for study according to the values of ΔE. After pigmentation with black tea, the specimens were kept in distilled water for six days to remove excess black tea, and the specimens were then subjected to prophylaxis with pumice and water to remove the surface stains.[30]

The described selection of the specimens was aimed at standardizing the initial color and the intensity of pigmentation of the dental blocks to facilitate standardization of the bleaching capacity of the specimens.

Bleaching Treatment and Irradiation

The 90 stained bovine teeth were randomly assigned to the following groups (n=15 per group): GI, placebo without light; GII, 35% HP without light; GIII, 17.5% HP without light; GIV, placebo with violet LED; GV, 35% HP with violet LED; and GVI, 17.5% HP with violet LED.

The bleaching gel was not applied to the GI and GIV groups, and thus these were considered as

Table 2: *Mean values (SD) of ΔE in the different experimental conditions and evaluation times*

Groups	T1	T2	T3
No light			
GI	01.30 (0.56) C a	01.52 (0.42) D a	01.26 (0.50) D a
GII	09.55 (1.44) A c	14.24 (1.77) A b	16.33 (1.55) A a
GIII	05.64 (1.77) B c	09.42 (1.64) B b	11.62 (1.73) B a
Violet light			
GIV	02.66 (1.85) C c	04.25 (1.36) C b	06.48 (1.54) C a
GV	10.24 (1.12) A b	14.10 (1.61) A b	16.10 (1.85) A a
GVI	06.56 (1.66) B c	11.59 (1.21) B b	14.32 (1.47) A a

Means followed by different letters represent significant difference according to statistical analysis ($p<0.05$). Different lowercase letters indicate statistical difference between columns in the same rows, and uppercase letters indicate statistical difference between rows within the same column. Three-way repeated-measures ANOVA and the Tukey test were performed.

control groups (Table 1). For the GII and GV groups, manipulation of the 35% HP bleaching gel (Whiteness HP Maxx, FGM Produtos Odontológicos, Santa Catarina, Brazil) was performed according to the manufacturer's recommendations, by mixing three drops of hydrogen peroxide with a drop of thickening agent. The gel (0.04 mL) was then applied to the enamel surface for 15 minutes. Subsequently, the bleaching gel was removed with cotton balls, and the surface of the enamel was washed with distilled water. Then, the product was reapplied twice more, totaling 45 minutes of contact between the bleaching gel and the dental enamel, in each session. Three such bleaching sessions were conducted, with seven-day intervals between the sessions (Table 1).

For the GIII and GVI groups, bleaching gel containing 17.5% HP was used. For this purpose, a 35% HP bleaching gel (Whiteness HP Maxx, FGM Produtos Odontológicos) was diluted with distilled water. Thus, two drops of the thickener and three drops of distilled water were added to three drops of hydrogen peroxide. The mode of application and the amount of the bleaching gel used were the same as described above (Table 1).

During the bleaching treatment, specimens in the GI, GII, and GIII groups were kept inside a dark chamber to avoid irradiation from any type of light source. The GIV, GV, and GVI groups were irradiated with violet light from an LED light source (Bright Maxx Whitening Light Source, MMOptics Ltda, São Paulo, Brazil), with a wavelength of 405-410 nm. Seven cycles of irradiation from the violet light source were performed at each exchange of the bleaching gel, totaling 21 cycles of irradiation at the end of each bleaching session. Each cycle involved one minute of irradiation followed by 30 seconds of rest (Table 1). At the end of each bleaching session, the teeth had thus undergone a total of 21 minutes of exposure to light.

Measurements of Color Change

The specimens were subjected to color measurement in a Visible Ultraviolet Reflection spectrophotometer*, Model UV-2450 (Shimadzu). The color measurements were made at the following time points: T0, before the bleaching treatment; T1, 7 days after the first bleaching session; T2, 7 days after the second bleaching session; and T3, 7 days after the third bleaching session.

The CIE system L*, a*, b* calculates the color distance between two points by means of the formula:

$$\Delta E = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{1/2}$$

Statistical Analysis

The software SigmaPlot version 12.0 (Systat, San Jose, CA, USA) was used for statistical analysis. A power analysis was performed to determine the sample size for each experiment group; a group size of n=15 provided a power of at least 0.826 at a significance level of 0.05. All the data passed the normality test. Three-way repeated-measures analysis of variance (ANOVA) and Tukey's *post hoc* tests were used for comparison between groups within time points.

