UNIVERSIDADE ESTADUAL DE PONTA GROSSA
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA – DOUTORADO
ÁREA DE CONCENTRAÇÃO: DENTÍSTICA RESTAURADORA

TAYNARA DE SOUZA CARNEIRO KVIATKOSKI

DIFERENTES ESTRATÉGIAS DE USO DO PERÓXIDO DE HIDROGÊNIO A 6% NO CLAREAMENTO DENTAL: ESTUDOS *IN VITRO* E ENSAIOS CLÍNICOS

PONTA GROSSA
2025

TAYNARA DE SOUZA CARNEIRO KVIATKOSKI

DIFERENTES ESTRATÉGIAS DE USO DO PERÓXIDO DE HIDROGÊNIO A 6% NO CLAREAMENTO DENTAL: ESTUDOS *IN VITRO* E ENSAIOS CLÍNICOS

Tese apresentada como pré-requisito para obtenção do título de Doutora em Odontologia na Universidade Estadual de Ponta Grossa, no curso de Doutorado em Odontologia – Área de Concentração Dentística Restauradora. Linha de Pesquisa: Pesquisa Clínica em Odontologia.
No âmbito do Acordo de Cotutela firmado entre a Universidade Estadual de Ponta Grossa e a Universidad Rey Juan Carlos (Espanha).

Orientadores: Dr. Alessandro Dourado Loguercio e Dra. Laura Ceballos García.

PONTA GROSSA
2025

Kviatkoski, Taynara de Souza Carneiro

K97 Diferentes estratégias de uso do peróxido de hidrogênio a 6% no clareamento dental: estudos *in vitro* e ensaios clínicos / Taynara de Souza Carneiro Kviatkoski. Ponta Grossa, 2025.

135 f.

Tese (Doutorado em Odontologia - Área de Concentração: Dentística Restauradora), Universidade Estadual de Ponta Grossa. No âmbito do Acordo de Cotutela firmado entre a Universidade Estadual de Ponta Grossa e a Universidad Rey Juan Carlos (Espanha).

Orientador: Prof. Dr. Alessandro Loguercio.
Coorientadora: Profa. Dra. Laura Ceballos García.

1. Clareamento dental. 2. Ensaios clínicos. 3. Peróxido - hidrogênio. 4. Odontologia. 5. Sensibilidade dental. I. Loguercio, Alessandro. II. Ceballos

CDD: 617.6

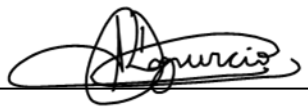
Ficha catalográfica elaborada por Maria Luzia Fernandes Bertholino dos Santos- CRB9/986

TAYNARA DE SOUZA CARNEIRO KVIATKOSKI

DIFERENTES ESTRATÉGIAS DE USO DO PERÓXIDO DE HIDROGÊNIO A 6% NO CLAREAMENTO DENTAL: ESTUDOS IN VITRO E ENSAIOS CLÍNICOS

Tese apresentada ao Programa de Pós-graduação Stricto sensu em Odontologia da Universidade Estadual de Ponta Grossa, como requisito parcial à obtenção do título de Doutora em Odontologia, área de concentração em Dentística Restauradora, linha de pesquisa de Pesquisa Clínica em Odontologia.
No âmbito do Acordo de Cotutela firmado entre a Universidade Estadual de Ponta Grossa e a Universidad Rey Juan Carlos (Espanha).

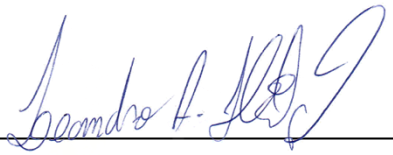
Ponta Grossa, 27 de fevereiro de 2025.



Prof. Dr. Alessandro Dourado Loguercio
Universidade Estadual de Ponta Grossa

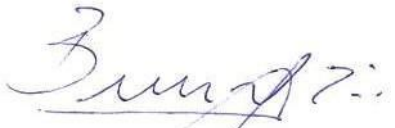
Profª. Drª. Maria Victoria Fuentes Fuentes
Universidad Rey Juan Carlos

Profª. Drª. Vanessa Cavalli Gobbo
Universidade Estadual de Campinas



Prof. Dr. Leandro Augusto Hilgert

Universidade de Brasília



Prof. Dr. André Luiz Fraga Briso

Universidade Estadual Paulista

Dedico este trabalho aos meus pais, Claudinei (in memoriam) e Jocilene, ao meu marido Murilo e ao meu irmão Otavio, pois sem eles este trabalho e muitos dos meus sonhos não se realizariam.

AGRADECIMENTOS

À Deus* e a *Nossa Senhora Aparecida pelo dom da vida e por estarem sempre presentes em meu caminho, guiando-me e dando-me forças para fazer as escolhas certas. Sou imensamente grata pelas graças alcançadas e pelas bênçãos e oportunidades recebidas ao longo desses anos.

Aos meus pais, Claudinei (in memoriam) e Jocilene, agradeço profundamente pelo amor incondicional, pela educação, cuidado e incentivo. Agradeço por terem abdicado de seus próprios sonhos para investir nos meus, sempre com compreensão e apoio.

Ao meu marido, Murilo, sou grata por seu apoio constante e por nunca permitir que eu desanimasse. Sua presença como meu companheiro de vida, seu cuidado e compreensão foram fundamentais em todos os momentos, obrigada por me acompanhar para outro país e viver o doutorado ao meu lado.

Ao meu irmão, Otavio, agradeço por ser meu companheiro incansável pelos momentos de descontração e animação, por acreditar em mim e por toda a ajuda e apoio ao longo dos anos.

À minha família, especialmente aos meus avós Joacy (in memoriam) e Soel, minhas avós Marlene e Leovir, meus tios Fernando, Jociane, Junior e Claudiomira, e meus primos Fernanda, Ricardo, Luís Gustavo e Lavínia, sou grata por sempre acreditarem em mim, cuidando e apoiando.

Ao meu orientador, Prof. Dr. Alessandro Loguercio, cuja admiração é imensa, agradeço pela confiança depositada em mim, por lá no início apostar em mim sem me conhecer, pelo incentivo e pela imensa inteligência, paciência e dedicação com que ensinou. Sua inspiração foi crucial, e uma agradecimento especial pela busca do convênio de cotutela que eu ainda nem acredito que conseguimos. Obrigada por tudo!

À minha orientadora, Prof.ª Dr.ª Laura Ceballos, também admiro profundamente, agradeço por confiar em mim e me receber tão bem na Espanha. Sou grata pela oportunidade, pelo cuidado, pelo incentivo e pela paciência, por todos os ensinamentos, além da incansável busca pelo convênio de cotutela, foi incrível estar com vocês!

Aos Professores Dr. Rodrigo Zuk e Dr.ª Fabiana Coppla, agradeço por me acompanharem desde a graduação, por acreditarem e apostarem em mim, por todo apoio e gentileza constante sempre que precisei.

Ao grupo de pesquisa Bleaching&Bond, em especial aos professores Alessandro e Alessandra que não tenho como descrever o quanto sou grata, foi uma honra poder fazer parte do grupo e aprender tanto com vocês, minha eterna gratidão e admiração.

Aos meus amigos, Michel, Michael, Romina, Helo, Alejandra, Gabi, Deisy, Laryssa, Elisama, Isabela, Mariah, João, Leonardo, Emanuel, Nayara, Roberta e Gabriel. Foi incrível a amizade que construímos nestes anos, o apoio de cada um de vocês, obrigada pelos dias alegres, de muita risada, pelos conhecimentos compartilhados. Não tenho palavras para descrever o quanto vocês foram essenciais nesta caminhada. Vou sentir muita falta de estarmos sempre juntos, obrigada por tudo! Agradeço também a todos meus amigos de longa data por sempre estarem presentes e me apoiarem em tudo, vocês são incríveis!

À empresa FGM, pela doação dos materiais que possibilitaram o desenvolvimento da maioria dos trabalhos.

A todos os meus professores, tanto da pós-graduação, graduação, quanto aqueles que me acompanham desde pequena, agradeço pelos conhecimentos compartilhados.

Ao Programa de Pós-Graduação em Odontologia da UEPG e a todos os funcionários da UEPG, sou grata pelo suporte, apoio e dedicação nos momentos necessários, grata de coração por ter feito parte desta instituição.

À equipe da Universidad Rey Juan Carlos, em especial ao Bruno que tanto me ajudou desde muito antes da minha viagem, a professora Victoria, Daniel, Olga, Nuria, Isabel, Belén, Cristina, agradeço a recepção calorosa, por todas as conversas, ensinamentos, foi um prazer estar com vocês, espero que possamos nos encontrar mais vezes!

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES), agradeço pelo incentivo à pesquisa e pela bolsa de estudos durante mestrado e doutorado.

A todos que contribuíram direta ou indiretamente para a realização desta tese, expresso meus mais sinceros agradecimentos. Cada gesto de apoio, palavra de incentivo e ajuda prática foi fundamental para tornar este trabalho uma realidade. Agradeço de coração por todo o suporte e colaboração ao longo desta jornada.

“Seja você quem for, seja qual for a posição social que você tenha na vida, a mais alta ou a mais baixa, tenha sempre como meta muita força, muita determinação e sempre faça tudo com muito amor e com muita fé em Deus, que um dia você chega lá. De alguma maneira você chega lá.”
(Ayrton Senna)

DADOS CURRICULARES

TAYNARA DE SOUZA CARNEIRO KVIATKOSKI

NASCIMENTO 09.02.1996	Palmeira, Paraná - Brasil
FILIAÇÃO	Claudinei Carneiro Jocilene Aparecida de Souza Carneiro
2014 - 2018	Graduação em Odontologia Centro de Ensino Superior dos Campos Gerais (CESCAGE), Ponta Grossa – PR, Brasil.
2016 - 2016	Curso de Aperfeiçoamento em Dentística Restauradora. Centro de Ensino Superior dos Campos Gerais (CESCAGE), Ponta Grossa – PR, Brasil.
2018-2018	Curso de Aperfeiçoamento em Harmonização Orofacial. Centro de Ensino Superior dos Campos Gerais (CESCAGE), Ponta Grossa – PR, Brasil.
2019 - 2021	Especialização em Docência em Ciências da Saúde. Centro de Ensino Superior Dom Alberto, Santa Cruz do Sul – RS, Brasil.
2020 - 2022	Curso de Especialização em Dentística Restauradora. Associação Brasileira de Odontologia (ABO). Ponta Grossa, PR – Brasil.

2020 – 2022	Curso de Pós-Graduação em Odontologia. Área de Concentração em Dentística Restauradora. Nível Mestrado. Universidade Estadual de Ponta Grossa. Ponta Grossa – PR, Brasil.
2022 – em andamento	Curso de Pós-Graduação em Odontologia. Área de Concentração em Dentística Restauradora. Nível Doutorado. Universidade Estadual de Ponta Grossa. Ponta Grossa – PR, Brasil.
2022 – em andamento	Curso de Pós-Graduação em Odontologia. Área de Concentração em Ciências da Saúde. Nível Doutorado. Universidad Rey Juan Carlos. Móstoles, Madrid, Espanha.

RESUMO

Carneiro, T. S. **Diferentes estratégias de uso do peróxido de hidrogênio a 6% no clareamento dental: estudos *in vitro* e ensaios clínicos.** Orientadores: Alessandro Dourado Loguercio e Laura Ceballos García. Ponta Grossa, 2025. Tese (Doutorado em Odontologia) - Universidade Estadual de Ponta Grossa; Universidad Rey Juan Carlos, Ponta Grossa, 2025.

O uso de baixas concentrações para o clareamento dental está se difundindo cada vez mais. No mercado, existem diferentes estratégias disponíveis para o uso de peróxido de hidrogênio (PH) a 6% no clareamento dental. No entanto, ainda faltam estudos que demonstrem quais das alternativas de aplicação mais recentes são as mais eficazes. Portanto, o objetivo desta tese de doutorado foi avaliar *in vitro* e clinicamente o clareamento com PH a 6%, e para isso foram realizados 2 estudos *in vitro* e 2 estudos clínicos. Para o primeiro estudo, foram comparados vernizes clareadores com PH a 6% em diferentes tempos de aplicação. Foi um estudo *in vitro*, com 90 pré-molares (n=10), e foi determinada a penetração de PH na câmara pulpar (µg/mL) e a mudança de cor (ΔE_{ab}, ΔE_{00}, ΔWI_D). No segundo estudo, foi comparado o efeito do uso de diferentes ponteiras de aplicação, convencionais (sem pincel) e com pincel, com produtos que continham PH a baixa concentração (6%) e alta (35%). Nele foi avaliado *in vitro*, com 40 pré-molares (n=8), a penetração de PH na câmara pulpar (µg/mL), a mudança de cor (ΔE_{ab}, ΔE_{00}, ΔWI_D) e a quantidade de gel clareador usado (g). No terceiro estudo foi analisado clinicamente o clareamento de consultório obtido com PH a 6% em adolescentes utilizando as duas ponteiras, sem pincel e com pincel, as mesmas que foram avaliadas no segundo estudo. O desenho foi um ensaio clínico randomizado, de boca-dividida e duplo-cego, com 60 voluntários (n=60; 120 hemiarcadas), foi avaliada a eficácia da mudança de cor (ΔE_{ab}, ΔE_{00}, ΔWI_D), o risco e a intensidade (EVA; 0-10) de sensibilidade dental (SD) e a autopercepção estética (EEO). O quarto, e último estudo, focou em determinar clinicamente se havia irritação gengival (IG) com a aplicação ou não da barreira gengival no clareamento com PH a 6% em adolescentes. Foi realizado um ensaio clínico randomizado, de boca-dividida e duplo-cego, com 60 voluntários (n=60; 120 hemiarcadas). Foi avaliado o risco e a intensidade (EVA; 0-10) de IG, a eficácia da mudança de cor (ΔE_{ab}, ΔE_{00}, ΔWI_D) e o impacto da condição bucal na qualidade de vida (OHIP-14). Os resultados mostraram-se promissores com o uso de PH a 6%. Por mais que tenha sido detectado algumas diferenças entre as diferentes formas de apresentação, foi observada eficácia clareadora, baixa penetração na câmara pulpar, baixo risco e intensidade de SD e IG. Apenas alguns vernizes clareadores não apresentaram um clareamento clinicamente aceitável. No primeiro estudo clínico, foi evidenciado que a ponteira com pincel deve ser considerada a primeira opção para o clareamento de consultório, pois, junto com os resultados do estudo *in vitro*, apresentou menor quantidade de gel clareador usado, reduziu a penetração de PH na câmara pulpar e, consequentemente, apresentou menor SD. No segundo estudo clínico, foi comprovado que o passo de aplicação da barreira gengival pode ser dispensado para o clareamento de consultório com PH a 6%, pois não teve efeito na IG. Por fim, o clareamento de consultório com PH a 6% teve um impacto positivo na qualidade de vida do paciente e produziu uma melhora na autopercepção estética.

Palavras-chave: Clareamento Dental; Permeabilidade Dental; Sensibilidade Dental; *In vitro*; Peróxido de Hidrogênio; Clareadores Dentários; Ensaio Clínico; Adolescente.

RESUMEN

Carneiro, T. S. **Diferentes estrategias de uso del peróxido de hidrógeno al 6% en el blanqueamiento dental: estudios *in vitro* y ensayos clínicos**. Directores: Alessandro Dourado Loguercio y Laura Ceballos García. Ponta Grossa, 2025. Tesis (Doctorado en Odontología) - Universidad Estatal de Ponta Grossa; Universidad Rey Juan Carlos, Ponta Grossa, 2025.

Disminuir la concentración de peróxido de hidrógeno parece ser la forma más viable de reducir los altos índices de sensibilidad dental observados durante el blanqueamiento dental. Algunos estudios demuestran que concentraciones alrededor del 6% serían ideales, ya que producen menor agresión al metabolismo y morfología celular. Así, el peróxido de hidrógeno al 6% se ha convertido en la concentración máxima permitida en algunos lugares del mundo. En la Unión Europea, por ejemplo, la concentración máxima permitida es del 6%, independientemente de la forma de aplicación. Además, la literatura sugiere que la cantidad de gel blanqueador aplicada en la superficie también puede estar relacionada con la sensibilidad dental. En respuesta a estas consideraciones, los fabricantes han desarrollado diferentes presentaciones de agentes blanqueadores con peróxido de hidrógeno al 6%, buscando reducir los efectos adversos, sin comprometer la eficacia del blanqueamiento. Entre las presentaciones comerciales disponibles, destacan los geles de peróxido de hidrógeno al 6% para blanqueamiento en consultorio. Estos geles blanqueadores están disponibles comercialmente junto con una punta. La punta convencional sin pincel es la más utilizada, pero entre sus variaciones está la de aplicador tipo pincel, que esparce el gel por toda la superficie para obtener una capa más delgada. Esta modificación se ha producido para dar respuesta a la indicación de aplicar una capa fina de gel, ya que se ha descrito que cuanto menor sea el espesor de la capa utilizada, menor será la cantidad de gel blanqueador, menor difusión y menor grado de sensibilidad dental. Otra presentación disponible de peróxido de hidrógeno al 6% es para blanqueamiento domiciliario junto con férulas. Sin embargo, también se comercializa como un "esmalte de uñas" o barniz, lo que permite que el procedimiento lo realice el propio paciente. El barniz blanqueador se aplica directamente sobre los dientes en una capa fina gracias a su pincel aplicador. Esta aplicación directa aumenta la superficie de contacto del peróxido de hidrógeno con los dientes, eliminando la necesidad de una férula personalizada, lo que facilita el día a día tanto del clínico como del paciente.

En cuanto al otro efecto adverso descrito para el blanqueamiento, la irritación gingival, ésta puede manifestarse como una molestia leve, o incluso puede llegar a provocar quemaduras y ulceraciones debido al contacto directo de los tejidos blandos con el gel blanqueador. La exacerbación de la irritación gingival está relacionada con el tiempo y la concentración del gel en contacto con el área gingival. En el caso del blanqueamiento en clínica, dado que se utilizan altas concentraciones de peróxido de hidrógeno, es esencial el uso de barreras fotopolimerizables para proteger los tejidos blandos, y la irritación gingival está directamente relacionada con cómo el operador realiza el proceso. El clínico debe tener un dominio total de la técnica; la no fotopolimerización correcta de la barrera gingival o un descuido en su aplicación pueden causar este efecto adverso. No obstante, a pesar de las bajas concentraciones utilizadas en los geles de blanqueamiento en clínica, como ocurre con el peróxido de hidrógeno al 6%, las barreras gingivales se siguen recomendando.

