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THE EFFECT OF AN IN-OFFICE BLEACHING AGENT WITH TWO DIFFERENT CONCENTRATIONS OF TITANIUM DIOXIDE NANOPARTICLES ON THE BIAXIAL FLEXURAL STRENGTH, SURFACE MICROHARDNESS, AND ROUGHNESS OF DIRECT AND INDIRECT RESTORATIVE COMPOSITES

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ABSTRACT

This study evaluated the impact of in-office bleaching treatments incorporating titanium dioxide nanoparticles (TiO_2NPs) on the mechanical properties of three universal nanohybrid composite materials: Grandio Direct, Grandio Indirect, and Admira Fusion. The investigation focused on flexural strength, surface roughness, and microhardness after bleaching with Opalescence Boost (40% hydrogen peroxide) alone and in combination with 5% or 10% TiO_2NPs. A total of 360 discs, 120 composite discs for each carried on test, (n=10 per group) were prepared and subjected to four bleaching protocols: no treatment (control), Opalescence Boost only, and Opalescence Boost combined with either 5% or 10% TiO_2NPs. After treatment, samples were stored in artificial saliva before testing.

Statistical analysis using two-way ANOVA revealed significant interactions between composite type and bleaching treatment for biaxial flexural strength and surface roughness ($p<0.001$). For microhardness, only main effects were significant. Grandio composites (direct and indirect) exhibited significantly higher hardness than Admira Fusion. The addition of 5% TiO_2NPs (Group 1) preserved surface roughness and maintained a bleaching effect comparable to the bleaching agent alone (Group 2), whereas 10% TiO_2NPs (Group 3) offered no additional benefit.

In conclusion, incorporating 5 wt% TiO_2NPs into an in-office bleaching agent provided a comparable whitening result to conventional bleaching without adversely affecting surface texture or mechanical properties. However, increasing the TiO_2NP concentration to 10 wt% did not further enhance outcomes and may not be clinically beneficial. These findings suggest that lower concentrations of TiO_2NPs can improve the safety profile of bleaching treatments on dental composites.

KEYWORD: nanotechnology, Titanium dioxide nanoparticles, office bleaching, biaxial flexural strength

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INTRODUCTION

Tooth bleaching is a common method for altering tooth color, but the chemicals used hydrogen peroxide can potentially harm both tooth structure and restorative materials.[1] Dentists often use direct and indirect resin composites restorations due to their conservative preparation, esthetic appearance and resistance to wear.[2]

Bleaching agents like hydrogen peroxide (HP) can negatively affect the organic and inorganic structures of composite materials. These changes may impact flexural strength and material hardness, which are vital for withstanding occlusal forces, [3] as well as surface roughness, as rougher surfaces can lead to increased plaque accumulation. The use of bleaching agents can make composite surfaces less smooth, facilitating bacterial adherence and resulting in issues such as restoration discoloration, secondary cavities, and gum irritation. [4, 5] these bleaching agents can induce structural alterations in these restorative materials, potentially undermining their mechanical and physical properties and resulting in early restoration failure.[6, 7]

The surface alterations of restorations after bleaching are mainly affected by the type of restorative material used, along with factors like the pH level, concentration of the bleaching agents, duration of exposure, and the specific ingredients in the bleaching products. These variables have contributed to the inconsistent results reported in earlier studies on this subject. [7, 8] In routine clinical practice, tooth-colored restorations are often present in teeth scheduled for bleaching.

Recently, Nanotechnology has been applied in dentistry to improve the mechanical and physical properties of materials, helping to minimize adverse effects. Titanium oxide (TiO_2), a substance frequently used in white industrial pigments products, has also been incorporated into tooth whitening treatments. This material is cost-effective due to its natural abundance and is considered safe for humans because of its chemical stability.[4, 9, 10]

The use of titanium oxides nanoparticles (TiO_2 NPs) as catalysts or oxidation reaction accelerators can enhance bleaching effects, allowing for more effective results in less time and with reduced level of HP. Additionally, the trend of using nanoparticles in dentistry, thanks to their biocompatibility and antimicrobial properties, suggests that TiO_2NPs could further improve the efficiency of bleaching treatments.[11]

Given the emergence of new direct and indirect composites with different matrices and manufacturing with the limited research on the effects of an in-office bleaching treatments supported with different concentrations of TiO_2NPs to bleach materials under investigation, this study aims to assess the bi-axial flexural strength, surface roughness, and microhardness of composites subjected to an in-office chemically activated bleaching treatments with two different concentrations of TiO_2NPs. "The hypothesis is that these physico-mechanical properties will change when the composites are exposed to bleaching agents."