RESULTS

Table 2 shows that all the groups that were treated with bleaching gels or violet light (GII, GIII, GIV, GV, and GVI) presented gradual and continuous color changes at all analysis time points (T1, T2, and

Table 3: *Mean values (SD) of ΔL in the different experimental conditions and evaluation times*

Groups	T1	T2	T3
No light			
GI	0.31 (0.79) B a	0.47 (0.86) C a	00.15 (0.96) B a
GII	9.33 (3.70) A b	14.61 (4.64) A a	15.07 (4.18) A a
GIII	6.43 (3.62) A b	10.84 (4.15) AB a	11.76 (3.79) A a
Violet light			
GIV	1.20 (2.00) B c	03.08 (2.00) C b	05.03 (2.12) B a
GV	08.51 (2.67) A b	12.11 (2.77) AB a	13.57 (2.39) A a
GVI	04.99 (1.83) AB b	08.74 (2.71) B ab	11.68 (2.73) A a

Means followed by different letters represent significant difference according to statistical analysis ($p<0.05$). Different lowercase letters indicate statistical difference between columns in the same rows, and uppercase letters indicate statistical difference between rows within the same column. Three-way repeated-measures ANOVA and the Tukey test were performed.

T3). In contrast, specimens from the GI group did not show significant differences throughout the study (Table 2). The comparison of the groups at a given time point showed that, at T1, the groups that received 35% HP treatment were similar (GII and GV), presenting greater chromatic alterations statistically significant than the other groups. Moreover, at T1, groups that received 17.5% HP gel, with or without the use of violet light (GIII and GVI), presented intermediate values, whereas the groups that received placebo gel had the lowest values of ΔE (GI and GIV). At T2, the results were similar to those described for T1; however, the action of violet light was evident in the GIV group, which even with the use of placebo gel presented chromatic alterations larger than those of GI, presenting a statistical difference. At the end of treatment (T3), the groups that received 35% HP gel, with or without light (GII and GV, respectively), and the group that received 17.5% HP with violet light (GVI) had similar values and presented greater chromatic changes than achieved with other treatments. As at T2, the values of GI and GIV specimens remained statistically different from each other.

Analysis of ΔL (Table 3) shows that GI specimens maintained luminosity throughout the study. The other experimental conditions yielded a gradual and continuous increase of ΔL values over time. At T1, the groups that received bleaching gels had similar values, and the ΔL value of GVI was similar to those of the groups that received the placebo product (GI and GIV). Treatments with more concentrated gels (GII and GV), and treatment with 17.5% HP without violet light (GIII) yielded highest ΔL values at T2. Treatments with placebo gel (GI and GIV) yielded lowest values. At T3, all treatments using bleaching gels (GII, GII, GV, and GVI) yielded similar values and were distinct from the placebo gel (GI) treatment.

Table 4 shows that, in all groups, Δa values were reduced at time T3. Comparisons between groups showed similar performance at all time points, with the highest values obtained with placebo gel treatment, followed by treatment with 17.5% HP gel,

Table 4: *Mean Values (SD) of Δa in the different experimental conditions and evaluation times*

Groups	T1	T2	T3
No light			
GI	0.66 (0.41) A a	0.75 (0.57) A a	0.47 (0.42) A b
GII	−1.65 (0.88) B a	−0.67 (1.03) B a	−1.79 (1.20) B b
GIII	-0.92 (0.95) C a	−0.74 (1.27) C a	−1.72 (0.85) C b
Violet light			
GIV	0.60 (0.35) A a	0.64 (0.77) A a	−0.23 (0.77) A b
GV	−1.66 (0.85) B a	−1.71 (0.76) B a	−2.64 (0.83) B b
GVI	−0.91 (0.76) C a	−1.01 (0.82) C a	−1.41 (0.86) C b

Means followed by different letters represent significant difference according to statistical analysis ($p<0.05$). Different lowercase letters indicate statistical difference between columns in the same rows, and uppercase letters indicate statistical difference between rows within the same column. Three-way repeated-measures ANOVA and the Tukey test were performed.