Sin embargo, no se utilizan en las técnicas de blanqueamiento domiciliario con productos que alcanzan incluso un 10% de peróxido de hidrógeno, independientemente del método de aplicación, ya que pocos pacientes reportaron irritación gingival. Por lo tanto, parece que no tiene mucho sentido la colocación de una barrera gingival cuando se utiliza gel blanqueador en bajas concentraciones para el blanqueamiento en clínica. Cabe señalar que eliminar el paso de aplicación y fotopolimerización de la barrera gingival puede hacer el procedimiento clínico más rápido, más práctico y, por lo tanto, más económico.

Los pacientes jóvenes expresan una mayor preferencia por dientes más blancos que los pacientes mayores. Actualmente, la técnica más recomendada para los pacientes jóvenes es el blanqueamiento domiciliario debido a la baja concentración. Es importante destacar que, cuando se realiza, algunos adolescentes describen que las férulas les resultaron muy fáciles de usar, aunque algunos encontraron difícil retirar el exceso de gel, por lo que la técnica en consultorio, si se realiza con baja concentración (peróxido de hidrógeno al 6%), podría ser una buena opción para estos pacientes. Sin embargo, hasta el momento, no tenemos conocimiento de estudios que hayan comparado las diferentes presentaciones más recientes desarrolladas por los fabricantes para el blanqueamiento dental con peróxido de hidrógeno al 6%, como son los barnices blanqueadores para aplicar en casa o la presentación para uso en clínica.Por lo tanto, el objetivo de este trabajo fue evaluar diferentes estrategias para el uso del peróxido de hidrógeno al 6% en el blanqueamiento dental. Se evaluaron *in vitro* y clínicamente el blanqueamiento con peróxido de hidrógeno al 6%, y para ello se realizaron 2 estudios *in vitro* y 2 estudios clínicos. **El primer estudio** tuvo como objetivo evaluar la penetración del peróxido de hidrógeno en la cámara pulpar y el cambio de color de diferentes barnices blanqueadores en bajas concentraciones utilizados para el blanqueamiento en casa. Se utilizaron noventa premolares sanos, distribuidos aleatoriamente en nueve grupos (n=10) según el barniz blanqueador (*PL*, PolaLuminate; *VS*, VivaStyle Paint On Plus; *CA*, Cavex Bite&White Whitening Pen y; *AW*, Aligner-White) y el tiempo de aplicación (10 y 30 minutos), además de un grupo de control (sin blanqueamiento). La penetración del peróxido de hidrógeno fue evaluada mediante espectroscopía UV-Vis. Para evaluar el cambio de color (ΔE_{ab}, ΔE_{00}, ΔWI_D) se utilizó un espectrofotómetro digital ($\alpha = 0.05$). El grupo *AW* a los 10 minutos y el grupo de control mostraron una penetración de peróxido de hidrógeno similar y menor en la cámara pulpar en comparación con los otros grupos ($p = 0.003$). Aumentar el tiempo de aplicación a 30 minutos elevó la cantidad de peróxido de hidrógeno dentro de la cámara pulpar para todos los grupos ($p = 0.003$), excepto para *PL* ($p > 0.05$). Cuando se aplicó durante 30 minutos, todos los barnices blanqueadores mostraron mayor cambio de color (ΔWI_D) en comparación con los 10 minutos ($p = 0.04$). Para todos los barnices blanqueadores evaluados, *PolaLuminate* aplicado durante 30 minutos mostró una menor penetración en la cámara pulpar y mayores efectos blanqueadores. **En el segundo estudio**, el objetivo fue evaluar si el método de aplicación (punta con pincel o punta sin pincel) y la concentración de peróxido de hidrógeno (peróxido de hidrógeno) (6% o 35% auto-mezclado) del gel de blanqueamiento en clínica influyen en la penetración del peróxido de hidrógeno en la cámara pulpar, el cambio de color y la cantidad de gel blanqueador utilizado. Cuarenta premolares sanos fueron divididos aleatoriamente en los siguientes cinco grupos (n=8): sin tratamiento; peróxido de hidrógeno al 6% utilizando una punta con pincel, peróxido de hidrógeno al 6% utilizando una punta sin pincel, peróxido de hidrógeno al

35% utilizando una punta con pincel, y peróxido de hidrógeno al 35% utilizando una punta sin pincel. Después del tratamiento, la concentración de peróxido de hidrógeno (µg/mL) en la cámara pulpar fue determinada usando espectrofotometría UV-Vis. El cambio de color (ΔE_{ab}, ΔE_{00} y ΔWI_D) fue evaluado usando un espectrofotómetro digital. La cantidad de gel utilizado (g) en cada grupo fue medida usando una balanza analítica de precisión. Los datos de cada prueba fueron sometidos a pruebas paramétricas (α=0.05). El uso de la punta con pincel dio lugar a que penetrara una menor cantidad de peróxido de hidrógeno dentro de la cámara pulpar y a un menor gasto de gel en comparación con la punta sin pincel, independientemente de la concentración de peróxido de hidrógeno (p<0.05). Sin embargo, en cuanto a la punta utilizada, aunque no se observó una diferencia significativa cuando se utilizó peróxido de hidrógeno al 35% (p>0.05), se observó un mayor efecto blanqueador cuando el peróxido de hidrógeno al 6% se aplicó sin pincel en comparación con la punta con pincel (p<0.05). El uso de una punta con pincel, independientemente de la concentración de gel blanqueador en consultorio (6% o 35% auto mezclado), produjo una menor penetración y que se gastara un menor volumen de gel en comparación con una punta sin pincel. Sin embargo, el efecto blanqueador dependía de la concentración de peróxido de hidrógeno utilizada. **El tercer estudio**, se centró en los geles de peróxido de hidrógeno al 6% para uso en clínica se realizó un ensayo clínico aleatorizado, a boca partida y doble ciego que evaluó la eficacia del blanqueamiento en clínica con peróxido de hidrógeno al 6% en adolescentes utilizando diferentes puntas de aplicación, así como la sensibilidad dental y la autopercepción estética. Sesenta participantes fueron aleatorizados, según el gel blanqueador de automezclado al 6% se aplicará sin pincel o con pincel. El blanqueamiento en clínica se realizó en 3 sesiones de 50 minutos. El cambio de color fue evaluado usando un espectrofotómetro digital (ΔE_{ab}, ΔE_{00} y ΔWI_D) y una guía de color (ΔSGU), el riesgo absoluto y la intensidad de la sensibilidad dental con una escala visual analógica, y la autopercepción estética con la escala estética oral (α=0.05). Los grupos lograron un blanqueamiento similar independientemente de la punta de aplicación (p>0.05). Sin embargo, solo para ΔWI_D, se observó una diferencia media significativa (MD) en la tercera semana (MD 2.3; IC 95% 1.2 a 3.3; p<0.001) y al mes (MD 1.6; IC 95% 0.6 a 2.6; p<0.03) a favor de la punta sin pincel. En cuanto a la sensibilidad dental, el 45% del grupo sin pincel y el 33% del grupo con pincel reportaron sensibilidad dental (razón de probabilidades 0.61; IC 95% 0.29 a 1.28; p<0.02), con una baja intensidad de sensibilidad dental (MD 0.05; IC 95% -0.06 a 0.17; p>0.36). Todos los pacientes reportaron una mejora en la autopercepción estética después del blanqueamiento (MD -1.3; IC 95% -1.8 a -0.9; p<0.001). Independientemente de la punta utilizada, el blanqueamiento con peróxido de hidrógeno al 6% logró una eficacia de blanqueamiento y mejoró la autopercepción estética. Sin embargo, se observó un menor riesgo de sensibilidad dental en la aplicación con pincel. **En el cuarto estudio**, se analizó si era necesaria la colocación de una barrera gingival cuando se realiza un blanqueamiento en clínica utilizando peróxido de hidrógeno al 6%. Este ensayo clínico a doble ciego, a boca partida y aleatorizado evaluó la irritación gingival del blanqueamiento en clínica utilizando peróxido de hidrógeno al 6% con y sin barrera gingival en adolescentes, así como el cambio de color y el impacto de la condición oral en la calidad de vida. Un total de 60 participantes fueron aleatorizados en cuanto a qué lado recibiría o no la barrera gingival. El blanqueamiento en clínica se realizó durante 50 minutos con peróxido de hidrógeno al 6% en tres sesiones. El riesgo

absoluto y la intensidad de la irritación gingival fueron evaluados con una escala visual analógica. El cambio de color fue evaluado utilizando un espectrofotómetro digital y guías de color. El impacto de la condición oral en la calidad de vida fue evaluado utilizando la versión brasileña del Perfil de Impacto de Salud Oral (α=0.05). La proporción de pacientes que presentaron irritación gingival para el grupo "con barrera" fue del 31.6% y para el grupo "sin barrera", del 30% (p=1.0). Existía equivalencia para los grupos evaluados en cuanto a la intensidad de la irritación gingival (p<0.01). Se detectó un cambio de color sin diferencias estadísticas (p>0.29). Hubo un impacto significativo de la condición oral en la calidad de vida después del blanqueamiento (p<0.001). Por tanto, el uso o no de la barrera gingival para el blanqueamiento en clínica con peróxido de hidrógeno al 6% fue equivalente en cuanto a irritación gingival, así como en la eficacia del blanqueamiento, con una mejora en el impacto de la condición oral en la calidad de vida.
Todo lo anteriormente expuesto nos lleva a concluir que se encontraron resultados prometedores con el uso de peróxido de hidrógeno al 6%. Aunque se detectaron algunas diferencias entre las diferentes formas de presentación, se observó eficacia blanqueadora, baja penetración en la cámara pulpar, bajo riesgo e intensidad de sensibilidad dental e irritación gingival. Solo en el caso de algunos barnices blanqueadores no se observó un blanqueamiento clínicamente aceptable. En el primer estudio clínico, se evidenció que la punta con pincel debe considerarse la primera opción para el blanqueamiento en clínica, ya que, junto con los resultados del estudio *in vitro*, presentó menor consumo de gel blanqueador, redujo la penetración de peróxido de hidrógeno en la cámara pulpar y, en consecuencia, presentó menor sensibilidad dental. En el segundo estudio clínico, se comprobó que se puede obviar el paso de colocación de la barrera gingival para el blanqueamiento con peróxido de hidrógeno al 6% en clínica al no tener efecto en la irritación gingival. Por último, el blanqueamiento en clínica con peróxido de hidrógeno al 6% tuvo una repercusión positiva en la calidad de vida del paciente y produjo una mejora en la autopercepción estética.

Palabras clave: Blanqueamiento Dental; Permeabilidad Dental; Sensibilidad Dental; In Vitro; Peróxido de Hidrógeno; Agentes Blanqueadores Dentales; Ensayo Clínico; Adolescente.

ABSTRACT

Carneiro, T. S. **Different strategies for using 6% hydrogen peroxide in dental bleaching: *in vitro* studies and clinical trials**. Advisors: Alessandro Dourado Loguercio and Laura Ceballos García. Ponta Grossa, 2025. Thesis (Doctorate in Dentistry) – State University of Ponta Grossa; Rey Juan Carlos University, Ponta Grossa, 2025.

The use of low concentrations for tooth bleaching is becoming increasingly widespread. On the market, there are different strategies available for the use of 6% hydrogen peroxide (HP) in tooth bleaching. However, there is still a lack of studies that demonstrate which of the most recent application alternatives are the most effective. Therefore, the aim of this doctoral thesis was to evaluate *in vitro* and clinical bleaching with 6% HP. To this end, 2 *in vitro* studies and 2 clinical studies were carried out. The first study compared 6% PH bleaching varnishes at different application times. This was an *in vitro* study with 90 premolars (n=10) and the penetration of PH into the pulp chamber (µg/mL) and the color change (ΔE_{ab}, ΔE_{00}, ΔWI_D) were determined. The second study compared the effect of using different application tips, conventional (without a brush) and with a brush, with products containing PH at low (6%) and high (35%) concentrations. In it, the penetration of PH into the pulp chamber (µg/mL), the color change (ΔE_{ab}, ΔE_{00}, ΔWI_D) and the amount of bleaching gel used (g) were evaluated in vitro with 40 premolars (n=8). The third study clinically analyzed in-office bleaching obtained with 6% PH in adolescents using the two tips, without a brush and with a brush, the same as those evaluated in the second study. The design was a randomized, split-mouth, double-blind clinical trial with 60 volunteers (n=60; 120 hemiarcades). The efficacy of the color change (ΔE_{ab}, ΔE_{00}, ΔWI_D), the risk and intensity (VAS; 0-10) of tooth sensitivity (TS) and aesthetic self-perception (OES) were evaluated. The fourth and final study focused on clinically determining whether there was gingival irritation (GI) with or without the application of the gingival barrier in 6% PH bleaching in adolescents. A randomized, split-mouth, double-blind clinical trial was carried out with 60 volunteers (n=60; 120 hemiarcades). The risk and intensity (VAS; 0-10) of GI, the effectiveness of color change (ΔE_{ab}, ΔE_{00}, ΔWI_D) and the impact of oral condition on quality of life (OHIP-14) were evaluated. The results were promising with the use of 6% PH. Although some differences were detected between the different forms of presentation, bleaching efficacy, low penetration into the pulp chamber, low risk and intensity of TS and GI were observed. Only a few bleaching varnishes did not show clinically acceptable bleaching. In the first clinical study, it was shown that the brush tip should be considered the first option for in-office bleaching because, in conjunction with the results of the *in vitro* study, it showed a lower amount of bleaching gel used, reduced PH penetration into the pulp chamber and, consequently, showed lower TS. The second clinical study showed that the step of applying the gingival barrier can be dispensed with for in-office bleaching with 6% PH, as it had no effect on GI. Finally, in-office bleaching with 6% PH had a positive impact on the patient's quality of life and produced an improvement in aesthetic self-perception.

Keywords: Tooth Bleaching; Dental Permeability; Dental Sensitivity; In Vitro; Hydrogen Peroxide; Dental Bleaching Agents; Clinical Trial; Adolescent.

LISTA DE FIGURAS

LISTA DE TABELAS

LISTA DE ABREVIATURAS E SIGLAS

a*	*Red-green axis* (Eixo vermelho-verde)
b*	*Blue-yellow axis* (Eixo azul-amarelo)
CI	*Confidence interval* (Intervalo de confiança)
CONSORT	*Consolidated Standards of Reporting Trials* (Declaração Consolidada de Normas de Relato de Ensaios Clínicos)
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
SD	*Standard Deviation* (Desvio Padrão)
ΔE	*Color variation* (Variação de cor)
ΔE_{ab}	*Color variation* $CIEL_{ab}$ (Variação de cor $CIEL_{ab}$)
ΔE_{00}	*Color variation* $CIEDE_{00}$ (Variação de cor $CIEDE_{00}$)
ΔWI_D	*Color variation Whiteness Index* (Variação de cor Índice de brancura)
SGU	*Shade Guide Units* (Unidades na Escala VITA)
ΔSGU	*Color variation Shade Guide Units* (Variação de cor de Unidades na Escala VITA)
cm	*Centimeters* (Centímetro)
L*	*Luminosity* (Luminosidade)
min	*Minute* (Minuto)
mm	*Millimete*r (Milímetro)
n	*Sample number* (Número amostral)
PC	Peróxido de Carbamida
CP	*Carbamide Peroxide* (Peróxido de Carbamida)
PH	Peróxido de Hidrogênio
HP	*Hydrogen Peroxide* (Peróxido de Hidrogênio)
pH	Potencial Hidrogeniônico
IG	Irritação Gengival
GI	*Gingival Irritation* (Irritação Gengival)
SD	Sensibilidade Dental
TS	*Tooth Sensitivity* (Sensibilidade Dental)
UEPG	Universidade Estadual de Ponta Grossa
URJC	Universidad Rey Juan Carlos
WI_D	*Whiteness Index for Dentistry* (Índice de Brancura para Odontologia)
EVA	Escala Visual Analógica
VAS	*Visual Analogic Scale* (Escala Visual Analógica)
EEO	Escala Estética Orofacial
OES	*Orofacial Esthetic Scale* (Escala Estética Orofacial)
OHIP	*Oral Health Impact Profile* (Perfil de Impacto na Saúde Oral)
vs	*Versus*

LISTA DE SÍMBOLOS

=	Igual
±	Mais ou menos
α	Alfa
<	Menor
>	Maior
%	Porcentagem
p	Valor da significância estatística
®	Marca Registrada
™	Trade Mark
µ	micro

SUMÁRIO

1 INTRODUÇÃO

A realização de procedimentos estéticos, como o clareamento dental, não apenas evidencia um aumento significativo na autoconfiança do paciente, mas também contribui para a melhoria do bem-estar emocional [1; 2]. Esse impacto positivo tem impulsionado a crescente popularidade desse procedimento [3; 4]. Considerando que 86% dos participantes de um estudo escolheram submeter-se à técnica de clareamento dental por iniciativa própria, e não por sugestão do dentista, evidencia-se a notável autonomia dos indivíduos na busca por este tratamento estético [5]. Notadamente, quando o assunto são dentes pigmentados, o clareamento dental é considerado como a primeira opção estética de tratamento [4], sendo considerado seguro e economicamente viável [6].

Em 1884, o peróxido de hidrogênio (PH), o qual é o agente mais empregado no clareamento dental, foi primeiramente relatado [7], entretanto, a introdução da técnica de clareamento, advém de um ortodontista chamado Bill Klusmier em 1968 [8; 9]. Nesse contexto, Bill Klusmier utilizou um antisséptico contendo peróxido de carbamida (PC) a 10%, um precursor do PH, originalmente destinado à reparação gengival, em um posicionador ortodôntico. Como resultado secundário, observou que os dentes dos pacientes se tornaram mais claros [8; 9]. No entanto, o procedimento só alcançou a popularidade a partir de 1989, após a publicação de Haywood e Heymann, que descreveram a técnica de clareamento caseiro realizada durante a noite, denominada de “Nightguard vital bleaching” [10]. Essa publicação é um marco importante na aceitação e adoção generalizada do clareamento dental como uma prática eficaz e acessível. Desde então, novas descobertas continuaram a surgir no campo do clareamento dental, com pesquisas dedicadas a buscar evidências adicionais para aprimorar ainda mais a técnica.

Para um tratamento eficaz, é essencial identificar a causa do escurecimento dos dentes (alteração cromática dental), podendo ser provocado por fatores extrínsecos e intrínsecos. Nos casos de escurecimento extrínseco, o tratamento usual é a remoção mecânica através de uma profilaxia, que frequentemente resulta em dentes mais claros e menos amarelados [11]. Este tipo de escurecimento pode ser devido a pigmentos presentes em bebidas e alimentos, tabagismo, uso de medicamentos, ou acúmulo de biofilme, entre outros [12; 13]. Essas substâncias

cromógenas se depositam na superfície do dente ou entre o dente e a película adquirida [14]. Já nos fatores intrínsecos, os pigmentos estão localizados no interior da estrutura dental e podem ser causados por trauma, escurecimento fisiológico, ou problemas durante a formação dos dentes, como a ingestão de certos medicamentos [4], uma vez que o clareamento dental é frequentemente indicado nesses casos [15; 16].