MATERIALS AND METHODS:

Three types of universal nano-hybrid composites were evaluated in the current study, all in A2 shade, along with the Opalescence Boost bleaching agent and TiO_2 nanoparticles, as outlined in the summary presented in Table 1.

Sample size:

A power analysis was conducted to ensure sufficient statistical power for testing the null hypothesis, which proposed no significant difference in flexural strength among the groups. With a significance level (α) of 0.05 and a power of 95% ($\beta = 0.05$), and using an effect size (f) of 0.780 derived from a previous study [12], The total sample size needed was calculated to be 60 specimens. This calculation was conducted using R statistical software, version 4.4.1 for Windows. [13]

TABLE (1) Materials

Material name and company	Chemical makeup	Lot number
Grandio® Direct composite (mathacrylate based) (Voco, Cuxhaven, Germany)	Functionalized nanoparticles (20–40 nm in size) are incorporated into a resin matrix composed of GMA, TEGDMA, and glass ceramic, with a total filler loading of 87%.	2148114
Admira fusion® Direct composite (Ormocer- based) (Voco, Cuxhaven, Germany)	Resin Ormocer matrix with nano fillers of aluminum, titanium, and zirconium alkoxides, along with glass ceramics (filler size: 40 nm to 1 µm). filler loading 84%.	2146606
Grandio® blocs CAD/CAM indirect. (Voco, Cuxhaven, Germany)	A polymer matrix composed of 14% UDMA and DMA, (0.5-3 µm glass ceramic particles) and nanoparticles of SiO2 (0-40nm), filler loading 89%.	2050504
Opalescence Boost 40% Ultradent, INC, USA.	One barrel contains 1.1% sodium fluoride and 3% potassium nitrate. This is mixed with another barrel that contains hydrogen peroxide, resulting in a final mixture with a hydrogen peroxide concentration of 32%.	BW3Z1
Titanium dioxide Nano particles. Nanostream company. Alex. Egypt.	It comes in a powdered form (32 nm) that should be mixed with distilled water to create a suitable mixture for application to the teeth and restorations.	NS0021

Study design:

A total of 360 discs made from the tested composite materials will be allocated into 12 experimental groups, each consisting of 10 samples (n = 10). These groups are organized based on two primary independent variables:

- **Factor 1:** Type of composite material (3 main categories)
- **Factor 2:** Type of bleaching procedure (4 groups):

a) Control group (no bleaching)

b) Bleaching with 40% Opalescence Boost gel only

c) Bleaching with 40% Opalescence Boost gel combined with 5% TiO_2 NPs.

d) Bleaching with 40% Opalescence Boost gel combined with 10% TiO_2 NPs.

To participate in three tests as part of this study, with each test involving 120 discs.

Specimen's preparation

In this study, 240 disc-shaped samples (n=40 each) of two composite materials, Admira Fusion® and Grandio®, were prepared using a 2 mm thick, 14 mm diameter split Teflon mold. Each mold was placed on a glass slide and slightly overfilled with composite. A Mylar strip and a second glass slide were used to level the surface and remove excess material. The specimens were then light-cured for 20 seconds using an LED curing unit (Ivoclar Vivadent, 1400 mW/cm^2), with light intensity monitored by a radiometer to ensure consistency. Post-curing, the samples were checked for voids, then wet-polished with 600–1200 grit silicon carbide papers to simulate clinical finishing. Surfaces were further cleaned in an ultrasonic bath. All steps were carried out by a single operator to reduce variability.

For the indirect CAD/CAM Grandio® blocs, 120 specimens were cut using a precision saw (Isomet 4000, Buehler, USA) to match the thickness of direct composite discs. All specimens underwent the same finishing and polishing procedures, then were dried and stored in 100% humidity at 37 °C for 24 hours before bleaching.

Bleaching procedures and samples grouping:

Group 0: Control Group (CG) Ten specimens in each the 12 experimental groups in this study were be control group, and subjected the performed test before bleaching agent application.