Table 5: *Mean values (SD) of Δb in the different experimental conditions and evaluation times*

Groups	T1	T2	T3
No light			
GI	0.67 (0.51) A a	0.28 (0.78) A a	0.08 (0.68) A a
GII	−2.08 (2.40) B a	−4.74 (2.21) BC a	−5.29 (2.99) C b
GIII	−1.02 (1.51) B a	−2.81 (1.34) AB b	−5.91 (1.29) BC c
Violet light			
GIV	0.69 (1.23) A a	−0.91 (2.20) AB a	−2.98 (2.19) AB b
GV	−5.75 (2.94) B a	−7.71 (3.30) C b	−9.43 (2.81) C c
GVI	−3.89 (2.26) B a	−6.46 (2.21) C b	−9.28 (2.06) C c

Means followed by different letters represent significant difference according to statistical analysis ($p<0.05$). Different lowercase letters indicate statistical difference between columns in the same rows, and uppercase letters indicate statistical difference between rows within the same column. Three-way repeated-measures ANOVA and the Tukey test were performed.

whereas treatment with 35% HP gel yielded the lowest values. The use of the violet light source did not influence these results.

Table 5 shows that Δb values were reduced for all groups throughout the course of treatment, with the exception of the GI values, which remained constant during the study. In a comparison between the groups, treatment with bleaching gels yielded results, and the lowest values of Δb were seen at T1. At T2, the groups that received bleaching gel along with violet light (GV and GVI), and the group that received 35% HP without violet light (GII) had the lowest, and similar, values. The group that received only violet light demonstrated similar values to those of both groups that received bleaching gels without violet light (GII and GIII) and that of the control group (GI). At T3, all the groups that received bleaching gel treatment (GII, GIII, GV, and GVI) demonstrated similar values, whereas the group that received only violet light irradiation (GIV) had a value similar to that of the control group (GI) and the group that received 17.5% HP gel without violet light (GIII).

DISCUSSION

Despite the numerous protocols published in the literature, bleaching therapies should be considered successful when they are capable of promoting marked chromatic alterations without causing significant side effects.[31]

Although in-office bleaching treatments can provide rapid chromatic changes, they also have significant side effects, as has been shown repeatedly.[11,12,29,32] In contrast, the at-home techniques, although also effective, present certain disadvantages such as the necessity of the daily use of the tray, slower chromatic alteration, and superficial changes in the dental enamel that could compromise the adhesion of restorative materials due to saturation of the dental tissues with residual oxygen generated by the degradation of bleaching products.[33]

Changing the color of teeth without subjecting them to the typical side effects of therapies based on topical application of peroxides may result in a shift in the esthetic dentistry paradigm and make safer treatments possible. The possibility of using violet light with or without bleaching gels has gained attention among clinicians but has been insufficiently studied.[21,34] Lago and others reported a clinical case in which this type of light was used for dental bleaching and observed that this technique was effective, changing the tooth color from A3 to A1 in only three bleaching sessions.[34] The bleaching sessions were performed using a method similar to that used in the present study, that is, the bleaching sessions lasted 30 minutes, with 20 cycles involving one minute of irradiation with 30-second intervals between the cycles.

The present study evaluated in-office dental bleaching protocol alternatives to identify an approach that could maintain bleaching efficacy while reducing side effects, using a violet LED light source for the partial or total breakdown of chromogenic molecules.[21] We found that the violet light did not influence the efficacy of the bleaching treatments involving 35% HP, possibly because the high availability of peroxides in the dental tissue masked the action of the violet light. Thus, the two groups that received this gel demonstrated the most significant values of chromatic alteration. Consequently, the first null hypothesis of this study was rejected.