Em relação a ação do clareamento dental, na literatura, é descrito que o mecanismo de ação se inicia quando o PH entra em contato com o dente. Ao penetrar na estrutura dental, o PH cliva e produz radicais livres, os quais oxidam os pigmentos (moléculas insaturadas) e as deixam saturadas, as quais devido ao índice de refração da dentina, dispersam mais luz e se mostra opaca e branca [7]. É descrito também, que quando o PH atua oxidando o conteúdo orgânico presente na dentina, o clareamento pode estar muito relacionado ao colágeno. Apesar do colágeno ser incolor antes de ser oxidado, após a oxidação ele se torna mais opaco e branco e, desta forma clareia a estrutura dental [17; 18]. Apesar de por muito tempo ser descrito que a cor dos dentes era influenciada pelos cromóforos orgânicos (moléculas carregadas de matiz) [19; 20; 21], quando realizadas técnicas de análise química, até o momento ainda não foram encontradas substâncias com aspecto de cromóforos em dentes vitais [17; 22; 23].

Uma variedade de produtos para o clareamento dental é disponibilizada pelos fabricantes, podendo variar em forma de apresentação e concentração. No contexto do clareamento em dentes vitais, duas técnicas bem estabelecidas e descritas na literatura são amplamente utilizadas pelos cirurgiões-dentistas: o clareamento caseiro e o clareamento de consultório [24]. Em ambas, os agentes clareadores mais utilizados são o PH e o PC.

O PH é um líquido incolor conhecido por seu forte poder oxidante [25]. Ele pode ser utilizado sozinho ou combinado com outros ingredientes, como nos géis de PC [9, 16]. As concentrações de PH variam entre 4% e 40%, enquanto as de PC variam entre 10% e 38% [24; 26]. O PC é um composto sólido, branco e cristalino, e seu uso advém desde a implementação por Haywood e Heymann [10]. Quando dissolvido em água, o PC se decompõe em ureia e PH [9]. A ureia, ao se dividir em dióxido de carbono e amônia, facilita a reação de clareamento, uma vez que uma menor energia de ativação é necessária para a formação de radicais livres, o qual aumenta o pH do meio e desta forma intensifica a ação do PH [9].

O clareamento de consultório, envolve o uso de concentrações mais elevadas de peróxido de hidrogênio (PH), chegando até 40%. Nesse método, a aplicação de gel é realizada diretamente pelo cirurgião-dentista [26] e desta forma não depende da cooperação do paciente, proporcionando um resultado mais rápido [8; 26]. Já para o clareamento caseiro, a técnica emprega concentrações menores de PH, geralmente até 10%. Nesse método, o próprio paciente realiza o procedimento em casa, aplicando o gel clareador tradicionalmente em moldeiras personalizadas e sob a supervisão do cirurgião-dentista [27].

Independente da técnica de clareamento, vale ressaltar a presença de alguns efeitos adversos que estão associados ao clareamento dental, sendo que os mais frequentemente relatados são a sensibilidade dental (SD) e a irritação gengival (IG) [28; 29]. Em relação a SD, ela pode ser atribuída à resposta inflamatória da polpa, que ocorre em função da capacidade que o peróxido de hidrogênio tem de penetrar na estrutura dental e atingir a câmara pulpar [9]. Além disso, é descrito que os odontoblastos e fibras nervosas presentes na polpa dental apresentam TRPs (receptores potencialmente transitórios), que são canais responsáveis pela transdução dos estímulos nocivos em sinais de dor que são enviados ao sistema nervoso central [30; 31; 32]. Quando as técnicas de clareamento são comparadas, observa-se que níveis mais altos de SD são frequentemente relatados para a técnica em consultório, justamente em virtude do uso de maiores concentrações de PH [33; 34]. Seus sintomas geralmente desaparecem em alguns dias ou apenas algumas horas após o tratamento [35; 36]. No entanto, em certos casos, a sensibilidade dentária pode levar os pacientes a descontinuar o tratamento [9].

Espera-se que esse efeito deletério seja ainda mais relevante em pacientes mais jovens (crianças e adolescentes), pois seus dentes são mais permeáveis devido à sua maturação a estímulos externos [37; 38]. Esses pacientes também têm uma câmara pulpar mais ampla em comparação com pacientes mais velhos [39], criando o potencial para SD mais intensa.

Diversos protocolos clínicos já foram estudados a fim de evitar ou reduzir a SD relatada pelos pacientes durante o clareamento dental. Essas abordagens incluem o uso de agentes dessensibilizantes, agentes clareadores com pH neutro ou alcalino, bem como a administração de medicamentos analgésicos ou anti-inflamatórios [40; 41; 42; 43].

Entretanto, diminuir a concentração de PH parece ser a maneira mais viável de conter os elevados índices de SD observados e, esta ideia tem cada vez mais tomado proporções globais. Alguns estudos demonstram que concentrações em torno de 6% seriam ideais por produzirem menor agressão ao metabolismo e morfologia celular [44; 45] já foi demonstrado que o peróxido de hidrogênio em altas concentrações pode ter mais efeitos citotóxicos em células MDPC-23 [46] do que em baixas concentrações [47].

Assim, PH a 6% tornou-se a concentração máxima permitida em alguns lugares do mundo. Na Comunidade Europeia, por exemplo, a concentração máxima permitida é de PH a 6%, independente da forma de aplicação [48]. Além disto, a literatura sugere que a quantidade de gel clareador aplicada na superfície pode também estar relacionada com a SD. Como resposta a essas considerações, os fabricantes têm desenvolvido diferentes formas de apresentação de agentes clareadores para o PH a 6%, buscando redução dos efeitos adversos, mas por outro lado tentando manter o padrão de eficácia do clareamento.

Dentre as formas comerciais disponíveis, destacam-se géis de PH a 6% destinados ao clareamento de consultório. Esses géis clareadores de consultório estão disponíveis comercialmente em conjunto com uma ponteira, associada ou não a um pincel. A ponteira convencional (sem pincel) é a mais utilizada, porém, entre suas variações, há a com aplicador tipo pincel, que espalha o gel por toda a superfície para ter uma espessura menor (camada fina), o que é desenvolvido desde que os fabricantes indicam a aplicação de uma camada fina de gel [49], uma vez que já foi descrito que quanto menor a espessura da camada utilizada [50], menor a quantidade de gel clareador utilizada [51], menor difusão [52] e menor grau de SD é esperado [49].

Outra forma comercial disponível do PH a 6% é destinada para clareamento caseiro, além da tradicional moldeira de clareamento, os géis de PH a 6% têm sido disponibilizados como um “esmalte de unha” ou verniz, sendo que o procedimento pode ser realizado pelo próprio paciente. O verniz clareador é aplicado diretamente nos dentes por meio também de uma fina camada, facilitada pelo seu pincel aplicador. Essa aplicação direta aumenta a superfície de contato do PH com os dentes. Desta forma, o verniz em baixa concentração, também elimina a necessidade de se fazer uma moldeira personalizada para clareamento, facilitando o dia a dia tanto do clínico quanto do paciente [53].

Visando o outro efeito adverso citado anteriormente, IG, ela pode se manifestar como desconforto leve, levando a queimaduras e ulcerações [54], devido ao contato direto dos tecidos moles com o gel clareador, sendo exacerbada de acordo com o tempo e a concentração do gel clareador em contato com a área gengival [55]. Em menor intensidade, pode causar desconforto indicado como irritação localizada na gengiva [56]. Para o clareamento de consultório, uma vez que utiliza altas concentrações de PH, é essencial o uso de barreiras fotopolimerizáveis para proteger o tecido mole [26] e, a IG nesta técnica está diretamente relacionada ao processo do operador. O operador deve ter domínio total da técnica; a falha em fotopolimerizar a barreira gengival corretamente ou o descuido na aplicação [57] podem causar esse efeito adverso.

No entanto, apesar das baixas concentrações usadas para géis de clareamento de consultório, como 6% de PH, as barreiras gengivais continuam sendo necessárias [58; 59; 60]. Nenhuma barreira é indicada para técnicas de clareamento caseiro (até 10% PH), independentemente do método de aplicação [28], porque poucos pacientes relataram IG [61; 62]. Portanto, parece que o uso de uma barreira gengival não faz muito sentido ao usar gel clareador em baixas concentrações para clareamento de consultório. Observe que remover a etapa de aplicação e fotopolimerização da barreira gengival pode tornar o procedimento clínico mais rápido, mais prático e, portanto, mais econômico.

Pacientes jovens expressam uma preferência maior por dentes mais claros do que pacientes mais velhos [63]. Atualmente, a técnica mais indicada para pacientes jovens é o uso de clareamento caseiro devido à baixa concentração [64], e, é importante destacar que quando realizada, alguns adolescentes descreveram que as moldeiras foram muito fáceis de usar, entretanto, alguns consideraram esse procedimento um pouco difícil, principalmente quando foi necessário remover o excesso de gel [65], desta forma, a técnica de consultório, a qual é controlada pelo cirurgião-dentista, se realizada em baixa concentração (PH a 6%), poderia ser uma boa opção para esses pacientes.

Contudo, até o presente momento, não temos conhecimento de estudos que tenham comparado as diferentes formas de apresentação desenvolvidas mais recentemente por fabricantes (clareamento caseiro com vernizes clareadores e clareamento de consultório) para o clareamento dental com PH a 6%. Portanto, o

objetivo deste trabalho é avaliar diferentes estratégias para o uso do peróxido de hidrogênio a 6% no clareamento dental.

2 PROPOSIÇÃO

2.1 ESTUDO 1

2.1.1 Proposição geral

Quantificar *in vitro* a penetração de PH na câmara pulpar de dentes humanos extraídos submetidos a diferentes vernizes clareadores em diferentes tempos de aplicação.

2.1.2 Proposições específicas

1. Quantificar a penetração do PH na câmara pulpar de dentes humanos submetidos a diferentes vernizes clareadores em diferentes tempos de aplicação.
2. Avaliar a mudança de cor de dentes humanos submetidos a diferentes vernizes clareadores em diferentes tempos de aplicação.

2.2 ESTUDO 2

2.2.1 Proposição geral

Quantificar *in vitro* a penetração do PH na câmara pulpar de dentes humanos extraídos submetidos ao clareamento de consultório com diferentes ponteiras de aplicação utilizando PH com baixa e alta concentração.

2.2.2 Proposições específicas

1. Quantificar a concentração de PH dentro da câmara pulpar em dentes humanos submetidos ao clareamento de consultório com diferentes ponteiras de aplicação utilizando PH com baixa e alta concentração.

2. Avaliar a mudança de cor de dentes humanos submetidos ao clareamento de consultório com diferentes ponteiras de aplicação utilizando PH com baixa e alta concentração.
3. Determinar o gasto de gel com o uso de diferentes ponteiras de aplicação do clareamento de consultório com PH com baixa e alta concentração.

2.3 ESTUDO 3

2.3.1 Proposição geral

Avaliar clinicamente a eficácia do clareamento em consultório com PH a 6% em adolescentes realizado com diferentes ponteiras de aplicação.

2.3.2 Proposições específicas

1. Avaliar a eficácia da mudança de cor, através das escalas VITA Classical, VITA Bleachedguide e espectrofotômetro VITA Easyshade, utilizando diferentes ponteiras de aplicação durante o clareamento de consultório em adolescentes com PH a 6%.
2. Determinar o risco absoluto e a intensidade da sensibilidade dental, por meio da Escala Visual Analógica (EVA), utilizando diferentes ponteiras de aplicação durante o clareamento de consultório em adolescentes com PH a 6%.
3. Estimar a autopercepção estética, por meio da Escala Estética Orofacial (EEO), antes e após o clareamento de consultório em adolescentes com PH a 6%.

2.4 ESTUDO 4

2.4.1 Proposição geral

Determinar clinicamente a irritação gengival durante o clareamento de consultório com PH a 6% em adolescentes realizado com e sem barreira gengival.

2.4.2 Proposições específicas

1. Determinar o risco absoluto e a intensidade de irritação gengival, utilizando a Escala Visual Analógica (EVA), com ou sem o uso de barreira gengival, durante o clareamento de consultório em adolescentes com PH a 6%.
2. Avaliar a eficácia da mudança de cor, através das escalas VITA Classical, VITA Bleachedguide e espectrofotômetro VITA Easyshade, com ou sem o uso de barreira gengival, durante o clareamento de consultório em adolescentes com PH a 6%.
3. Estimar o impacto da condição bucal na qualidade de vida, por meio do Oral Health Impact Profile (OHIP-14), antes e após o clareamento de consultório em adolescentes com PH a 6%.

3 MATERIAL E MÉTODOS

A descrição abrangente dos materiais e métodos utilizados em cada estudo pode ser encontrada na próxima seção de cada artigo individual, oferecendo aos leitores uma compreensão detalhada da metodologia empregada em cada estudo.

4 ARTIGO 1 - IN VITRO EVALUATION OF THE EFFECT OF DIFFERENT BLEACHING VARNISHES: HYDROGEN PEROXIDE PENETRATION INTO THE PULP CHAMBER AND COLOR CHANGE

STATUS: Publicado em 2023

REVISTA: Journal of Esthetic and Restorative Dentistry

DOI: 10.1111/jerd.13133

Taynara S. Carneiro DDS, MSc, PhD student[1,2] | Michael W. Favoreto DDS, MSc, PhD student[1] | Alexandra Mena-Serrano DDS, PhD[3] | Michel Wendlinger DDS, MSc, PhD student[1] | Heloisa Forville DDS, MSc, PhD student[1] | Alessandra Reis DDS, PhD[1] | Laura Ceballos DDS, PhD[2] | Alessandro D. Loguercio DDS, MSc, PhD[1].

1 Department of Restorative Dentistry, School of Dentistry, State University of Ponta Grossa, Ponta Grossa, PR, Brazil

2 Area of Stomatology, IDIBO research group, Health Sciences Faculty, Rey Juan Carlos University, Alcorcon, Madrid, Spain

3 School of Dentistry, Universidad de Las Américas, Quito, Ecuador

Correspondence

Alessandro D. Loguercio, Curso de Odontologia, Universidade Estadual de Ponta Grossa, Avenida Carlos Cavalcanti 4748, CEP: 84.030-900, Bloco M, Sala 64-A, Ponta Grossa PR, Brazil. Email: aloguercio@hotmail.com

Abstract

Objective: To evaluate the penetration of hydrogen peroxide (HP) into the pulp chamber and the color change of different bleaching varnishes in low concentrations used for at-home bleaching.

Materials and Methods: Ninety healthy premolars were used, randomly distributed into nine groups (n = 10) according to bleaching varnish (PL, PolaLuminate; VS, VivaStyle Paint On Plus; CA, Cavex Bite&White whitening pen and; AW Aligner- White) and time (10 and 30 min), and a control group (no bleaching). The penetration of HP was evaluated by UV–Vis spectroscopy. To evaluate the color change (ΔE_{ab}, ΔE_{00}, ΔWI_D) a digital spectrophotometer was used ($\alpha = 0.05$).

Results: The AW group in 10 min and the control group showed similar and lower HP penetration in the pulp chamber when compared to the other groups ($p = 0.003$).

Increasing the application time to 30 minutes elevated the amount of HP inside the pulp chamber for all groups (p = 0.003), except for PL (p > 0.05). When applied for 30 min all bleaching varnishes showed higher color change (ΔWI_D) when compared to 10 min (p = 0.04).

Conclusions: For all bleaching varnishes evaluated, PolaLuminate applied for 30 min showed lower penetration into the pulp chamber and higher bleaching effects.

Clinical Significance: The use of bleaching varnishes seems promising for teeth bleaching, but it varies according to user product and protocol.

KEYWORDS

bleaching agents, dental enamel permeability, hydrogen peroxide, *in vitro* techniques, tooth bleaching

INTRODUCTION

Cosmetic procedures, such as tooth bleaching, have increased patients' self-confidence and improved emotional well-being,[1] making the procedure increasingly popular.[2,3] In a recent study, it was observed that 86% of the participants underwent the bleaching technique on their initiative and not at the dentist's suggestion.[4]

Different tooth bleaching techniques on vital teeth performed or supervised by the dentist are described in the literature in search of color change.[5-8] Among them, the most established is the in-office bleaching which uses higher concentrations of hydrogen peroxide (HP) (up to 40%),[9-13] the gel application being performed by the dentist,[14] and the at-home bleaching, which uses lower concentrations of HP (up to 10%), performed by the patient himself with the application of bleaching gel in custom trays.[15] However, both techniques showed adverse effects and tooth sensitivity induced by bleaching was among the most prevalent.[16]

Tooth sensitivity induced by bleaching can be explained by damage to pulp cells and oxidative stress caused by HP and/or by-products that manage to reach the pulp due to their low molecular weight.[17–26] Given this fact, there is a tendency to decrease the concentration of HP to be applied, and some studies demonstrate that concentrations of around 6% would be ideal because they produce lower aggression to the metabolism and cell morphology.[27,28] It has already been demonstrated that

peroxide of hydrogen at high concentrations may have more cytotoxic effects on MDPC-23 cells[29] than at low concentrations.[30]

Thus, 6% HP has become the maximum allowable concentration in some places around the world,[31] and different forms of application for this concentration were developed by manufacturers, not only for the traditional at-home bleaching with trays[24] but also in-office bleaching[32] and at-home bleaching through varnishes.[33-40]

The use of bleaching varnishes has several advantages, such as disposing of the need to make a custom tray for bleaching or facilitating the day-to-day for both the clinician and the patient. Also, it is easy to use by the patient himself because all commercial brands include an applicator, similar to the brushes used to apply nail polish. It has already been demonstrated that when a brush applicator was used, a thin layer was achieved due to the increase in the contact surface of the HP with the tooth.[32,41] Recently, at least two studies showed that the thinner the bleaching layer, the less penetration of HP into the pulp,[32,41] and this makes the use of bleaching varnishes seemingly promising.[33]

As far as the authors are aware, and due to the recent launching of some commercial brands, *in vitro* studies evaluating several bleaching varnishes and the different application times indicated by the manufacturers have not yet been carried out. With this in mind, this *in vitro* study's objective was to evaluate HP's penetration into the pulp chamber and the color change through different bleaching varnishes with HP around 6% and application times. The null hypothesis to be tested is that: (1) there will be no difference in HP penetration, and (2) there will be no difference in color change using different bleaching varnishes at different application times.