Group 1: Ten specimens in each the 12 experimental groups in this study were subjected to bleaching Opalescence Boost agent only. It is chemically activated, in- office bleaching agent consisting of HP gel with a 40% concentration. When mixed, it achieves a concentration of 32%. A 2mm-thick layer of gel was directly applied to the polished surfaces of the specimens. It was then removed using suction without rinsing, preparing the surfaces for a new application. This process was repeated three times, with the gel left on for 15 minutes each time, totaling 45 minutes of bleaching gel application. [4, 14]

Group 2: Ten specimens in each the 12 experimental groups in this study were subjected to bleaching Opalescence Boost agent mixed with 5% TiO_2NPs. To prepare the mixture, 0.25 mg of TiO_2NPs powder was weighed using a digital scale and mixed with 10 ml of distilled water to form a suspension. This was then blended with 2 mm of bleaching gel. The resulting mixture was applied to the polished surfaces of the specimens using a brush and left for 15 minutes. The procedure was repeated three times.[4]

Group 3: Ten specimens in each the 12 experimental groups in this study were subjected to Opalescence Boost bleaching agent mixed with 10% TiO_2NP concentration. To prepare the mixture, A 0.5 mg of TiO_2NPs powder was weighed and mixed with 10 ml of distilled water. This was then blended with 2 mm of the bleaching gel. The resulting mixture was applied to the polished surfaces of the specimens, similar to the method used in Group 2.

Specimens from all groups were kept in tightly sealed containers filled with artificial saliva after all bleaching procedures to mimic the oral environment until the tests were conducted.

Biaxial flexural strength test BFS:

FS) test was conducted following ISO 6872:2015 standards. Each specimen was supported by three stainless steel balls (3.2 mm diameter) arranged 120° apart on a 10 mm diameter circle. A 1.6 mm diameter piston, connected to an Instron 3345 universal testing machine, applied a load at a rate of 1 mm/min to the center of each specimen until fracture occurred. The fracture force was recorded, and BFS values were calculated using Blue Hill Universal software (Instron, UK).

Surface roughness evaluation using stylus contact profilometer

The mean surface roughness (Ra) of each specimen was determined using a contact-mode surface profilometer (TR 220 Surface Roughness Tester, Pittsburgh, USA). (figures 1 &2). Measurements were taken with a 0.8 mm cutoff and a 40 µm range. Each specimen was measured three times, and the mean Ra was calculated for both the control and bleached groups based on the sample grouping.

Vickers's hardness

Microhardness testing was conducted using a Vickers microhardness tester. Each composite specimen was subjected to a load of 200g for a dwell time of 10 seconds before (control group) and after bleaching agents' application according to samples grouping of this study. The Vickers hardness number was automatically calculated by the software of the microhardness tester. Three indentations were made for each specimen, and their averages were taken, with five means calculated for each composite specimen for subsequent statistical analysis.

TR 220 Surface Roughness Tester, Pittsburgh, USA

Statistical analysis:

Numerical data were reported as means with 95% confidence intervals, standard deviations, and minimum and maximum values. Normality and homogeneity of variances were assessed using distribution plots, Shapiro-Wilk's test, and Levine's test. After checking assumptions, Box-Cox transformations were applied due to violations in normality and variance for biaxial strength and roughness data. Two-way ANOVA and Tukey's post hoc test were used, with false discovery rate (FDR) adjustment for multiple comparisons. Significance was set at $p < 0.05$.[13]

RESULTS

Descriptive statistics for biaxial flexural strength and roughness data before transformation are presented in Tables (2) and (3). Further analysis was conducted on the data after the Box-Cox transformation. Descriptive statistics for hardness data are presented in Table (4).

The two-way ANOVA results presented in Table (5) showed that for biaxial strength and roughness data, there was a significant interaction between both tested variables ($p<0.001$). However, for hardness, they showed only the main effects to be statistically significant. For material type, they showed Grandio samples, either indirect (100.34±20.66) or direct (94.25±20.30), to have significantly higher hardness than Admira Fusion (77.12±14.48) ($p<0.001$). Additionally, for bleaching treatments, the results showed G1 (95.70±21.83) to have significantly higher G2 (82.44±19.27) ($p=0.036$). G0 (91.48±21.19) and G3 (92.66±20.29) were not significantly different from other treatments.