The use of more concentrated bleaching substances favors faster and more intense chromatic changes early during treatment, although the results of the different protocols tended to equalize over longer analysis periods. There have been several reports of

chromatic saturation after three bleaching sessions[12]; however, in the present study that used artificially pigmented teeth, the various treatments still resulted in significant differences even after the third bleaching session. This may be related to pigmentation of the substrate, which allowed values of ΔE higher than 16 to be obtained; this hardly occurs in routine clinical situations, in a naturally stained substrate presents ΔE values between 5 and 8.[35]

In agreement with our findings, de Oliveira Duque and others compared the performance of a 10% HP-based bleaching gel with that of the traditional 35% HP treatment.[36] They observed that the less-concentrated gel was effective as a bleaching therapy; nevertheless, they emphasized that to reach the desired bleaching effect, it was necessary to increase the number of sessions. The authors also observed that the premolar teeth reached saturation of color change after the fifth session, whereas the central incisors saturated in the second session when 35% HP was used. When using an experimental gel based on 10% HP, they observed that the premolars did not reach color saturation even after six sessions of 15-minute applications, whereas in the specimens that simulated the central incisors, saturation was obtained in the fifth bleaching session.

Violet light enhances the efficacy of treatment with a 17.5% HP gel. It is possible that the light emission band of violet light (405-410 nm), which coincides with the absorption peak of pigmented molecules, results in selective interaction with and breakdown of these molecules into smaller and colorless components. These molecules may attain molecular stability when they react with the ROS released by the bleaching product.

The results obtained in the group treated with violet light alone, without any peroxide product, should also be highlighted. This treatment provided a significant chromatic alteration, as compared with that in the control group (G1), at times T2 and T3, negating the second null hypothesis of this study. Although this group presented a less marked bleaching effect as compared with the treatments using gels, the alteration would be clinically perceptible, because they surpassed a value of 3.3, which is considered as visually detectable.[37] Therefore, this new technology is promising, and may be feasible for clinical application, enabling bleaching treatment with reduced exposure to peroxides.

When analyzing the coordinates separately, a significant increase in the values of L* and a decrease in the values of b* were observed. On the other hand, the values of a* varied little and were independent of the treatment used. These findings are in agreement with results reported by Kiomars and others, who emphasized that color analysis in bleaching treatments should consider mainly the former parameters (L* and b*).[38] It should be noted that L* identifies an increase in the brightness of the surface of the specimen, whereas b* represents the color change. In the present study, the decrease in this parameter indicated that there was a decrease in yellowish tones, with more predominant bluish tones in the dental enamel. In this study, in which pigmentation was achieved using black tea, we observed that a* also showed some differences, indicating that the specimens showed reduced reddish coloration and obtained more greenish tones with treatment.

The color change observed in the group that received only the violet light probably occurred due to the breakdown of pigment molecules by violet light, because pigment remnants were not observed visually in the storage medium, which could have suggested leaching of the pigmentation produced by tea. According to Zanin, the pigment molecules of the dental structure are photoreceptive, and therefore highly reactive to light.[21] Violet light wavelengths (405-410 nm) coincide with the absorption peak of the pigment molecules present in dental structures, which may result in light activation of the molecules, and their breakdown into smaller, colorless compounds.[21]

Panhoca and others studied the efficacy of violet light in pigmented teeth and obtained results similar to those of the present study.[39] However, the authors did not compare the results of light use with the traditional technique involving bleaching gel, emphasizing only that the use of violet light was effective for tooth bleaching. In the present study, it was observed that the isolated light yielded results that were significantly different from those obtained with conventional techniques and increased number of sessions or use in conjunction with bleaching gels were required to obtain a desirable bleaching effect.

The present study had some limitations. First, this was an in vitro experimental model using artificially pigmented bovine teeth. Nevertheless, this model has been used extensively in dental bleaching studies, yielding results that were relevant to those observed clinically.[40] We here used a new technique, seeking to improve the safety of tooth whitening procedures, and needed to standardize conditions and samples, which we could not achieve under

clinical conditions. On the other hand, it is not clear whether our results can be generalized to other pigmentation agents, or whether chromatic stability would remain over longer periods than those analyzed. Because the technology is new, it will be necessary to study the possible adverse effects thereof on adhesion, the mechanical properties of dentin, as well as possible biological effects. Nevertheless, the results of this study revealed that bleaching can be achieved with reduced, or even without, exposure to oxidizing agents, forming the basis for further development of an oxidizing agent-free tooth bleaching process.

CONCLUSION

In this study, we demonstrated that techniques using 35% HP had the greatest bleaching effect, regardless of whether violet light was used. The use of violet light in association with 17.5% HP gel enhanced the bleaching effect. Moreover, violet light alone can also whiten teeth, but to a lesser extent than when used in conjunction with HP-base bleaching gels.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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