MATERIALS AND METHODS

The study was submitted to the Ethics Committee of the State University of Ponta Grossa, PR, Brazil, which approved it under number 5.778.595. Ninety healthy premolars with similar sizes were obtained from Human Teeth Bank of the State University of Ponta Grossa. A stereomicroscope (Lambda LEB-3; ATTO instrument, Hong Kong, China) was used to analyze the enamel surface at 10× magnification. Teeth with morphological changes or enamel cracks were excluded. The teeth were previously analyzed with a digital spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik, Germany), and teeth lighter than A2 were also excluded. To

standardize the buccal surface thickness of the specimens and to prevent this thickness from influencing the penetration of HP, radiographs were taken (Timex 70C; Gnatus, Ribeirão Preto, Brazil). Each radiograph was made with an exposure time of 0.5 s and a focus-object distance of 30 cm (70 kVp, 7 mA). The central X-ray beam was focused at a 90° angle on the buccal surface of the tooth. After exposure, the images were digitally obtained, and the buccal surface thickness was measured with the New IDA software (Dabi Atlante, Ribeirão Preto, Brazil), teeth with a thickness of <2.5 and >3.5 mm were excluded.[42,43]

Sample size calculation

The primary outcome of this study was the amount of HP within the pulp cavity. Based on a previous study where the penetration value of 6% of HP was 0.033 µg/mL with a deviation of 0.016 µg/mL,[18,32] for control group (30 min). Taking into consideration that in the experimental group, the bleaching materials were applied for 10 min, i.e., for only 35% of the application time previous evaluated (30 min), it was expected a decrease of the amount of HP inside the pulp chamber of 65% (0.012 µg/mL) in the experimental group. Using a bilateral test with an alpha of 5% and a study power of 80%, ten teeth were needed for each experimental group.

Nevertheless, the sample size was also determined based on color change (secondary outcome) as per the whiteness index for dentistry (ΔWI_D).[8] A previous study showed that the ΔWI_D value of 6% of HP was 5.7 with a deviation of 2.1.[32] Taking into consideration that the acceptability threshold (AT) for ΔWI_D is 2.6,[6] that means, it was occur a bleaching considered clinically acceptable and using a bilateral test with an alpha of 5% and a study power of 80%, 10 teeth were needed for each experimental group.

Experimental groups

The selected teeth were randomly assigned into nine groups (n = 10). A group not exposed to bleaching agents was the control (GC). The other groups were divided according to the commercial brands and time of application, as follows: PL (Pola Luminate HP 6%; SDI); VS (VivaStyle Paint On Plus HP 6%; Ivoclar Vivadent, Schaan, Liechtenstein); CA (Cavex Bite&White whitening pen HP 6%; Cavex Holland BV,

Netherlands) and AW (Aligner White HP 5%, EverSmile; Garden Grove, CA, USA). All products were applied for 10 or 30min.

Specimen preparation

The roots of the teeth were removed approximately three millimeters from the enamel-cement junction, using a low-speed diamond disk (Isomet 1000; Buehler Ltd., Lake Bluff, IL, USA). The pulp tissue was removed, and the pulp chamber was rinsed with deionized water. The access to the pulp cavity was slightly expanded using a #1014 spherical drill (KG Sorensen, Serra, ES, Brazil), taking care not to touch the inner vestibular region of the pulp cavity. This was done with the purpose of introducing 25 µL of solution inside, using a micropipette (LABMATE Soft, HTL Lab Solutions, Warsaw, Poland). After specimen preparation, new radiographs (Timex 70C; Gnatus) were taken to verify the buccal surface thickness of the specimens by groups measured with the New IDA software (Dabi Atlante).[32,41] The premolars were procured from the Human Teeth Bank of the same university when all teeth were stored in distilled water. Only teeth extracted within the last 6 months were selected for use in the present study. After the preparation of the specimens, 1 week before the start of the study, all teeth were stored in artificial saliva.

Obtaining the analytical curve and quality control measurements

The study used analytical products without prior purification and all solutions were prepared using deionized water. Initially, a standard analytical curve was drawn from a 5.000 µg/mL stock solution prepared from a concentrated solution (50% HP; Pharmacy Eficácia, Ponta Grossa, PR, Brazil). This solution was diluted in an acetate buffer solution (pH = 4) and titrated using traditional methods. The solution was titrated with a potassium permanganate solution to determine the analytical grade and the actual concentration of the solution. Based on this initial concentration, serial volumetric dilutions of 0.000–0.403 µg/mL were performed to draw the analytical curve. The known concentrations of HP were obtained using a Cary UV–Vis 50 spectrophotometer (Varian, Palo Alto, CA, USA). This procedure yielded a standard reference line for the extrapolation of the study samples' results (R = 0.992; not shown data).[32,41]

For quality control measurements, the pH and initial concentration were measured. The pH of each bleaching agent was measured with a pH meter placed directly in contact with a bleaching gel (Extech pH 100: ExStik pH Meter; Extech Instruments, Nashia, NH, USA; Table 1).[44]

To determine the initial concentrations of HP, the bleaching gels used in the study were titrated with a standardized solution of potassium permanganate before the bleaching procedure, as described in the literature[18] and compared with those provided by the manufacturers.

Table 1 - Means (± standard deviations) of the buccal surface thickness, initial concentration, pH of varnishes, and HP concentration detected inside the pulp chamber in different experimental groups

Bleaching varnishes	Bleaching time (min)	Buccal thickness (mm)[a]	Initial concentration (%)	pH	HP (µg/mL)[a]
PL	10	3.0 ± 0.2 A	5.6	5.7 ± 0.1	0.034 ± 0.024 B
	30	3.3 ± 0.3 A			0.030 ± 0.030 B
VS	10	3.5 ± 0.6 A	6.8	5.0 ± 0.0	0.039 ± 0.040 B
	30	3.4 ± 0.3 A			0.077 ± 0.077 C
CA	10	3.3 ± 0.6 A	4.7	5.4 ± 0.2	0.023 ± 0.024 B
	30	3.3 ± 0.4 A			0.068 ± 0.045 C
AW	10	3.2 ± 0.5 A	4.6	4.9 ± 0.1	0.005 ± 0.004[b] A
	30	3.2 ± 0.3 A			0.040 ± 0.031 B
Control	–	3.2 ± 0.4 A	–	–	0.001 ± 0.001[b] A

[a]Identical capital letters in each column indicates statistically similar means (Two-way ANOVA and Tukey's test, α = 0.05).

[b]The control group and Aligner White were statistically similar and statistically different when compared to all groups (Two-way ANOVA and Dunnet's test, α = 0.05).

Treatment bleaching protocols and HP quantification into the pulp chamber

A single experienced and calibrated operator, blinded to the assigned groups, was responsible for the application of the material. For all groups, the specimens were vertically fixed to a wax plate with the occlusal surface toward the plate. Before the bleaching agent was applied, the buccal surface of each specimen was isolated by applying a light-cured resin barrier enclosing an area of 6 mm^2 (Topdam, FGM Dental Group, Joinville, SC, Brazil). A 25 µL aliquot of the acetate buffer (pH = 4) was inserted into the pulp chamber of each tooth to preserve and absorb all the HP that entered the pulp chamber during bleaching procedures.

In the groups that received bleaching treatment, the varnishes were applied in the region of the vestibular enamel according to the different experimental groups. The bleaching varnishes were applied until they completely covered the buccal area of the teeth to be whitened. For all bleaching varnishes, a thin layer of bleaching varnish was applied for 10 or 30 min according to each experimental group. For all groups, the bleaching varnishes were applied for 14 days. Each product was removed with gauze and carefully washed with deionized water only on the vestibular surface. The control group was kept out of contact with bleaching agents.

After performing the first application of bleaching varnish, the acetate buffer solution in the pulp cavity of each sample was removed immediately after the bleaching session, according to the application time to be tested. The removed solutions were transferred to a glass tube. To remove the maximum amount of HP, this procedure was repeated with the cleaning of the pulp cavity of each tooth four times with 25 µL of the acetate buffer. This solution was transferred to the same glass tube. Sequentially, 100 µL of 0.5 mg/mL (Leucocrystal Violet, Sigma Chemical Co., St. Louis, MO, USA) and 50 µL of 1 mg/ mL of horseradish peroxidase (Peroxidase Type VI-A, Sigma Chemical Co.) were added to the glass tube, along with deionized water (2.725 µL). This sequence was repeated separately for each tooth at different times. The resulting solution was measured using a Cary 50 UV–Vis spectrophotometer (Varian). Despite other available methods in the literature,[25] this is the most used to measure the amount of HP inside the pulp chamber.[9–11,18,19,22,23,27–29,32,33,41–43] According to the Beer Law, absorbance directly corresponds to the concentration. Therefore, the concentration of HP (µg/mL) was determined by comparing it with the calibration curve previously obtained.[32,41]

Color change evaluation

The color change was measured before and after 14 days of the bleaching procedure. It was performed using a digital spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik). To measure the initial color of the specimens, guides were made with dense condensation silicone (Coltoflax and Cub Kit Profile; Vigodent, Rio de Janeiro, RJ, Brazil), and a 6 mm diameter window was made with a metal device in the middle third of the buccal surface of each specimen to standardize the position of the tip of the spectrophotometer. During this period, the specimens were immersed

in artificial saliva. Daily changes of artificial saliva were performed at a controlled temperature of 37◦C.

The color parameters (L*, a*, and b*) were recorded through the tip of the device inserted in the silicone guide. The L* value represented the lightness (the values ranged from 0 for black to 100 for white), the a* value represented the green-red coordinate (-a* green and +a* red) and the b* value represented the blue-yellow coordinate (-b* blue and +a* yellow). The color change before (baseline) and after bleaching was given by the difference between the colors measured with the spectrophotometer using the following CIELab formulas: CIELab (Delta E_{ab}) = $[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$,[45] and CIEDE 2000 (Delta E_{00}) = $[(\Delta L/kLSL)^2 + (\Delta C/kCSC)^2 + (\Delta H/kHSH)^2 + RT\ (\Delta C^*\Delta H/SC^*SH)]^{1/2}$.[7] Also, the Whiteness index for Dentistry was calculated according to the following formula: $WI_D = 0.551 \times L - 2.324 \times a - 1.1 \times b$. Moreover, changes in WI_D caused by each step were calculated by subtracting the values observed at each assessment time from those calculated in the prior step (ΔWI_D).[8]

Statistical analysis

Data were analyzed using the Kolmogorov–Smirnov test to assess whether the data had a normal distribution and using the Barlett test for equality of variance to verify the hypothesis of equality of variances (data not shown). As the data showed normality and homoscedasticity of variances, the thickness of buccal surface (mm), amount of HP concentration (µg/mL) detected in the pulp chamber, as well as color change (ΔE_{ab}, ΔE_{00}, and ΔWI_D) were submitted to two statistical evaluations: (1) two-way ANOVA (bleaching varnish vs. bleaching time) and Tukey's post hoc test to compare different bleaching varnishes and; (2) two-way ANOVA (bleaching varnish vs. bleaching time) and Dunnet's post hoc test to compare the values obtained in different bleaching varnishes with those of the control group ($\alpha = 0.05$).

RESULTS

Buccal surface thickness and hydrogen peroxide quantification into the pulp chamber measurements

Regarding the buccal surface thickness, the cross-product interaction (bleaching varnishes vs. bleaching time), as well as the main factors were not

statistically significant ($p < 0.24$; Table 1). The mean and standard deviation of the buccal surface thickness of the specimens, according to the radiographs taken for all groups are described in Table 1.

The analysis of the hydrogen peroxide (HP) content within the pulp chamber revealed a statistically significant cross-product interaction between bleaching varnishes and bleaching time ($p = 0.003$; Table 1). Regarding the factor “bleaching varnishes”, the control group and the AW group at 10 min showed a smaller amount of HP in the pulp chamber compared to the other experimental groups. In contrast, the VS and CA groups displayed a notably higher and more significant HP content within the pulp chamber when subjected to a bleaching time of 30 min (Table 1). Regarding the factor “bleaching time”, the PL groups exhibited no significant difference in the amount of HP within the pulp chamber. In contrast, the VS, CA, and AW groups demonstrated a considerable and significant increase in the amount of HP within the pulp chamber when subjected to a bleaching time of 30 min ($p = 0.003$; Table 1).

Color change assessment

The color changes observed in the different experimental groups are presented in Table 2. Statistical analysis revealed a significant cross-product interaction between bleaching varnishes and bleaching time for both ΔE_{ab} and ΔE_{00} ($p = 0.03$ and $p = 0.01$, respectively; Table 2). Regarding the factor “bleaching varnishes”, a smaller color change was evident in the control group, exhibiting lower ΔE_{ab} and ΔE_{00} values in comparison to all experimental groups (Table 2; $p = 0.03$ and $p = 0.01$ respectively). Notably higher and significant color changes (ΔE_{ab} and ΔE_{00}) were observed in the VS 30 min and CA 10 and 30min groups when compared to the other groups. Irrespective of bleaching time, no significant differences were observed in terms of color change as measured by ΔE_{ab} and ΔE_{00} for PL, AW, and CA (Table 2).

Regarding ΔWI_D, the cross-product interaction (bleaching varnishes vs. bleaching time) was not statistically significant ($p = 0.95$), but both main factors displayed significance ($p = 0.002$ and 0.04, respectively; Table 2). Among the bleaching varnishes, VS exhibited a significantly higher color change, showing a difference only when compared to AW ($p = 0.002$; Table 2). Furthermore, for all bleaching varnishes, significantly higher color changes were detected with a 30-minute application ($p = 0.04$; Table 2).

Table 2 - Means (± standard deviations) of the color change in different objective assessments (ΔE_{ab}, ΔE_{00}, and ΔWI_D) in different experimental groups[a]

Bleaching varnishes	Bleaching time (min)	ΔE_{ab}*	ΔE_{00}*	ΔWI_D[c]
PL	10	3.4 ± 1.3 B	2.1 ± 0.8 b	-0.9 ± 4.4 ^{Aab}
	30	2.9 ± 1.6 B	1.9 ± 1.0 b	3.1 ± 5.7 ^{Bab}
VS	10	3.7 ± 1.8 B	2.3 ± 1.0 b	2.3 ± 3.1 ^{Aa}
	30	6.4 ± 2.1 A	4.0 ± 1.4 a	6.0 ± 1.7 ^{Ba}
CA	10	6.5 ± 1.9 A	3.9 ± 0.8 a	-2.0 ± 7.2 ^{Aab}
	30	6.1 ± 1.8 A	4.0 ± 1.2 a	1.9 ± 5.8 ^{Bab}
AW	10	3.5 ± 1.4 B	2.3 ± 1.2 b	-3.6 ± 6.1 ^{Ab}
	30	4.6 ± 2.0 B	3.0 ± 0.8 b	2.1 ± 7.2 ^{Bb}
Control[b]	-	1.3 ± 0.8	0.9 ± 0.5	-0.5 ± 1.2

[a]Identical letters indicate statistically similar values among the groups in each column. (Two-way ANOVA and Tukey's test, α = 0.05).

[b]The control group was statistically different when compared to all groups in each column (Two-way ANOVA and Dunnet's test, α = 0.05).

[c]For ΔWI_D, identical capital letters indicate statistically similar values for different bleaching time in each bleaching varnish and identical lower-case letters indicate statistically similar values for different bleaching varnishes in each bleaching time.

DISCUSSION

Low concentration bleaching varnishes seem promising since they are used quickly and do not require trays,[33] making day-to-day life easier for patients and clinicians. Different bleaching varnishes are available on the market, and few have been described in the literature.[35-37] Therefore, this is the first study that compares different bleaching varnishes in terms of penetration into the pulp chamber and color change. The present study evaluated the buccal surface thickness of all analyzed groups. This is important because it has already been described that the tooth's thickness influences HP's penetration.[21] According to the results, no significant difference in buccal surface thickness among groups was observed.

The results of the present study, in terms of HP penetration, showed that significant differences were observed when different bleaching varnishes and times were evaluated, leading to the no acceptance of the first null hypothesis. However, several differences between materials and protocols were observed. HP penetration may be related to tooth sensitivity, as previously described, and may depend on some variables, such as the concentration of the bleaching agent and the application time.[18,19,32]

Regarding the bleaching varnishes, note that the AW showed low penetration of HP inside the pulp chamber when applied for 10 min, like that of the control group. This may be related to the viscosity of AW since, from the clinical point of view, it is the most viscous varnish among those evaluated. When the material is very viscous, there is not enough release of HP. Consequently, the lower HP release of the material could be responsible for the lower HP inside the pulp chamber.[19,32] As pointed out previously, not only the viscosity can affect the amount of hydrogen peroxide released, but also solvent, matrix composition, and type of application could be considered as potential factors to influence the kinetics of release of hydrogen peroxide.[25] Unfortunately, only a few studies evaluated the viscosity of bleaching gels, which did not allow the authors give more explanations.[13,26] It is worth mentioning that, except for AW applied for 10 min, all the values of HP penetration observed in the present study are in accordance with the previous literature.[18,32,34]

When different application times were compared, an increase in the amount of HP inside the pulp chamber was registered for three of the four bleaching varnishes when applied for 30 min. The longer the bleaching agent remains in contact with the tooth surface, the greater penetration has been observed when peroxide is still available,[22,27] which can be explained by HP's diffusion dynamics in the dental tissues.[20]

The unique exception was PL, which showed no significant differences when comparing both application times. The pH can explain this. It is well known that the higher the pH of a bleaching material, the lower the penetration of HP inside the pulp chamber.[9,23] It should be noted that PL exhibited a higher pH (5.7) compared to the other evaluated bleaching varnishes. Typically, the pH of bleaching gels is highly acidic to enhance the product's shelf life.[24] However, more acidic gels can have detrimental effects on the enamel surface,[9,12] and enhance the diffusion of HP into the pulp, as previously observed for in-office bleaching gels.[10,23]

Regarding the color change, it was expected that the color change would be similar because the bleaching varnishes tested had similar concentrations of HP. However, according to the manufacturer's recommendation, the application time of the bleaching varnish is relatively short, therefore, it was not expected significant differences between 10 and 30min. Despite that, the results of the present study showed that significant differences were observed for a color change when different

bleaching varnishes were applied at various times on the tooth surface, leading to the no acceptance of the second null hypothesis.