As shown in Table 6, comparisons of simple effects for biaxial flexural strength revealed statistically significant differences among the tested materials across all bleaching treatments ($p < 0.001$). In the control group (G0), both Grandio variants had significantly higher strength than Admira ($p < 0.001$). In G1 and G3, all pairwise comparisons were significant, with indirect Grandio showing the highest strength, followed by direct Grandio, and Admira the lowest. In G2, all comparisons remained significant, but the order shifted slightly: direct Grandio had the highest strength, followed by indirect Grandio, and Admira again had the lowest. Significant differences in biaxial flexural strength were found among materials across all bleaching treatments. Grandio consistently outperformed Admira, with strength rankings varying slightly between direct and indirect versions depending on the group.

For Admira samples, there was no significant difference between different bleaching treatments (p=0.206). For direct Grandio, the difference was statistically significant, with G0 having a significantly higher value than G1 and G2 (p<0.001). Additionally, G2 had a significantly higher value than G1 (p<0.001). For indirect Grandio, G0 and G3 had significantly higher values than G1 and G2 (p<0.001).

For roughness, there was a significant difference between tested materials within different treatments (p<0.001). For G0, post hoc pairwise comparisons showed direct Grandio and Admira had significantly higher values than indirect Grandio (p<0.001). For G1, Admira had significantly higher values than both Grandio groups (p<0.001). For G2, direct Grandio had a significantly higher value than Admira and indirect Grandio (p<0.001). For G3, all comparisons were statistically significant, with Admira having the highest value, followed by direct Grandio and then indirect Grandio.

For Admira samples, all pairwise comparisons were statistically significant (p<0.001). For direct Grandio, G0 and G2 had significantly higher values than G1 and G3 (p<0.001). For indirect Grandio, G2 had a significantly higher value than G0 and G3. Additionally, G1 and G2 had a significantly higher value than G3 (p<0.001).

TABLE (2) Descriptive statistics for biaxial flexural strength (non-transformed data).

Material	Treatment	Mean	95% Confidence interval		SD	Min.	Max.
			Lower	Upper			
Admira Fusion	G0	170.20	148.51	191.89	34.99	120.00	220.00
	G1	166.21	143.09	189.34	37.31	97.00	200.00
	G2	145.50	123.91	167.09	34.83	126.00	229.49
	G3	142.42	124.16	160.67	29.45	109.00	220.00
Grandio direct	G0	517.38	446.62	588.13	114.16	290.00	700.00
	G1	266.50	229.37	303.63	59.91	210.00	400.00
	G2	373.00	314.15	431.86	94.96	253.00	525.00
	G3	443.37	378.74	507.99	104.27	255.00	558.00
Grandio indirect	G0	540.00	470.18	609.82	112.64	370.00	750.00
	G1	326.00	283.64	368.36	68.35	220.00	450.00
	G2	285.14	249.98	320.30	56.73	240.00	420.00
	G3	575.27	490.17	660.36	137.30	420.00	900.00

TABLE (3) Descriptive statistics for roughness (non-transformed data).

Material	Treatment	Mean	95% Confidence interval		SD	Min.	Max.
			Lower	Upper			
Admira Fusion	G0	0.22	0.19	0.25	0.05	0.14	0.26
	G1	0.27	0.24	0.31	0.06	0.17	0.40
	G2	0.15	0.13	0.17	0.03	0.12	0.23
	G3	0.33	0.28	0.38	0.07	0.17	0.39
Grandio direct	G0	0.25	0.22	0.29	0.06	0.19	0.34
	G1	0.15	0.13	0.17	0.03	0.13	0.24
	G2	0.25	0.22	0.28	0.05	0.19	0.30
	G3	0.15	0.13	0.17	0.03	0.13	0.24
Grandio indirect	G0	0.14	0.12	0.16	0.03	0.10	0.19
	G1	0.17	0.15	0.20	0.04	0.13	0.25
	G2	0.18	0.16	0.21	0.04	0.09	0.25
	G3	0.11	0.10	0.12	0.02	0.10	0.15

TABLE (4) Descriptive statistics for hardness.