Different formulae were used to evaluate color change in the present study. The ΔE_{ab} was used because it is the most widely used parameter in bleaching studies.[5] The ΔE_{00}, a formula improvement of ΔE_{ab}, is more faithful to color differences as the human eye can perceive them.[5,7] When the different experimental groups were compared, similar results were observed when ΔE_{ab} or ΔE_{00} were applied. However, although the ΔE_{ab} and ΔE_{00} can give the magnitude of color change, they do not provide information on the direction of the color change, whether whiter or darker. WID indicates the degree of whitening toward the lighter end of the scale.[6,8]

Despite some differences among bleaching varnishes and application time, when the color change was evaluated by ΔE_{ab} or ΔE_{00}, for all experimental groups, the color change was higher than the 50:50 acceptability (AT) threshold for ΔE_{ab} (AT = 2.7) or ΔE_{00} (AT = 1.8). The AT value represents an existing difference acceptable to most people. This means that a perceptible color change occurs, and the results are similar to those observed in the two studies.[27,34] Nevertheless, a closer view regarding the ΔWI_D showed that for all bleaching varnishes applied for 10 min and for CA and AW applied for 30 min, the values observed did not reach the AT threshold value (2.6) for ΔWI_D.[6] This means that, despite some bleaching occurring, it should not be considered clinically acceptable. However, when a longer application time (30 min) is performed for PL and VS, the bleaching values exceed the AT threshold value. This finding seems to be the most important for color change since the Whiteness Index for Dentistry is recently used specifically to evaluate how much the teeth became whiter.[8]

This does not imply that CA and AW should not be used. In fact, this suggests that it is necessary to prolong the application duration of these bleaching varnishes to achieve improved bleaching outcomes. For example, following the manufacturer's recommendations, CA should be applied twice daily, and AW should be used for a duration of 8 hours. Increasing the application time is likely to yield better results. Future studies need to be conducted to evaluate the bleaching effect of CA and AW when applied according to the manufacturers' recommendations.

Unfortunately, there is a high variation in manufacturer's instructions for the materials evaluated in the present study. Also, despite an increase in the availability of bleaching varnishes on the market, only a few studies were found and usually

evaluated only one commercial material (VS).[38-40] Therefore, future studies need to be performed to assess these hypotheses.

The exception of higher values than ΔWI_D AT threshold was observed for PL and VS applied for 30 min. Despite that, a closer view of the ΔWI_D results showed that for all bleaching varnishes, a significant and higher color change occurred when 30 min was compared to 10 min. This indicates that the increase in time of application should improve the final bleaching results, as previously observed.[11] When different varnish bleaching was compared, significant differences were only observed between VS and AW. The former is more fluid than AW, leading to the fastest release of hydrogen peroxide.[38] Also, VS showed a higher initial concentration (6.8%) when compared to all varnishes evaluated.

Finally, it is essential to clarify that, despite a better whitening effect observed for PL and VS when applied for 30 min, only the manufacturer of the former indicates the application for 30 min. Also, VS showed twice as much HP in the pulp chamber as PL, mainly when evaluated for 30 min. Therefore, considering both properties, PL seems to be better than the other bleaching varnishes evaluated.

Although, to the authors' knowledge, this is the first study to evaluate different bleaching varnishes at different times, one of the study's limitations can be attributed to using only four commercial brands. Since the differences in the composition of bleaching varnishes from other brands may differ from the results presented in this study. In addition, there is huge variability in the application times of the varnishes, since only two times of use were tested. Furthermore, since the collection of the permeability solution was conducted immediately after the final application time, it is important to note that all interpretations of the results in the present study should be confined to the immediate time point. Therefore, further studies are needed to evaluate bleaching varnishes that may be launched. Given this, and based on these results, randomized clinical trials must be developed to verify the advantages of using different bleaching varnishes clinically.

CONCLUSIONS

Despite the numerous differences observed among the various combinations of bleaching varnishes and application times assessed, the following conclusions can be drawn:

1. A lower amount of hydrogen peroxide within the pulp chamber was noted when all bleaching varnishes were applied for 10 min over a span of 14 days. However, none of these treatments achieved a clinically acceptable bleaching outcome.
2. Only two of the tested bleaching varnishes, namely Pola Luminate HP 6% and VivaStyle Paint On Plus HP 6%, exhibited a clinically acceptable level of bleaching when applied for 30 min over a period of 14 days. Nonetheless, Pola Luminate HP 6% demonstrated a lower hydrogen peroxide content compared to VivaStyle Paint On Plus HP 6% when both were applied for a duration of 30 min.

ACKNOWLEDGMENTS

This study was partially supported by the National Council for Scientific and Technological Development (CNPq) under grants 304817/2021-0 and 308286/2019-7 and Coordenação de Aperfeiçoamento de Pessoal de Nível SuperiorBrasil (CAPES)—Finance Code 001.

CONFLICT OF INTEREST STATEMENT

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

1. Bersezio C, Estay J, Jorquera G, et al. Effectiveness of dental bleaching with 37.5% and 6% hydrogen peroxide and its effect on quality of life. *Oper Dent*. 2019;44(2):146-155.
2. Nie J, Tian F-C, Wang Z-H, Yap AU, Wang XY. Comparison of efficacy and outcome satisfaction between in-office and home teeth bleaching in Chinese patients. *J Oral Sci*. 2017;59(4):527-532.

3. Rodríguez-Martínez J, Valiente M, Sánchez-Martín MJ. Tooth whitening: from the established treatments to novel approaches to prevent side effects. *J Esthet Restor Dent*. 2019;31(5):431-440.
4. Mazilu Moldovan A, Popescu V, Ionescu CV, et al. Various aspects involved in the study of tooth bleaching procedure: a questionnaire- based study. *Int J Environ Res Public Health*. 2022;19(7):3977.
5. Paravina RD, Ghinea R, Herrera LJ, et al. Color difference thresholds in dentistry. *J Esthet Restor Dent*. 2015;27(Suppl 1):S1-S9.
6. Pérez MM, Herrera LJ, Carrillo F, et al. Whiteness difference thresholds in dentistry. *Dent Mater*. 2019;35(2):292-297.
7. Luo M, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Res Appl*. 2001;26: 340-350.
8. Pérez Mdel M, Ghinea R, Rivas MJ, et al. Development of a customized whiteness index for dentistry based on CIELAB color space. *Dent Mater*. 2016;32(3):461-467.
9. Acuña ED, Parreiras SO, Favoreto MW, et al. In-office bleaching with a commercial 40% hydrogen peroxide gel modified to have different pHs: color change, surface morphology, and penetration of hydrogen peroxide into the pulp chamber. *J Esthet Restor Dent*. 2022;34(2): 322-327.
10. da Silva KL, Favoreto MW, Centenaro GG, et al. Can all highly concentrated in-office bleaching gels be used as a single-application? *Clin Oral Investig*. 2023;27:3663-3671.
11. Soares DG, Ribeiro AP, da Silveira Vargas F, et al. Efficacy and cytotoxicity of a bleaching gel after short application times on dental enamel. *Clin Oral Investig*. 2013;17(8):1901-1909.
12. Azrak B, Callaway A, Kurth P, et al. Influence of bleaching agents on surface roughness of sound or eroded dental enamel specimens. *J Esthet Restor Dent*. 2010;22(6):391-399.
13. Torres C, Moecke SE, Mafetano A, Cornélio LF, di Nicoló R, Borgesd AB. Influence of viscosity and thickener on the effects of bleaching gels. *Oper Dent*. 2022;47(3):E119-E130.
14. Reis A, Mendonça Da Silva L, Martins L, et al. In-office tooth whitening. *Clin Dent Rev*. 2018;2(1):10.

15. Haywood VB, Sword RJ. Tray bleaching status and insights. *J Esthet Restor Dent.* 2021;33(1):27-38.
16. de Geus JL, Wambier LM, Kossatz S, Loguercio AD, Reis A. At-home vs In-office bleaching: a systematic review and meta-analysis. *Oper Dent*. 2016;41(4):341-356.
17. Kwon SR, Wertz PW. Review of the mechanism of tooth whitening. *J Esthet Restor Dent*. 2015;27(5):240-257.
18. Parreiras S, Favoreto M, Cruz G, et al. Initial and pulp chamber concentration of hydrogen peroxide using different bleaching products. *Braz Dent Sci*. 2020;23(2):1-8.
19. Soares DG, Basso FG, Hebling J, de Souza Costa CA. Concentrations of and application protocols for hydrogen peroxide bleaching gels: effects on pulp cell viability and whitening efficacy. *J Dent*. 2014;42(2):185-198.
20. Ubaldini AL, Baesso ML, Medina Neto A, et al. Hydrogen peroxide diffusion dynamics in dental tissues. *J Dent Res*. 2013;92(7):661-665.
21. Costa CA, Riehl H, Kina JF, et al. Human pulp responses to in-office tooth bleaching. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2010;109(4):e59-e64.
22. Marson FC, Gonçalves RS, Silva CO, et al. Penetration of hydrogen peroxide and degradation rate of different bleaching products. *Oper Dent*. 2015;40(1):72-79.
23. Balladares L, Alegría-Acevedo LF, Montenegro-Arana A, et al. Effects of pH and application technique of In-office bleaching gels on hydrogen peroxide penetration into the pulp chamber. *Oper Dent*. 2019; 44(6):659-667.
24. Abdel-Halim ES, Al-Deyab SS. One-step bleaching process for cotton fabrics using activated hydrogen peroxide. *Carbohydr Polym*. 2013; 92(2):1844-1849.
25. Dias S, Mata A, Silveira J, et al. Hydrogen peroxide release kinetics of four tooth whitening products-in vitro study. *Materials*. 2021;14(24):7597.
26. Kwon SR, Pallavi F, Shi Y, Oyoyo U, Mohraz A, Li Y. Effect of bleaching gel viscosity on tooth whitening efficacy and pulp chamber penetration: an *in vitro* study. *Oper Dent*. 2018;43(3):326-334.
27. Almeida LC, Soares DG, Azevedo FA, et al. At-home bleaching: color alteration, hydrogen peroxide diffusion and cytotoxicity. *Braz Dent J*. 2015;26(4):378-383.

28. Soares DG, Basso FG, Hebling J, de Souza Costa CA. Immediate and late analysis of dental pulp stem cells viability after indirect exposition to alternative in-office bleaching strategies. *Clin Oral Investig*. 2015; 19(5):1013-1020.
29. de Almeida LC, Soares DG, Gallinari MO, et al. Color alteration, hydrogen peroxide diffusion, and cytotoxicity caused by in-office bleaching protocols. *Clin Oral Investig*. 2015;19(3):673-680.
30. de Lima AF, Lessa FC, Gasparoto Mancini MN, Hebling J, de Souza Costa CA, Marchi GM. Cytotoxic effects of different concentrations of a carbamide peroxide bleaching gel on odontoblast-like cells MDPC-23. *J Biomed Mater Res B Appl Biomater*. 2009;90(2):907-912.
31. Scientific Committee on Consumer Products. Public consultation on a preliminary opinion on hydrogen peroxide in tooth whitening products. 2005. Accessed July 22, 2023. https://ec.europa.eu/health/ph_risk/committees/04_sccp/docs/sccp_q_158.pdf.
32. Carneiro TS, Favoreto MW, Bernardi LG, et al. Application tip and concentration of a self-mixing bleach: hydrogen peroxide inside the pulp chamber, color change, and amount of bleaching gel used. *Oper Dent*. 2023;48(2):146-154.
33. Greenwall L. Tooth whitening: the last 25 years. *Aesthetic Dent Today*. 2016;6(2):15-19.
34. Centenaro GG, Favoreto MW, Carneiro TS, et al. The effect of different bleaching techniques using 6% hydrogen peroxide: penetration inside the pulp cavity, bleaching efficacy and toxicity (in press). 2023.
35. Yildirim E, Vural UK, Cakir FY, et al. Effects of different over – the – counter whitening products on the microhardness, surface roughness, color and shear bond strength of enamel. *Acta Stomatol Croat*. 2022; 56(2):120-131.
36. Kielbassa AM, Beheim-Schwarzbach NJ, Neumann K, Nat R, Zantner C. In vitro comparison of visual and computer aided pre- and post-tooth shade determination using various home bleaching procedures. *J Prosthet Dent*. 2009;101(2):92-100.
37. Pessanha S, Silva S, Silveira JM, et al. Evaluation of the effect of fluorinated tooth bleaching products using polarized Raman microscopy and particle induced gamma-ray emission. *Spectrochim Acta A Mol Biomol Spectrosc*. 2020;236:118378.

38. Marques DN, da Mata AD, Silveira JM, et al. Hydrogen peroxide release kinetics into saliva from different whitening products: a double- blind, randomized clinical trial. *Clin Oral Investig*. 2012;16(1):155-163.
39. Karatas O, Gul P, Akgul N, et al. Effect of staining and bleaching on the microhardness, surface roughness and color of different composite resins. *Dent Med Probl*. 2021;58(3):369-376.
40. Polydorou O, Scheitza S, Spraul M, Vach K, Hellwig E. The effect of long-term use of tooth bleaching products on the human enamel surface. *Odontology*. 2018;106(1):64-72.
41. Bernardi LG, Favoreto MW, Carneiro TS, et al. Use of an applicator brush with high concentration bleaching gels. *Clin Oral Investig*. 2022; 26(10):6387-6395.
42. Mena-Serrano AP, Parreiras SO, do Nascimento EM, et al. Effects of the concentration and composition of in-office bleaching gels on hydrogen peroxide penetration into the pulp chamber. *Oper Dent*. 2015;40(2):E76-E82.
43. Favoreto MW, Madureira MP, Hass V, et al. A novel carbamide peroxide polymeric nanoparticle bleaching gel: color change and hydrogen peroxide penetration inside the pulp cavity. *J Esthet Restor Dent*. 2021;33(2):277-283.
44. Soares AF, Bombonatti JFS, Alencar MS, Consolmagno EC, Honório HM, Mondelli RFL. Influence of pH, bleaching agents, and acid etching on surface wear of bovine enamel. *J Appl Oral Sci*. 2016; 24(1):24-30.
45. Commission Internationale de l'éclairage. Recommendations on uniform color spaces, color-difference equations, psychometric color terms. *Color Res Applic*. 1977;2(1):5-6.

5 ARTIGO 2 - APPLICATION TIP AND CONCENTRATION OF A SELF-MIXING BLEACH: HYDROGEN PEROXIDE INSIDE THE PULP CHAMBER, COLOR CHANGE, AND AMOUNT OF BLEACHING GEL USED

TS Carneiro et al (2023). Application tip and concentration of a self-mixing bleach: hydrogen peroxide inside the pulp chamber, color change, and amount of bleaching gel used. J Op Dent, 48(2), 146-154.

STATUS: Publicado em 2023

REVISTA: Operative Dentistry

DOI: 10.2341/21-053-L

TS Carneiro [DDS, MSc, PhD student][1,2], MW Favoreto [DDS, MSc, PhD student][1], LG Bernardi [DDS, MSc, PhD student][1], MC Bandeca [DDS, MSc, PhD][3], CPF Borges [DDS, PhD][4], A Reis [DDS, PhD][1], AD Loguercio [DDS, MSc, PhD][1]

[1] Department of Restorative Dentistry, School of Dentistry, State University of Ponta Grossa, PR, Brazil.

[2] Department of Stomatology, IDIBO research group, Health Sciences Faculty, Rey Juan Carlos University, Alcorcón, Madrid, Spain.

[3] Department of Restorative Dentistry, School of Dentistry, CEUMA University, São Luís, MA, Brazil.

[4] Department of Chemistry, State University of Ponta Grossa, PR, Brazil.

Corresponding author:

Alessandro D Loguercio, Rua Carlos Cavalcanti, 4748 Bloco M, Sala 64-A, Uvaranas, Ponta Grossa, Paraná, Brazil 84030-900; e-mail: aloguercio@hotmail.com

Clinical Relevance

The application of a self-mixing in-office bleaching gel using a tip with a brush should be recommended because its use diminishes the penetration of hydrogen peroxide into the pulp chamber, and it results in less bleaching gel waste.

SUMMARY

Purpose: The objective of this study was to evaluate if the application method (tip with brush or tip without brush) and hydrogen peroxide (HP) concentration (6% or

35% self-mixing) of in-office bleaching gel influences the penetration of HP into the pulp chamber, color change, and the amount of bleaching gel used.

Methods: Forty healthy premolars were randomly divided into the following five groups (n=8): no treatment; HP6% using a tip with a brush, HP6% using a tip without a brush, HP35% using a tip with a brush, and HP35% using a tip without a brush. After treatments, the HP concentration (µg/mL) within the pulp chamber was determined using UV-Vis spectrophotometry. The color change (ΔE_{ab}, ΔE_{00}, and ΔWI_D) was evaluated using a digital spectrophotometer. The amount of gel used (g) in each group was measured using a precision analytical balance. Data from each test were submitted to parametric tests (α=0.05).

Results: The tip with a brush resulted in a lower amount of HP inside the pulp chamber and less gel used when compared with the tip without a brush, regardless of HP concentration ($p<0.05$). However, regarding the tip used, although no significant difference was observed when HP35% was used ($p>0.05$), a higher whitening effect was observed when the 6% HP was applied without a brush as opposed to with a tip brush ($p<0.05$).

Conclusions: The use of a tip with a brush, regardless of the in-office bleaching gel concentration (6% or 35% self-mixing), presented a lower penetration and lower volume of spent gel when compared to a tip without brush. However, the whitening effect depends on the concentration of HP used.

INTRODUCTION

Tooth color is an important factor for patients' self- confidence.[1] The search for a perfect white smile is greatly influenced by the media, mainly due to the evolution in the quality of colors in films, on TV, in print or electronic media, and on social media.[2]

Tooth bleaching is the procedure of choice for most professionals when it comes to whitening effect, being a safe, conservative, and effective procedure.[3] Usually, among the tooth bleaching techniques, in-office products use high concentrations (up to 40% hydrogen peroxide [HP]) of the bleaching gel,[4] whereas at-home bleaching uses low concentrations (around 3-3.5% of HP).[5]

When the techniques are compared, in-office bleaching presents some advantages, because it does not depend on patient collaboration, and faster whitening

results are observed. On the other hand, as higher HP concentrations are applied, higher tooth sensitivity (TS) levels also occur with in-office bleaching compared with at-home bleaching.[6-8] This is because TS after bleaching procedures is due to the ability of HP to penetrate the dental structure and reach the pulp chamber during bleaching, promoting an inflammatory response of the pulp.[9]

Various strategies have been tested to reduce the intensity or risk of TS, such as the application of desensitizing agents,[10] incorporation of desensitizing agents in the bleaching gel,[11] use of medications,[12] changes in pH,[13] and decreasing the concentrations of the bleaching gel used for in-office treatment.[14-18]

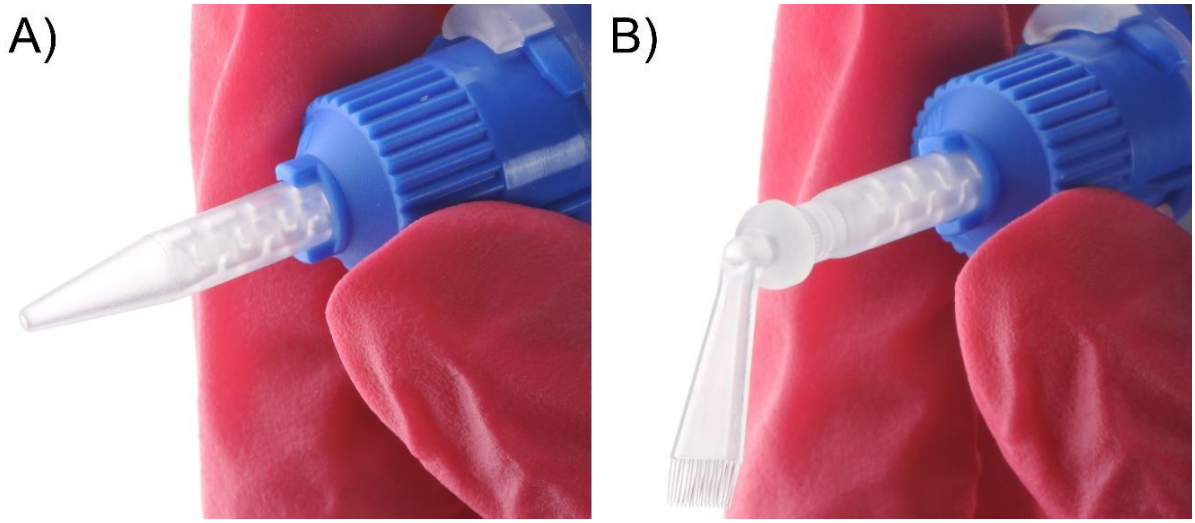
As is known, a lower concentration of HP leads to a decreased cytotoxic effect on pulp cells due to less diffusion of HP in the pulp chamber when compared with high concentrations.[19,20] In an effort to reduce this adverse effect, low-concentration bleaching gels using 6%–20% HP were placed on the market for in- office bleaching.[15-17,21] However, 6%–20% HP is usually associated with light application,[14-18] which does not simplify the application procedure.