Material	Treatment	Mean	95% Confidence interval		SD	Min.	Max.
			Lower	Upper			
Admira Fusion	G0	79.63	72.01	87.25	12.30	50.00	99.00
	G1	79.64	69.56	89.72	16.26	69.60	120.00
	G2	68.67	59.84	77.50	14.24	58.80	100.00
	G3	80.54	72.13	88.95	13.56	68.90	110.00
Grandio direct	G0	88.18	77.45	98.91	17.31	50.00	120.00
	G1	106.29	92.31	120.27	22.56	60.00	150.00
	G2	90.38	78.52	102.24	19.13	55.00	120.00
	G3	92.16	79.96	104.36	19.68	60.00	130.00
Grandio indirect	G0	106.64	91.80	121.48	23.94	90.00	170.00
	G1	101.16	90.10	112.22	17.85	60.00	130.00
	G2	88.28	77.37	99.19	17.60	60.00	130.00
	G3	105.29	92.66	117.92	20.38	60.00	121.60

TABLE (5) Two-way ANOVA.

Measurement	Source	Sum of squares	df	Mean square	*f-value*	*p-value*
Biaxial strength	**Material**	8.54	2	4.27	**85.69**	**<0.001***
	Treatment	0.23	3	0.08	**1.55**	**0.206**
	Material * treatment	2.70	6	0.45	**9.02**	**<0.001***
Roughness	**Material**	0.09	2	0.04	**19.21**	**<0.001***
	Treatment	0.18	3	0.06	**27.00**	**<0.001***
	Material * treatment	0.35	6	0.06	**25.66**	**<0.001***
Hardness	**Material**	11598.60	2	5799.30	**17.48**	**<0.001***
	Treatment	2926.25	3	975.42	**2.94**	**0.036***
	Material * treatment	2145.84	6	357.64	**1.08**	**0.380**

df degree of freedom, * significant ($p<0.05$).

TABLE (6) Simple effects comparisons.

Measurements	Treatment	(Mean±SD)			*f-value*	*p-value*
		Admira Fusion	Grandio direct	Grandio indirect		
BFS (MPa)	**G0**	5.12±0.21^{Ba}	6.22±0.25^{Aa}	6.27±0.20^{Aa}	**85.69**	**<0.001***
	G1	5.09±0.26^{Ca}	5.56±0.21^{Bc}	5.77±0.21^{Ab}	**24.63**	**<0.001***
	G2	4.96±0.21^{Ca}	5.89±0.27^{Ab}	5.64±0.18^{Bb}	**46.51**	**<0.001***
	G3	4.94±0.18^{Ca}	6.07±0.26^{Bab}	6.33±0.21^{Aa}	**109.08**	**<0.001***
	f-value	**1.55**	**16.01**	**24.77**		
	p-value	**0.206**	**<0.001***	**<0.001***		
Roughness	**G0**	0.46±0.05^{Ac}	0.50±0.05^{Aa}	0.37±0.04^{Bbc}	**19.21**	**<0.001***
	G1	0.52±0.05^{Ab}	0.39±0.04^{Bb}	0.41±0.04^{Bab}	**21.05**	**<0.001***
	G2	0.39±0.04^{Bd}	0.50±0.05^{Aa}	0.42±0.05^{Ba}	**13.50**	**<0.001***
	G3	0.57±0.07^{Aa}	0.39±0.04^{Bb}	0.33±0.02^{Cc}	**67.97**	**<0.001***
	f-value	**27.00**	**17.67**	**7.26**		
	p-value	**<0.001***	**<0.001***	**<0.001***		

Values with **different upper and lowercase superscripts** ***within the*** **same horizontal row and vertical column,** ***respectively, are significantly different, * significant ($p<0.05$).***

DISCUSSION

Teeth bleaching is a commonly used technique in cosmetic dentistry and is generally recognized as an effective clinical procedure. [5, 7, 8] while it is considered relatively safe in terms of systemic effects, recent controversies have emerged regarding its impact on restorative materials. It is essential to evaluate how whitening agents affect these materials, as any negative changes in their physical and mechanical properties could have significant clinical implications, potentially influencing the success and durability of dental restorations.[15, 16]

Vickers׳s hardness is a method for assessing surface properties, specifically the material's resistance to plastic deformation, indentation, and scratching. This measurement provides insights into how a material may perform when used in posterior restorations. Factors such as the volume and weight fraction of fillers, as well as their size, can influence the hardness of resin composites. [17] in this study for Vickers Hardness test, tested materials showed only the main effects to be statistically significant. For material type, they showed Grandio samples, either indirect (100.34±20.66) or direct (94.25±20.30), to have significantly higher surface hardness than Admira Fusion (77.12±14.48) ($p<0.001$). This might indicate that Grandio materials may offer superior mechanical properties, which is crucial for their longevity and effectiveness in dental applications due to high filler loading which is 89%, 86% for direct and indirect Grandio composites respectively while Admira fusion filler loading is 84%.