However, it has been reported that TS does not depend only on HP concentration.[22,23] It could also depend on the amount of bleaching gel applied to the surface during the bleaching procedure. According to Fick's second law, the higher the volume of product applied, the greater the diffusion.[24] Therefore, it would be expected that if a lower amount of bleaching gel were applied, a lower amount of HP would penetrate the pulp chamber. This is the main reason that the majority of instructions from the manufacturers of in- office bleaching gels indicate the application of a thin layer of bleaching gel.[13,25,26]

Some in-office bleaching agents are in self-mixing form, where the mixture of two phases occurs without a brush tip (Figure 1A). However, more recently, these bleaching gels have also been available with a brush tip (Figure 1B). According to the manufacturers, brush tips have the ability to spread a thin and homogeneous layer of gel over the entire surface, saving a high amount of bleaching gel (Figure 2). However, to the extent of the authors' knowledge, no studies have evaluated the effect of different applicators/tips on the TS and whitening effect of in-office bleaching gels.

Therefore, the aim of the present *in vitro* study was to assess whether the application form (tip with or without brush) of higher and lower concentration self-mixing in-office bleaching gel influences the penetration of HP into the pulp chamber. The color change and amount of gel used were also evaluated. The null hypotheses tested were that: (1) there will be no difference in the concentration of HP within the pulp chamber, (2) there will be no difference in the amount of gel used, and (3) there will be no difference in the bleaching effectiveness when higher and lower concentration bleaching gels are applied with and without a brush tip.

Figure 1 - Tips for application of bleaching gels. A, tip without brush. B, tip with brush



METHODS AND MATERIALS

This study was submitted to the ethics committee of the State University of Ponta Grossa, PR, Brazil, which approved the study. Sound maxillary first and second premolars were obtained from the tooth bank of the local university. A stereomicroscope (Lambda LEB-3, ATTO instrument, Hong Kong, China) was used to analyze the enamel surface at 10× magnification. Specimens with morphological changes or cracks in the enamel were excluded. The teeth were previously analyzed with a digital spectrophotometer (VITA Easyshade Advance 4.0, VITA Zahnfabrik, Bad Säckingen, Germany); teeth lighter than A2 were excluded. Finally, teeth with a buccal thickness less than 2.5 mm and greater than 3.5 mm through previously performed radiography (Timex 70C, Gnatus, Ribeirão Preto, SP, Brazil) were also excluded. The products used are described in Table 3.

Sample Size Calculation

The main objective of the present study was quantifying the amount of HP that reaches the pulp chamber. Based on a pilot study carried out with low concentrations of 6% HP, an average of 0.030 ± 0.010 μg/mL of HP was observed inside the pulp chamber (data not shown). Using an alpha of 0.05, 80% power and a two-sided test, the minimum sample size was seven teeth per group in order to detect a 50% difference in the amount of HP inside the pulp chamber. However, taking into account possible losses of samples, eight teeth per group were used.

Table 3 - Commercial bleaching gel used in the study (manufacturer, composition, and application method)

Product (Manufacturer)	Composition	Application Method
Whiteness HP AutoMixx 6% (FGM, Jonville, SC, Brazil) pH 7.4±0.1[a]	6% Hydrogen peroxide(final concentration of HP 5.0%)[b] and digluconate calcium	1. With the self-mixing pointer (tip with or without brush) duly coupled to the double-body syringe that contains the whitening gel 2. Press the piston until the phases (peroxide and thickener) are slowly mixed 3. A small quantity of gel was dispensed into a container prior to applying the product to the tooth surface, to assure that the applied product is properly homogenized 4. The bleaching gel was applied until it completely covered the area of the teeth that were bleached, with a gel layer as thin as possible, using the self-mixing tip with brush or without brush, according to the experimental group 5. After applied, the gel left in contact with the tooth for 50 minutes 6. At the end, the gel was removed with a suction cannula and washing with deionized water only on the vestibular surface
Whiteness HP AutoMixx 35% (FGM) pH 6.1±0.4[a]	35% Hydrogen peroxide (final concentration of HP 32%)[b] and digluconate calcium	1. With the self-mixing pointer (tip with or without brush) duly coupled to the double-body syringe that contains the whitening gel 2. Press the piston until the phases (peroxide and thickener) are slowly mixed 3. A small quantity of gel was dispensed into a container prior to applying the product to the tooth surface, to assure that the applied product is properly homogenized 4. The bleaching gel was applied until it completely covered the area of the teeth that were bleached, with a gel layer as thin as possible, using the self-mixing tip with brush or without brush, according to the

		experimental group
		5. After applied, the gel left in contact with the tooth for 50 minutes 6. At the end, the gel was removed with a suction cannula and washing with deionized water only on the vestibular surface

[a]Measured pH assessed in triplicate (n=3).

[b]Measured HP amount assessed in triplicate (n=3).

Specimen Preparation

Prior to specimen preparation, X-ray radiographs were performed (Timex 70C, Gnatus, Ribeirão Preto, SP, Brazil). The purpose of this procedure was to exclude teeth with a buccal thickness less than 2.5 mm and greater than 3.5 mm, and thus prevent the influence of buccal thickness on the penetration of HP. For this purpose, the mesial face of the tooth was put in contact with the X-ray film. Each radiograph was taken with an exposure time of 0.5 seconds and a 30 cm focus-object distance (70 kVp-7 mA). The central X-ray beam was focused at a 90° angle to the tooth's distal surface. After exposure, the images were digitally obtained and the corresponding buccal tooth thickness was measured with New IDA software (Dabi Atlante, Ribeirão Preto, SP, Brazil). The mean buccal tooth thickness of the teeth employed in this study was 3.0 ± 0.3 mm (range = 2.7 to 3.3 mm). After specimen preparation, a low-speed diamond disk (Isomet 1000, Buehler Ltd, Lake Bluff, IL, USA) was used to remove approximately 3 mm apically to the cementum-enamel junction. Pulp tissue was removed and flushed with deionized water. A spherical bur (#1014, KG Sorensen, SP, Brazil) was used to carefully expand access to the pulp chamber to introduce 25 µL of the solution using a micropipette (LABMATE Soft, HTL Lab Solutions, Warsaw, Poland).

Obtaining the Study Calibration Curve and Quality Control Measurements

The analytical products used in this study were not purified in advance, and all solutions were prepared with deionized water. First, a typical reference line was plotted employing a 5.000 µg/mL stock solution prepared from a concentrated solution (50% HP, Pharmacy Eficácia, Ponta Grossa, PR, Brazil) this solution was diluted in an acetate buffer solution (pH=4) and calibrated using traditional methods. A

potassium permanganate solution was used to titrate the solution, determining its analytical grade and the actual concentration of the solution.[27] Based on this verified initial concentration, serial volumetric dilutions of 0.000–0.464 µg/mL were performed to plot the line of work. The known HP concentrations were added to the glass tubes and placed in a Cary 50 UV-Vis spectrophotometer (Varian, Palo Alto, CA, USA). This procedure yielded a standard reference line for the extrapolation of the study samples' results (R=0.996).

For quality control measurements, the amount of HP in the bleaching gel and pH were measured. The gel was titrated before the whitening procedure with a standard potassium permanganate solution to determine its concentrations within the tube (Table 4).[28,29] The pH of the bleaching agent was measured with a pH meter placed directly in contact with a bleaching gel (Extech pH100: ExStik pH Meter, Extech Instruments, Nashua, NH, USA) (Table 3).[29,30]

Experimental Groups and Treatment Protocols

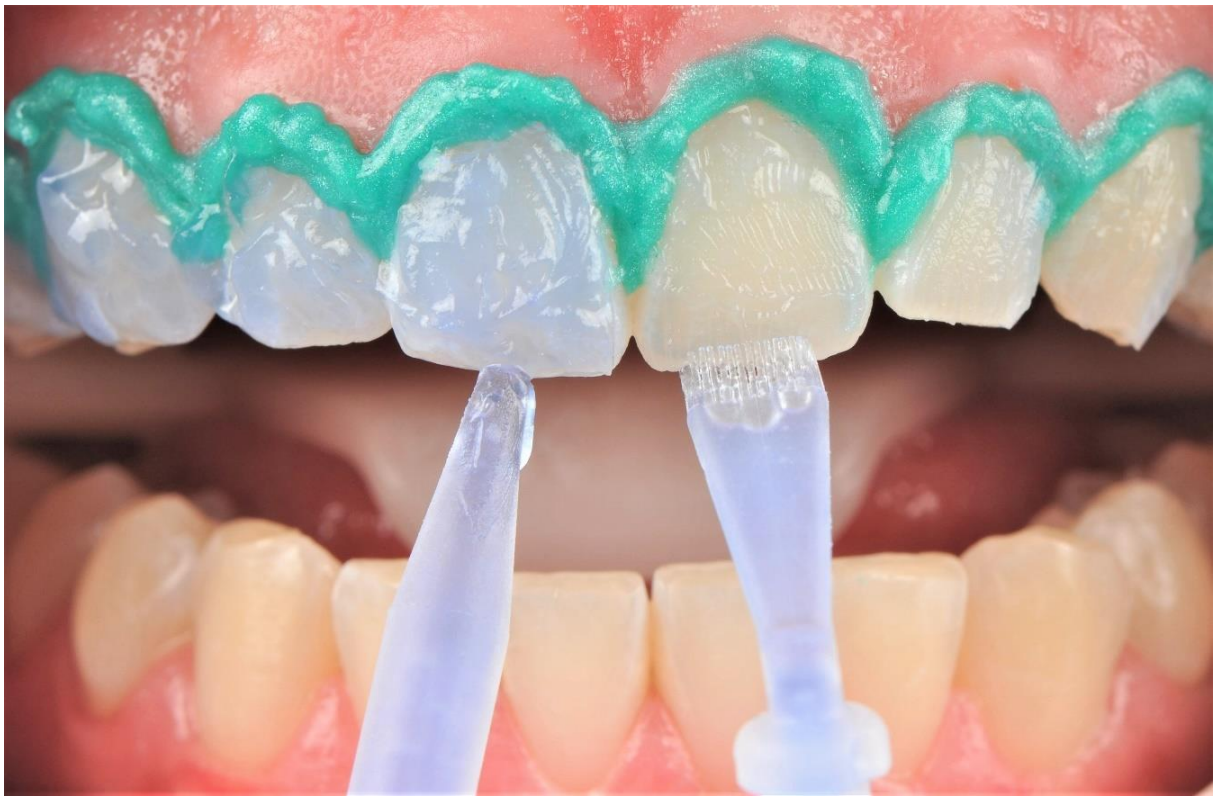
According to the treatment protocol, the 40 maxillary premolars previously selected were randomly divided into five groups (n=8). In the control group, no bleaching procedure was performed. The self-mixing gel (Whiteness HP Automixx 6%, FGM, Joinville, SC, Brazil) was used for two experimental groups, one of them using the tip with brush and the second one, using the tip without brush (Figure 1). The self-mixing gel (Whiteness HP Automixx 35%, FGM) was used for the two other experimental groups, one of them using the tip with brush and the second one, using the tip without brush (Figure 2). A single experienced operator, blinded to the assigned groups, was responsible for the materials application.

For all groups, the specimens were vertically fixed to a wax plate with the occlusal surface toward the plate. Before the bleaching agent was applied, the buccal surface of each specimen was isolated by applying a light-cured resin barrier enclosing an area of 6 mm^2 (Topdam, FGM). A 25-µL aliquot of the acetate buffer was inserted into the pulp chamber of each tooth to preserve and absorb all the HP that entered the pulp chamber during bleaching procedures.

In the experimental groups, the materials were manipulated according to the manufacturer's instructions (Table 3) and applied to the vestibular enamel area

according to the bleaching self-mixing gel used. The self-mixing was made using tips with brush and without brush (Sulzer Mixpac, Sulzer Ltd, Winterthur, Switzerland) for low concentration bleaching gel (Whiteness HP Automixx 6%, FGM) and using tips with brush and without brush (Sulzer Mixpac, Sulzer Ltd) for high concentration bleaching gel (Whiteness HP Automixx 35%, FGM).

Figure 2 - Examples of both tips for application of bleaching gels. On the left side, a tip without a brush, and on the right side, a tip with a brush. A thin and homogeneous layer of gel can be observed over the entire surface, saving a high amount of bleaching gel, when a tip with a brush was used



Evaluation of the Amount of Bleaching Gel Used

To evaluate the amount of gel used during each application according to the application tip used (with and without brush), each specimen was weighed individually on a precision analytical digital balance AUX220 (SHIMADZU, Kyoto, Japan) before and immediately after the application of the different bleaching agents.

HP Quantification Into the Pulp Chamber

After the bleaching procedure, using a mechanical micropipette, the acetate buffer solution inside the pulp chamber of each sample was removed and transferred to

a glass tube. This procedure was performed by rinsing the pulp chamber of each sample four times with 25 µL of acetate buffer and transferring this solution to the same glass tube. Thereafter, more distilled water (2.725µL) was added to the glass tube along with 100µL of 0.5 mg/mL (Leucocrystal Violet, Sigma Chemical Co, St Louis, MO, USA) and 50 µL of 1 mg/mL horseradish peroxidase enzyme (Peroxidase Type VI- A, Sigma Chemical Co). This procedure was repeated separately for each specimen. The resulting solution had a violet color with a maximum absorbance peak at 596 nm, which was measured using a Cary 50 UV-Vis spectrophotometer (Varian). According to Beer's Law, absorbance corresponds directly to concentration. Therefore, HP concentration (µg/mL) was determined by comparing it with the calibration curve already obtained.

Color Change Evaluation

A digital spectrophotometer (VITA Easyshade Advance 4.0, VITA Zahnfabrik) was used to measure the color change before and one week after the bleaching treatment. During this period, the specimens were immersed in artificial saliva, with a temperature control of 37°C. The artificial saliva was changed every day.

To measure the initial color of the specimens, guides were made with dense condensation silicone in order to standardize the position of the spectrophotometer (Perfil, Coltène, Rio de Janeiro, RJ, Brazil) through a 6 mm diameter window with a metal device on the third of the buccal surface for each specimen.

The color parameters (L*, a* and b*) were recorded through the tip of the device inserted in the silicone guide. The L* value represents the lightness (the values varied from 0 for black to 100 for white), the a* value represents the color along the red-green axis, and the b* value represents the color along the yellow-blue axis. The color change before (baseline) and after treatment (in each evaluation period) was given by the difference between the measurements with the spectrophotometer using the CIELab formula[31]: $\Delta E_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. In addition, the color change was also based on the CIEDE 2000 formula[32]: $\Delta E_{00} = [(\Delta L /kLSL)^2 + (\Delta C/kCSC)^2 + (\Delta H/kHSH)^2 + RT (\Delta C^*\Delta H /SC^*SH)]^{1/2}$. The whiteness index ($WI_D$) was calculated according to the following formula[33]:

$$WI_D = 0.551 \times L - 2.324 \times a - 1.1 \times b$$

Moreover, changes in WI_D caused by each step were calculated by subtracting the values observed at each assessment time from those calculated in the prior step (ΔWI_D).

Statistical Analysis

The data were analyzed using the Kolmogorov-Smirnov test to assess whether the data were normally distributed and via the Bartlett test for equality of variance to verify the assumption of equality ofvariances (data not shown). As the data failed to show normality, the data of amount of gel used (g), on the penetration of HP (µg/mL) into the pulp chamber, as well as the color change (ΔE_{ab}, ΔE_{00}, and ΔWI_D) were subjected to parametric one-way ANOVA and Tukey test for pairwise comparisons (α=0.05).

RESULTS

Evaluation of the Amount of Bleaching Gel Used

The amount of bleaching gel expended is shown in Table 4. A higher amount of HP was expended when HP35% groups were compared with HP6% groups (Table 4; p<0.05). However, regardless of the concentration, a lower amount of HP was used when a tip with a brush was used compared with a tip without a brush (Table 4; p<0.05).

HP Penetration Into the Pulp Chamber

The amount of HP inside the pulp chamber is shownin Table 4. A lower amount of HP was found inside thepulp chamber in the control group (Table 4; p<0.05). On the other hand, the amount of HP from the HP35% groups was significantly higher than from the HP6% groups (Table 4; p<0.05). Independent of the bleaching gel used, the tip with a brush resulted in a lower amount of HP inside the pulp chamber when compared withthe tip without a brush (Table 4; p<0.05).

Table 4 - Means (± standard deviations) of the amount of gel used for bleaching (g) and HP concentration (µg/mL) detected inside the pulp chamber in different experimental groups

Experimental Groups	Gel Used for Bleaching (g)[a]	HP Concentration (µg/mL)[a]
Control	0.000 ± 0.000 A	0.003 ± 0.002 a

HP6%	Tip with brush	0.041 ± 0.027 B	0.012 ± 0.006 b
	Tip without brush	0.088 ± 0.046 C	0.039 ± 0.033 c
HP35%	Tip with brush	0.045 ± 0.026 B	0.363 ± 0.117 d
	Tip without brush	0.094 ± 0.083 C	1.209 ± 0.783 e

[a]Identical capital or lowercase letters in each column indicate statistically similar means (one-way ANOVA and Tukey test, α=0.05).