For bleaching treatments, the results showed G1 (95.70±21.83) to have significantly higher than G2 (82.44±19.27) ($p=0.036$). G0 (91.48±21.19) and G3 (92.66±20.29) were not significantly different from other treatments. This suggests that the specific bleaching treatment applied can influence the hardness of the dental materials. Conversely, other bleaching treatment as TiO_2NP could not influence the hardness of the dental materials indicating that these treatments may not adversely affect the hardness of the materials.

These results align with previous studies showing that bleaching treatments did not significantly affect the microhardness of conventional composite resins.[5, 18, 19] Specifically, composites bleached with carbamide peroxide CP or HP maintained their microhardness values. However, other research has reported a reduction in microhardness following bleaching procedures.[20, 21, 22] These conflicting findings are likely due to variations in bleaching protocols such as application time and duration as well as differences in bleaching agents and the types of restorative materials used.[23]

The three-point bending test is considered an appropriate method for evaluating the flexural strength of a composite, as it typically results in a lower standard deviation, reduced coefficient of variation, and a more straightforward crack distribution. [12, 24] When evaluating the BFS, the direct and indirect Grandio composites showed higher values than admira fusion composite regardless of the bleaching treatment (control group). In this study, several factors can contribute to the observed differences in this performance; higher filler content again often leads to improved load-bearing capabilities,[25,26] Different fillers can interact differently with the resin matrix, affecting the overall material performance, Matrix properties and resin formulation; contribute to better stress distribution under load, enhancing the flexural strength.[27,28,29]

The bleaching treatment showed a statistically significant effect on BFS (Table 6). This finding aligns with previous research by Feiz et al. (2016) [12] and Yu et al. (2011) [22], who also reported significant changes in flexural strength following bleaching treatment. However, it contrasts with the findings reported by Helen et al. (2020)[5], who observed that no significant impact of bleaching on BFS. These discrepancies are likely due to variations in bleaching methods, analytical procedures, and the types of composite materials used across studies.

The findings from the of simple effects comparisons illustrated in Table (6) provide valuable insights into the impact of different bleaching treatments on BFS of various materials. The bleaching treatments (G1, G2, and G3) appear to have differential effects on the materials. The significant variations in strength indicate that some treatments may compromise the integrity of the materials more than others, possibly due to the chemical composition and concentration of the bleaching agents and their interactions with the restorative materials.

The absence of significant differences in Admira samples across different treatments ($p=0.206$) suggests that this material may possess a more stable structure or better resistance to the effects of bleaching agents. This suggests that Admira may maintain its strength regardless of bleaching treatment. Admira Fusion is a composite material that does not contain methacrylate. It is an organically modified ceramic featuring tightly integrated organic–inorganic networks. This innovative material combines the surface properties of silicone, the toughness of organic polymers, the hardness of ceramics, and excellent thermal stability. [30, 31]

The significant differences observed in direct and indirect Grandio strength values highlight how bleaching treatments can affect its performance. The higher values in G0 indicate that untreated or minimally treated samples perform better, potentially due to the bleaching agent Opalescence Boost alone or with adding TiO_2 NP causing microstructural changes or degradation in the material, but for not sure adversely affect their integrity.

The long-term polishability of dental resin composites are crucial for the long-term durability and success of restorations, directly impacting the frequency of dental restoration replacements or repairs. The surface texture of resin composites can change as a result of their intrinsic material characteristics as well as external influences like pigment absorption and the type of surface finishing techniques as well as bleaching procedures planned to teeth. [5, 30]

In this study for roughness evaluation test, control group showed direct Grandio and Admira had higher roughness values significantly than Grandio indirect blocs ($p<0.001$). This could be explained by (CAD/CAM) technology is becoming more common for composite restorations. The aim is to improve their mechanical strength, biocompatibility and physical characteristics of the materials. Research shows that the production methods for resin-based CAD/CAM blocs enhance material consistency, minimize defects, and increase reliability.[30, 32, 33]

Meanwhile there was a significant difference between tested materials within different bleaching treatments ($p<0.001$). It was only possible to verify, changes on the superficial smoothness of the composite resins, in which all of them presented a roughness increase after the bleaching treatments. The deterioration of resin composite surfaces is related to the pH level and acidity of their environment, aligning with many earlier studies that demonstrate how prolonged exposure to acidic conditions can gradually change the physical properties of resin composites.[5, 30]

The verification of changes in the superficial smoothness of composite resins was generally possible, revealing that all tested resins exhibited an increase in roughness following bleaching treatments (Table 5 and 6). Similar findings have been reported in other studies that assessed the impact of bleaching on composite resin roughness. For instance, Rodrigues et al. (2011) [34] observed alterations when using CP 10% and 35% and HP 35%. Wongpraparatana et al. (2018) [35] also confirmed that all composites tested showed increased superficial roughness after treatment with CP (10%) and HP (40%).

Additionally, Mendes et al. (2012) [36] reported significant changes in the roughness of nanoparticle and nanohybrid composite resins treated with 10% and 35% HP. Also, Renan et al. (2020) [12] and

Markovic et al (2014) [39] noted that the surface roughness of composite resins is mainly affected by filler particles protruding from the resin matrix. Prolonged and repeated exposure to carbamide peroxide can degrade the resin matrix, while the inorganic filler particles stay unaffected even in acidic environments. This degradation may cause the dislodgement of filler particles, and studies have shown that certain composite resins are more susceptible to various bleaching agents, resulting in changes in surface roughness. Additionally, resins with lower filler content and a higher proportion of organic matrix, such as microparticulate resins, are particularly prone to erosion from bleaching agents. This erosion exposes previously embedded particles and creates porosities, potentially leading to cracks and increased surface roughness.

Other studies contradict these results, reporting no negative impact on surface smoothness when evaluating the roughness of nanoparticle composites. This inconsistency may be attributed to variations in the composition of the materials tested, as well as differences in polymerization time, different application procedures and exposure time of the bleaching agents. [37, 38]

The addition of TiO_2NPs as a catalyst to bleaching agents is currently being explored as a safer alternative non-toxic colorant with no known adverse effects on human dental tissues.[4, 40, 41] This environmental mineral can be processed into fine particles. [40] Previous studies have utilized TiO_2 as a catalyst in oxidative reactions due to its strong reducible properties. The adsorption of O_2 leads to the formation of peroxides, which accounts for the high catalytic activity of TiO_2. [4, 40, 41] The current study presents findings on the changes in surface roughness of tested restorative materials when using Opalescence Boost bleaching agent alone and when it is combined with two different concentrations of TiO_2NP (5% and 10%).

This contradicts with previous studies that stated that incorporation of TiO_2NPs into HP gel can lower the necessary concentration of HP while enhancing the safety of the bleaching process [4, 42] These studies demonstrated that bleaching agents with reduced HP concentrations and added TiO_2 can be equally or even more effective than traditional 38% HP formulations, with the added advantage of reducing the risk of tooth sensitivity.

Our study suggests that peroxide-based materials may play a role in the surface roughness and mechanical properties of methacrylate and non-methacrylate composites as well as indirect CAD/CAM composites restorations. Additionally, the impact of incorporating TiO_2 NPs into dental bleaching varies with concentration. The clinical implications and importance of these concentration changes need further investigation. Longitudinal clinical studies and clinical follow-up evaluations should be conducted to evaluate the long-term performance of these restorative materials after aesthetic procedures involving bleaching agents.

CONCLUSIONS

Clinical Implications

- The superior flexural strength of indirect Grandio blocs suggests they may be more suitable for load-bearing applications in dentistry, such as posterior restorations. Their performance under bleaching treatments also indicates they may be more resilient in aesthetic procedures where bleaching is common.
- The nanohybrid ormocer Admira Fusion direct composite did not demonstrate superior surface integrity compared to the conventional methacrylate-based nanohybrid composite.
- In this study, the addition of TiO2NPs at a 5 wt.% concentration to an in-office bleaching agent nearly demonstrated a similar bleaching effect when compared to the agent used alone, without compromising the surface texture. However, increasing the TiO_2 nanoparticle concentration to 10 wt.% did not yield any benefits, neither in

terms of surface roughness nor in enhancing the action of the peroxides.

- The findings underscore the complex interactions between bleaching treatments and different restorative materials. A thorough understanding of these effects is crucial for optimizing treatment protocols and ensuring the longevity and effectiveness of dental restorations.

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