Color Change Evaluation

The color change measurements are shown in Table 5. No significant bleaching was found in the control group (Table 5; $p>0.05$). The HP35% groups presented significantly more whitening than the HP6% groups did when measured in terms of ΔE_{ab}, ΔE_{00}, and ΔWI_D (Table 5; $p<0.05$). Regarding the tip used, a higher whitening effect was observed when HP6% was applied without a brush for all color measurements, although it was only significant for ΔE_{ab} and ΔWI_D (Table 5; $p<0.05$).

Table 5 - Means (± standard deviations) of the color change in different objective assessments (ΔE_{ab}, ΔE_{00}, and ΔWI_D) in different experimental groups[a]

	Experimental Groups	**ΔE_{ab}**	**ΔE_{00}**	**ΔWI_D**
Control		1.2 ± 0.6 D	0.8 ± 0.4 c	1.2 ± 0.8 D
HP6%	Tip with brush	4.5 ± 0.9 C	2.8 ± 0.6 b	5.7 ± 1.5 C
	Tip without brush	6.7 ± 1.4 B	4.5 ± 1.1 b	8.2 ± 2.6 B
HP35%	Tip with brush	8.1 ± 1.6 A	4.7 ± 1.0 ab	11.3 ± 3.7 A
	Tip without brush	8.6 ± 2.4 A	5.1 ± 0.8 a	10.1 ± 3.2 A

[a]Identical capital or lowercase letters in each column indicate statistically similar means (one-way ANOVA and Tukey test, α=0.05).

DISCUSSION

The results of the present study showed a high amount of HP observed inside the pulp for HP35% when compared with HP6%, leading us to partially reject the first null hypothesis. This was expected because several studies have shown that the higher the HP concentration, the higher the amount of HP inside the pulp chamber.[19,28,34]

However, as pointed out in the introduction, the excessive amount of HP that reaches the pulp tissue when HP35% is applied promotes an intense inflammatory response.[9] For instance, clinical studies have shown that more than 80% of patients undergoing bleaching reported TS during and soon after an in- office session with

HP35%.[10,12,17,18] Although this adverse effect is usually considered temporary and moderate, it can produce considerable discomfort to the patient and, in some cases, considerable pulpal damage could be seen in histological studies.[35-37]

However, a significantly lower amount of HP was observed inside the pulp chamber when HP35% bleaching gel was applied with a brush tip, instead of without a brush tip. It seems that the lower amount of HP inside the pulp chamber is directly related to the 50% lower volume of bleaching gel used with a brush tip when compared with application without a brush tip for the HP35% groups. This leads us to partially reject the second null hypothesis.

Although no previous study has evaluated the amount of gel wasted when different tips are used, some studies have shown that when the amount of HP was lower, the TS was lower. For instance, Cintra and others[35] showed that doubling the amount of HP further enhanced the extent of damage to the pulp tissue when compared with one application. Kose and others[38] confirmed that a higher number of patients with TS was observed when the in-office bleaching gel was applied twice, in comparison with only once. However, both studies only applied the bleaching product without a brush tip.[35,38] Therefore, future clinical studies need to be conducted to evaluate the effect of different tips for application of HP35% gel on decreasing the TS induced by in- office bleaching.

Another alternative to diminish the TS induced by bleaching is to use low-concentration HP products. In fact, in the majority of countries in the European Union, it is totally forbidden to use HP35%. The Scientific Committee on Consumer Products of the European Union only considers bleaching products with concentrations of up to 6% HP as safe to use.[39] This is the main reason, in the present study, for using a low-concentration gel for in-office bleaching.

As expected, low amounts of HP inside the pulp,[28,40] as well as a lower whitening effect, were observed for HP6% when compared with higher concentrations.[14,16] Despite some differences among color change values according to the measurements used (ΔE_{ab}, ΔE_{00}, and ΔWI_D), HP35% was more effective in terms of bleaching than HP6%, as observed in the clinical study published by Bortolatto.[16] This leads us to partially reject the third null hypothesis. In fact, because the whitening effect occurs due to the

oxidation of the pigments by HP, the higher the concentration, the greater the bleaching effect.[9]

This seems to be a disadvantage to HP6% gels, because the main reason to use in-office bleaching is to produce faster and immediate whitening results.[4] However, a closer view regarding the color change results showed that the application of HP6% caused a good bleaching effect pattern, with only 12-32% lower whitening results compared with the application of HP35%, despite a huge difference in HP concentration. HP6% contains only 17% of the amount of HP when compared with HP35%.

In reality, as opposed to the HP35% groups, a significantly higher bleaching effect (ΔE_{ab} and ΔWI_D) was observed for HP6% when applied without the brush tip as opposed to with the brush tip. In the same way, a significantly higher volume of HP bleaching gel was spent when the former was used. When a higher amount of bleaching gel was available, as for HP35%, increasing the volume of gel used did not seem to necessarily improve the whitening effect. On the other hand, due to increasing the amount of gel spent, application without the brush tip, instead of with the brush tip, was important when an HP6% in-office gel was used. Even when more HP was spent, as through application without the brush tip for HP6%, the amount of HP inside the pulp was only 5% of the quantity observed when HP35% was applied with a brush tip, indicating that lower levels of TS should be expected when HP6% is applied without a brush tip. However, these results need to be evaluated in future clinical studies.

Unfortunately, even when no brush tip was used for HP6%, a lower effectiveness of bleaching was observed when compared with the HP35% groups (ΔE_{ab} and ΔWI_D). It is worth mentioning that only one application time in one bleaching session was evaluated in the present study, which is not enough, from the clinical point of view, to achieve patient satisfaction when in- office bleaching is applied.[38,41-43] In reality, increasing the number of changes, applications, or sessions of in-office bleaching gel could improve the *in vitro* and clinical results.[19,38,42,44] Future studies evaluating different factors to improve the whitening effect of HP6% should be conducted.

Another factor to be considered is that the viscosities of the products used could interfere with penetration of HP inside the pulp chamber, since a previous study

reported that gels with lower viscosity tend to have greater penetration and gels with higher viscosity have a lower penetration of HP.[23] Unfortunately, the viscosity of these gels are not measured yet and future studies should be conducted to evaluate this hypothesis. Although two different commercial products were evaluated, the results should not be extrapolated for all commercial brands, and this should be considered as a limitation of the present study. Therefore, future studies evaluating different commercial brands should be conducted.

Although, to the extent of the authors' knowledge, this is the first study to evaluate different tips and their effect on bleaching characteristics, it is worth mentioning that only two self-mixing in-office products were evaluated. Due to the several differences among in-office bleaching materials, it is not clear to the authors if these results could be indicated for all commercial brands available in the market. Therefore, future studies need to be conducted to confirm these hypotheses in other self-mixing bleaching materials.

CONCLUSION

A brush tip should be indicated for a self-mixing in- office HP35% gel due to a significantly lower amount of HP penetrating the pulp chamber, as well as less bleaching gel waste. Using a smaller amount of gel during bleaching would theoretically make this procedure more economically profitable, presenting a cost-effective protocol for dentists. On the other hand, application without a brush tip should be considered a primary indication for a self-mixing in-office HP6% gel, mainly because a significant improvement in the bleaching effect was observed.

Acknowledgments

The authors would like to thank FGM Dental Group and Sulzer for the generous donation of the bleaching products employed in this study. This study was partially supported by the National Council for Scientific and Technological Development (CNPq) under grants 304817/2021-0 and 308286/2019-7 and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES) – Finance Code 001.

Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects oversight committee guidelines and policies of State University of Ponta Grossa. Approval code 4.647.755.

Conflict of Interest

The authors of this article 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.

REFERENCES

1. Campos LA, Costa MA, Bonafé FSS, Marôco J, & Campos JADB (2020) Psychosocial impact of dental aesthetics on dental patients International *Dental Journal* **70(5)** 321-327. doi: 10.1111/idj.12574
2. Theobald AH, Wong BKJ, Quick AN, & Thomson WM (2006) The impact of the popular media on cosmetic dentistry *New Zealand Dental Journal* **102(3)** 58-63.
3. Kihn PW (2007) Vital tooth whitening *Dental Clinics of North America* **51(2)** 319-331. viii. doi: 10.1016/j.cden.2006.12.001
4. Reis A, da Silva LM, Martins L, & Loguercio A (2018) In-office tooth whitening *Clinical Dentistry Reviewed* **2(1)** 10. https://doi. org/10.1007/s41894-018-0021-9
5. De Geus JL, Wambier LM, Boing TF, Loguercio AD, & Reis A (2018) At-home bleaching with 10% vs more concentrated carbamide peroxide gels: A systematic review and meta-analysis *Opererative Dentistry* **43(4)** E210-E222. doi: 10.2341/17-222-L
6. Machado LS, Anchieta RB, dos Santos PH, Briso AL, Tovar N, Janal MN, Coelho PG, & Sundfeld RH (2016) Clinical comparison of at-home and in-office dental bleaching procedures: A randomized trial of a split-mouth design *International Journal of Periodontics & Restorative Dentistry* **36(2)** 251-260. doi: 10.11607/ prd.2383
7. Tay LY, Kose C, Herrera DR, Reis A, & Loguercio AD (2012) Long-term efficacy of in-office and at-home bleaching: A 2-year double-blind randomized clinical trial *American Journal of Dentistry* **25(4)** 199-204.

8. Bernardon JK, Sartori N, Ballarin A, Perdigão J, Lopes GC, & Baratieri LN (2010) Clinical performance of vital bleaching techniques *Operative Dentistry* **35(1)** 3-10. doi: 10.2341/09-008CR
9. Kwon SR & Wertz PW (2015) Review of the mechanism of tooth whitening *Journal of Esthetic and Restorative Dentistry* **27(5)** 240- 257. doi: 10.1111/jerd.12152
10. Martini EC, Parreiras SO, Szesz AL, Coppla FM, Loguercio AD, & Reis A (2020) Bleaching-induced tooth sensitivity with application of a desensitizing gel before and after in-office bleaching: A triple-blind randomized clinical trial *Clinical Oral Investigations* **24(1)** 385-394. doi: 10.1007/s00784-019-02942-9
11. Basting RT, Amaral FLB, França FMG, & Flório FM (2012) Clinical comparative study of the effectiveness of and tooth sensitivity to 10% and 20% carbamide peroxide home-use and 35% and 38% hydrogen peroxide in-office bleaching materials containing desensitizing agents *Operative Dentistry* **37(5)** 464-473. doi: 10.2341/11-337-C
12. Paula E, Kossatz S, Fernandes D, Loguercio A, & Reis A (2013) The effect of perioperative ibuprofen use on tooth sensitivity caused by in-office bleaching *Operative Dentistry* **38(6)** 601-608. doi: 10.2341/12-107-C
13. Loguercio AD, Servat F, Stanislawczuk R, Mena-Serrano A, Rezende M, Prieto MV, Cereño V, Rojas MF, Ortega K, Fernandez E, & Reis A (2017) Effect of acidity of in-office bleaching gels on tooth sensitivity and whitening: A two-center double-blind randomized clinical trial *Clinical Oral Investigations* **21(9)** 2811-2818. doi: 10.1007/s00784-017-2083-5
14. Estay J, Angel P, Bersezio C, Tonetto M, Jorquera G, Peña M, & Fernández E (2020) The change of teeth color, whiteness variations and its psychosocial and self-perception effects when using low vs. high concentration bleaching gels: A one-year follow-up *BMC Oral Health* **20(1)** 255. doi: 10.1186/s12903-020-01244-x
15. Bortolatto JF, Pretel H, Floros MC, Luizzi ACC, Dantas AAR, Fernandez E, Moncada G, & de Oliveira OB, Jr. (2014) Low Concentration H(2)O(2)/TiO_N in office bleaching: A randomized clinical trial *Journal of Dental Research* **93(7 Supplement)** 66S-71S. doi: 10.1177/0022034514537466

16. Bortolatto JF, Trevisan TC, Bernardi PSI, Fernandez E, Dovigo LN, Loguercio AD, de Oliveira BO Jr, & Pretel H (2016) A novel approach for in-office tooth bleaching with 6% H_2O_2/TiO_N and LED/laser system-a controlled, triple-blinded, randomized clinical trial *Lasers in Medical Science* **31(3)** 437-444. doi: 10.1007/ s10103-016-1866-2
17. Mena-Serrano AP, Garcia E, Luque-Martinez I, Grande Rhm, Loguercio AD, & Reis A (2016) A single-blind randomized trial about the effect of hydrogen peroxide concentration on light-activated bleaching *Operative Dentistry* **41(5)** 455-464. doi: 10.2341/15-077-C
18. Lima SNL, Ribeiro IS, Grisotto MA, Fernandes ES, Hass V, Tavarez RRdJ, Pinto SCS, Lima DM, Loguercio AD, & Bandeca MC (2018) Evaluation of several clinical parameters after bleaching with hydrogen peroxide at different concentrations: A randomized clinical trial *Journal of Dentistry* **68** 91-97. doi: 10.1016/j.jdent.2017.11.008
19. Soares DG, Basso FG, Hebling J, & de Souza Costa CA (2014) Concentrations of and application protocols for hydrogen peroxide bleaching gels: Effects on pulp cell viability and whitening efficacy *Journal of Dentistry* **42(2)** 185-198. doi: 10.1016/j.jdent.2013.10.021
20. Soares DG, Basso FG, Pontes ECV, Garcia LdFR, Hebling J, & Costa CAdS (2014) Effective tooth-bleaching protocols capable of reducing H_2O_2 diffusion through enamel and dentine *Journal of Dentistry* **42(3)** 351-358. doi: 10.1016/j.jdent.2013.09.001
21. Ferraz NKL, Nogueira LC, Neiva IM, Ferreira RC, Moreira AN, & Magalhães CS (2019) Longevity, effectiveness, safety, and impact on quality of life of low-concentration hydrogen peroxides in-office bleaching: A randomized clinical trial *Clinical Oral Investigations* **23(5)** 2061-2070. doi: 10.1007/s00784-018-2607-7
22. Torres CRG, Wiegand A, Sener B, & Attin T (2010) Influence of chemical activation of a 35% hydrogen peroxide bleaching gel on its penetration and efficacy—*in vitro* study *Journal of Dentistry* **38(10)** 838-846. doi: 10.1016/j.jdent.2010.07.002
23. Kwon SR, Pallavi Fnu, Shi Y, Oyoyo U, Mohraz A, & Li Y (2018) Effect of bleaching gel viscosity on tooth whitening efficacy and pulp chamber

penetration: An *in vitro* study *Operative Dentistry* **43(3)** 326-334. doi: 10.2341/17-099-L

24. Crank J (1979) The Mathematics of Diffusion Oxford University Press, *Oxford*.
25. Kossatz S, Martins G, Loguercio AD, & Reis A (2012) Tooth sensitivity and bleaching effectiveness associated with use of a calcium-containing in-office bleaching gel *Journal of the American Dental Association* **143(12)** e81-e87. doi: 10.14219/jada. archive.2012.0075
26. Martins Ieb, Onofre S, Franco N, Martins LM, Montenegro A, Arana-Gordillo LA, Reis A, Loguercio AD, & da Silva LM (2018) Effectiveness of in-office hydrogen peroxide with two different protocols: A two-center randomized clinical trial *Operative Dentistry* **43(4)** 353-361. doi: 10.2341/17-128-C
27. Mendham J, Denney RC, Barnes JD, & Thomas MJK (2002) Vogel's Análise Química Quantitativa *Livros Técnicos e Científicos Editora Ltd Brazil* 144-156.
28. Parreiras SO, Favoreto MW, Cruz GP, Gomes A, Borges CPF, Loguercio AD, & Reis A (2020) Initial and pulp chamber concentration of hydrogen peroxide using different bleaching products *Brazilian Dental Science* **23(2)** 1-8. doi: 10.14295/ bds.2020.v23i2.1942
29. Favoreto MW, Madureira MP, Hass V, Maran BM, Parreiras SO, Borges CPF, Reis A, & Loguercio AD (2021) A novel carbamide peroxide polymeric nanoparticle bleaching gel: Color change and hydrogen peroxide penetration inside the pulp cavity *Journal of Esthetic and Restorative Dentistry* **33(2)** 277-283. doi: 10.1111/ jerd.12652
30. Soares AF, Bombonatti JFS, Alencar MS, Consolmagno EC, Honório HM, & Mondelli RFL (2016) Influence of pH, bleaching agents, and acid etching on surface wear of bovine enamel *Journal of Applied Oral Science* **24(1)** 24-30. doi: 10.1590/1678-775720150281
31. De L'Eclairage (1978) Recommendations on uniform color spaces, color-difference equations, psychometric color terms. *Color Research and Application* **2(1)** 5-6. doi: 10.1002/j.1520-6378.1977.tb00102.x.
32. Luo MR, Cui G, & Rigg B (2001) The development of the CIE 2000 colour-difference formula: CIEDE2000 *Color Research and Application* **26(5)** 340-350. doi: 10.1002/col.1049

33. Pérez MdM, Ghinea R, Rivas MJ, Yebra A, Ionescu AM, Paravina RD, & Herrera LJ (2016) Development of a customized whiteness index for dentistry based on CIELAB color space *Dental Materials* **32(3)** 461-467. doi: 10.1016/j.dental.2015.12.008
34. Cintra LTA, Benetti F, Ferreira LL, Gomes-Filho JE, Ervolino E, Gallinari MdO, Rahal V, & Briso ALF (2016) Penetration capacity, color alteration and biological response of two in-office bleaching protocols *Brazilian Dental Journal* **27(2)** 169-175. doi: 10.1590/0103-6440201600329
35. Cintra LTA, Benetti F, da Silva Facundo AC, Ferreira LL, Gomes-Filho JE, Ervolino E, Rahal V, & Briso ALF (2013) The number of bleaching sessions influences pulp tissue damage in rat teeth *Journal of Endodontics* **39(12)** 1576-1580. doi: 10.1016/j. joen.2013.08.007
36. Roderjan DA, Stanislawczuk R, Hebling J, Costa CAdS, Reis A, & Loguercio AD (2015) Response of human pulps to different in- office bleaching techniques: Preliminary findings *Brazilian Dental Journal* **26(3)** 242-248. doi: 10.1590/0103-6440201302282
37. Costa CAdS, Riehl H, Kina JF, Sacono NT, & Hebling J (2010) Human pulp responses to in-office tooth bleaching *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **109(4)** e59-e64. doi: 10.1016/j.tripleo.2009.12.002
38. Kose C, Calixto AL, Bauer JRO, Reis A, & Loguercio AD (2016) Comparison of the effects of in-office bleaching times on whitening and tooth sensitivity: A single blind, randomized clinical trial *Operative Dentistry* **41(2)** 138-145. doi: 10.2341/15-085-C
39. European Commission Scientific Committee on Consumer Products (2005) Public consultation on a preliminary opinion on hydrogen peroxide in tooth whitening products. Available at: https://ec.europa.eu/health/scientific_committees/consultations/public_consultations/sccp_cons_01_en.htm
40. Joiner A & Thakker G (2004) In vitro evaluation of a novel 6% hydrogen peroxide tooth whitening product *Journal of Dentistry* **32(Supplement 1)** 19-25. doi: 10.1016/j.jdent.2003.10.007

41. Gottardi MdS, Brackett MG, & Haywood VB (2006) Number of in-office light-activated bleaching treatments needed to achieve patient satisfaction *Quintessence International* **37(2)** 115-120.
42. Reis A, Tay LY, Herrera DR, Kossatz S, & Loguercio AD (2011) Clinical effects of prolonged application time of an in-office bleaching gel *Operative Dentistry* **36(6)** 590-596. doi: 10.2341/10- 173-C
43. Bernardon JK, Ferrari P, Baratieri LN, & Rauber GB (2015) Comparison of treatment time versus patient satisfaction in at- home and in-office tooth bleaching therapy *Journal of Prosthetic Dentistry* **114(6)** 826-830. doi: 10.1016/j.prosdent.2015.05.014
44. Sulieman M, Addy M, MacDonald E, & Rees JS (2004) The effect of hydrogen peroxide concentration on the outcome of tooth whitening: An in vitro study *Journal of Dentistry* **32(4)** 295- 299. doi: 10.1016/j.jdent.2004.01.003

6 ARTIGO 3 - IN-OFFICE DENTAL BLEACHING IN ADOLESCENTS USING 6% HYDROGEN PEROXIDE WITH DIFFERENT APPLICATION TIPS: RANDOMIZED CLINICAL TRIAL

STATUS: Publicado em 2023

REVISTA: Journal of Applied Oral Science

DOI: 10.1590/1678-7757-2023-0216

Taynara de Souza CARNEIRO[1,2] Michael Willian FAVORETO[1] Michel Wendlinger Cantanhede FERREIRA[1] Laís Giacomini BERNARDI[1] Heloísa Forville de ANDRADE[1] Matheus Coelho BANDECA[1] Alessandra REIS[1] Laura CEBALLOS GARCÍA[2] Alessandro Dourado LOGUERCIO[1]

[1]Universidade Estadual de Ponta Grossa, Departamento de Dentística Restauradora, Ponta Grossa, Brasil.

[2]Universidad Rey Juan Carlos, Facultad de Ciencias de la Salud, IDIBO, Madrid, España.

Corresponding address: Alessandra Reis Universidade Estadual de Ponta Grossa - Curso de Odontologia - Avenida Carlos Cavalcanti, 4748 - Bloco M - Sala 64-A - 84.030-900 - Ponta Grossa - Brasil. Phone: +55 4232203740 e-mail: reis_ale@hotmail.com

Abstract

Despite the availability of in-office bleaching gels with a 6% concentration of hydrogen peroxide (HP), these gels have not been evaluated in younger patients. They are commercially available with a tip, associated or not with a brush, where the tip with a brush spreads the gel over the entire surface to have a smaller thickness (thin layer) since the manufacturers indicate the application of a thin layer of gel. Objective: This randomized, split-mouth, double-blind clinical trial evaluated the efficacy of in-office bleaching with 6% HP in adolescents using different application tips, as well tooth sensitivity (TS) and aesthetic self-perception. Methodology: Sixty participants were randomized for 6% HP self-mixing bleaching gel tip design: without brush andwith brush. In-office bleaching was performed in 3 sessions of 50 minutes. Color change was evaluated using a digital spectrophotometer (ΔE_{ab}, ΔE_{00}, and ΔWI_D) and color guide

(ΔSGU), the absolute risk and intensity of TS with a visual analogue scale and aesthetic self-perception with the oral aesthetic scale (α=0.05). Results: The groups achieved similar bleaching regardless of the application tip (p>0.05). However, only for ΔWI_D, a significant mean difference (MD) was observed in the third week (MD 2.3; 95% CI 1.2 to 3.3; p<0.001) and at one month (MD 1.6; 95% CI 0.6 to 2.6; p<0.03) favoring the tip without brush. Regarding TS, 45% in the tip-without-brush group and 33% in the tip-with-brush group reported TS (odds ratio 0.61; 95% CI 0.29 to 1.28; p<0.02), with low TS intensity (MD 0.05; 95% CI -0.06 to 0.17; p>0.36). All patients reported improved aesthetic self-perception after bleaching (MD -1.3; 95% -1.8 to -0.9; p<0.001). Conclusions: Regardless of the tip used bleaching with 6% HP achieved a bleaching efficacy and improved the aesthetic self-perception. However, a lower risk of TS for application using the tip with brush was observed.

Keywords: Tooth Bleaching. Hydrogen Peroxide. Adolescent. Clinical Trial. Bleaching Agents.

Introduction

At-home bleaching, a technique for vital teeth, consists of applying a bleaching gel in low concentrations, distributed in individual trays and performed by the patient.[1,2] However, while some adolescents find the trays very easy to use, others consider this procedure a little difficult, especially when excess gel needs to be removed.[3] In-office bleaching is an option that does not depend on the patient's cooperation and provides a faster result.[4,5] However, since in-office bleaching requires higher concentrationsof bleaching gel [up to 40% hydrogen peroxide (HP)],higher levels of tooth sensitivity (TS) are reported.[6]

TS is explained by the inflammatory response of the pulp, which is a consequence of HP penetrating the tooth structure and reaching the pulp chamber.[7,8,9,10] TS after bleaching may be expressed as a momentary sharp pain or discomfort. It is important to highlight that post-bleaching TS is transient and usually disappears as the inflammatory response subsides.[7-10] However, in certain cases, TS can lead patients to discontinue treatment.[7]

This deleterious effect is expected to be even more relevant in younger patients (children and adolescents), as their teeth are more permeable to external stimuli due to maturation.[11,12] These patients also have a larger pulp chamber compared with older patients,[13] creating the potential for more intense TS. Moreover, they express a greater preference for lighter teeth than older patients.[14] Aesthetic procedures can improve the patient's emotional well-being and self-esteem[15,16] and, among these procedures, tooth bleaching is the least invasive technique,[17] improving color.[18,19] However, more than 68% of the members of an important academy of pediatric dentistry reported that they do not provide vital bleaching for young patients.[20] Currently, the most suitable technique for young patients is the use of low-concentration at-home bleaching.[21]

Several manufacturers have introduced low- concentration (HP 6–20%) in-office bleaching gels to the market,[22-27] and only a few studies have been performed in younger patients, usually evaluating in-office bleaching gel at a concentration of around 20–25% HP.[28,29] Interestingly, despite the availability of in-office bleaching gels with a concentration lower than 20% (i.e., 6%), these gels have not been evaluated in younger patients.[22,30,31] These in-office bleaching gels are marketed with a tip, with or without brush. The conventional tip (without brush) is the most commonly used, however, among its variations, there is one with an applicator brush, which spreads the gel over the entire surface to obtain a smaller thickness (thin layer) and increases contact with the surface, since manufacturers recommend applying a thin layer of gel.[32] It has been established that the thinner the layer used,[33] the lower the amount of bleaching gel used,[8,9] the lower the diffusion,[34] and the lower the degree of TS.[32]

A recent *in vitro* study[8] tested the effectiveness of various application tips for 6% HP. Results showed that when the tip with a brush was used, the gel penetrated less into the pulp chamber and required approximately three times less gel compared with the tip without brush. However, when evaluating color change, a small difference was detected, favoring the tip without brush. Although *in vitro* studies are necessary to create hypotheses, they are not sufficient to make clinical recommendations. Therefore, to the best of the authors' knowledge, no clinical studies have been conducted in adolescents to evaluate the bleaching effect of using different application tips with 6% HP bleaching gel in an in-office technique.

Therefore, this study aimed to evaluate the efficacyof in-office bleaching with 6% HP in adolescents using different application tips, as well as the risk and intensity of TS and aesthetic self-perception. We tested the following four null hypotheses: when performing in-office bleaching with 6% HP in adolescents, the use of different application tips 1) will not affect color change; 2) will not affect the absolute risk of TS; 3) will not affect the intensity of TS; and 4) will not affect aesthetic self-perception.

Methodology

Study design

The study was a randomized, split-mouth, double-blind clinical trial with a 1:1 allocation ratio. The description of the experimental design is in accordance with the specifications of the Consolidated Standards of Reporting Trials (CONSORT).[35] This study was approved by the Research Ethics Committeeof the State University of Ponta Grossa, PR, Brazil (4.825.578) and registered in the Brazilian Clinical Trials Registry (RBR-274vf96).

Recruitment

All participants were recruited via social media. The authors designed attractive visual content for dissemination on Instagram®, respecting specific eligibility criteria. Along with these posts, a link was shared to a form with fields for providing names and contact details. Once participants had completed the form, they were added to a list. The authors then contacted them to schedule the initial assessment and verify whether participants met the established inclusion and exclusion criteria. This approach consisted of sharing posts on the Instagram® feed and stories of the research group's user account (@bleachingbond). The authors and other members of the research team also reposted this content to further amplify its reach.

Eligibility criteria

Inclusion criteria: Adolescents aged 12 to 16 years, with vital teeth, no periodontal disease, carious lesions, endodontic treatment, in good oral and general health, and with both upper canines colored A2 or darker, according to the VITA Classical Shade Guide (VITA Zahnfabrik, Bad Säckingen, Germany). Moreover, their

guardians read and signed an informed consent form before their inclusion in the study.

Exclusion criteria: Participants who had undergone previous tooth bleaching, had previous TS, were on chronic medication, used fixed orthodontic appliance or prosthesis, had gingival recession, parafunction, discoloration due to tetracycline or fluorosis, were pregnant or lactating women, smoked, or had visible cracks in their teeth.

All data were collected from September 2021 to January 2022 at the State University of Ponta Grossa.

Study intervention

Two weeks before bleaching, participants underwent prophylaxis to remove extrinsic stains. The ArcFlex retractor (FGM, Joinville, SC, Brazil) was placed. The gingiva was protected by applying the Top Dam light-curing resin (FGM, Joinville, SC, Brazil). The operator then opened the envelope defining the hemiarch and started bleaching, using a tip with or without brush (Sulzer Mixpac™, Sulzer Ltd., Winterthur, Switzerland). The bleaching gel Whiteness HP Automixx 6% (FGM, Joinville, SC, Brazil) was applied (Figure 3). The treatment consisted of three sessions with an interval of seven days between them and each session lasted 50 minutes, according to the manufacturer's recommendations.

Outcomes

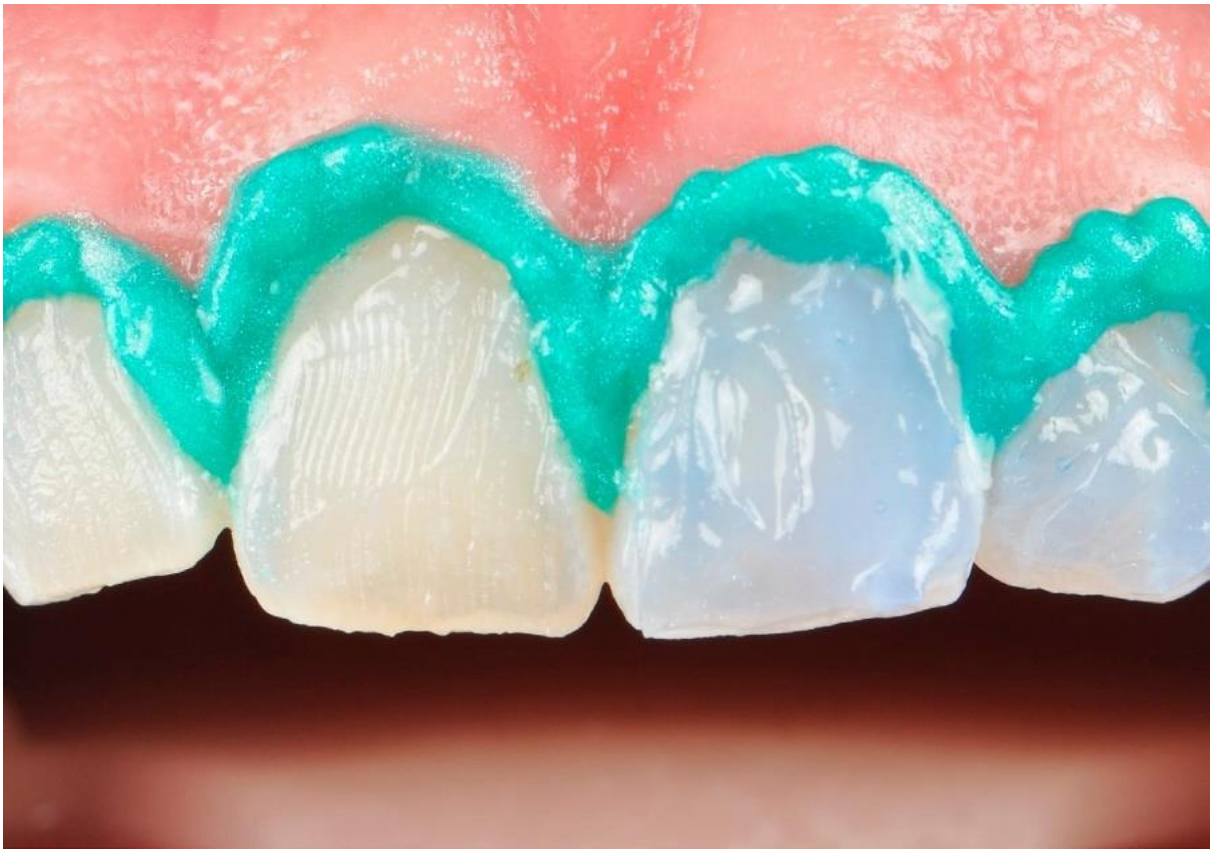
Color

Two operators calibrated performed color evaluation in the study, according to ISO/TR 28642,[36] with at least 85% agreement for the kappa statistic. Color was recorded initially, weekly for three weeks and one month after the end of treatment.

To evaluate the subjective color, the VITA Classical (VITA Zahnfabrik, Bad Säckingen, Germany) and VITA Bleachedguide 3D-MASTER (VITA Zahnfabrik, Bad Säckingen, Germany) scales were used, and the color change was evaluated by the variation of the VITA scale units (ΔSGU).[15,29,30-32] The objective evaluation was performed using the VITA Easyshade digital spectrophotometer (VITA Zahnfabrik, Bad Säckingen, Germany),[15,22,30,31] which was always calibrated before each evaluation, according to the CIELAB system. In order to standardize the evaluation with the

spectrophotometer, a guide was made with condensation silicone (Perfil, Coltène, Rio de Janeiro, RJ, Brazil) on the anterior maxillary teeth, and the middle third of the right and left canines wasperforated with a circular scalpel (Biopsy Punch, Miltex, York, NJ, USA) with the diameter corresponding to the active tip of the spectrophotometer. The color change recorded before and during all periods evaluated was estimated using the following formulas: $\Delta E_{ab}=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$,[37] and $\Delta E_{00}=[(\Delta L/kLSL)^2+(\Delta C/\ kCSC)^2+(\Delta H/kHSH)^2+RT\ (\Delta C^*\Delta H/SC^*SH)]^{1/2}$;[38] and the Whiteness Index for Dentistry was estimated by $WI_D=0.551\times L-2.324\times a-1.1\times b$. Moreover, the changes in WI_D caused by each step were estimated by subtracting the values observed at each evaluation time from the values of the previous step (ΔWI_D).[18]

Figure 3 - Demonstration of the amount of gel applied to the tooth surface. Patient's right hemiarch, tip with a brush and patient's left hemiarch, tip without brush (varying according to randomization)



Tooth sensitivity

To assess the absolute risk and intensity of TS, participants were instructed to

record their sensitivity using a visual analogue scale (VAS; 0–10)[30-32] at each tooth bleaching session. Regarding risk, any value greater than zero represented the presence of TS, expressed as percentage, and intensity was measured in cm (worst-case scenario). Zero corresponded to no TS and ten corresponded to severe TS. The highest result was always recorded with a vertical line immediately after, up to one hour after, up to 24 hours after, and up to 48 hours after the bleaching session. The right and left hemiarches were always evaluated separately.

Aesthetic self-perception

Aesthetic self-perception was assessed using the orofacial esthetic scale (OES),[39] which contains eight items. Participants were instructed to respond by marking with an "X" how satisfied they were with each of the eight aesthetic aspects, using a numerical scale (0–10), where zero represented very dissatisfied and ten represented very satisfied. The scale was delivered to be answered before the start of bleaching and after the end of all treatments.

Sample size

The primary outcome of this study was to assess the efficacy of color change (ΔE_{ab}). Considering a standard deviation of 4.25 for 6% HP,[15] with an equivalence limit of 2.70,[40] a study power of 90%, and alpha of 5%, a minimum of 54 volunteers per group was required (*https://www.sealedenvelope. com*). A sample of 60 participants was used, totaling 120 hemiarches.

Randomization, allocation concealment and implementation

Using a split-mouth design, in this study, a simple randomization was performed via the website www. sealedenvelope.com to determine the sequence of application of the respective experimental groups. According to this randomization process, each specified group was enclosed in an opaque, sequentially numbered envelope. Consequently, each envelope had instructions detailing the order in which the experimental groups should be applied to a hemiarch. Given the split-mouth design, the second experimental group was consistently assigned to the second hemiarch.

Throughout the study, the initial randomized group started the process with the

right upper hemiarch, while simultaneously the left upper hemiarch underwent bleaching together with the second group. The allocation sequence was disclosed immediately before the bleaching procedure in the first session and this same allocation sequence was followed in the subsequent sessions (implementation). This procedure was conducted by a researcher who was not directly involved in any of the experimental phases.

Blinding

As this was a double-blind study, neither the evaluator nor the participant knew how the bleaching procedure was performed (tip with or without brush). Due to the different application methods evaluated during the bleaching procedure, the operator could not be blinded.

Statistical Analysis

The statistician was blinded for both groups and the analysis involved all participants and followed the intent-to-treat protocol. Two one-sided t-tests for paired samples (TOST-P) were performed to test the equivalence of the study groups at the different evaluation points. Regarding the evaluation of color change, a paired Student's t-test was used for all scales and evaluation time points. The absolute risk of TS was compared using the McNemar test. Odds ratios were also estimated, as well as the confidence interval (CI) and Spearman correlation. The intensity of TS was analyzed using the paired Student's t-test, and differences between the groups were detected by the Pearson correlation. Aesthetic self-perception was assessed using the paired Student's t-test. All statistical tests were performed with an alpha of 5%.

Results

Characteristics of the included participants

According to the inclusion criteria, of the 76 volunteers evaluated, only 60 were included in the study. During the bleaching treatment, there was no loss of participants (Figure 4). Table 6 presents their characteristics.

Figure 4 - CONSORT flowchart of the study design phases, including allocation and inclusion criteria

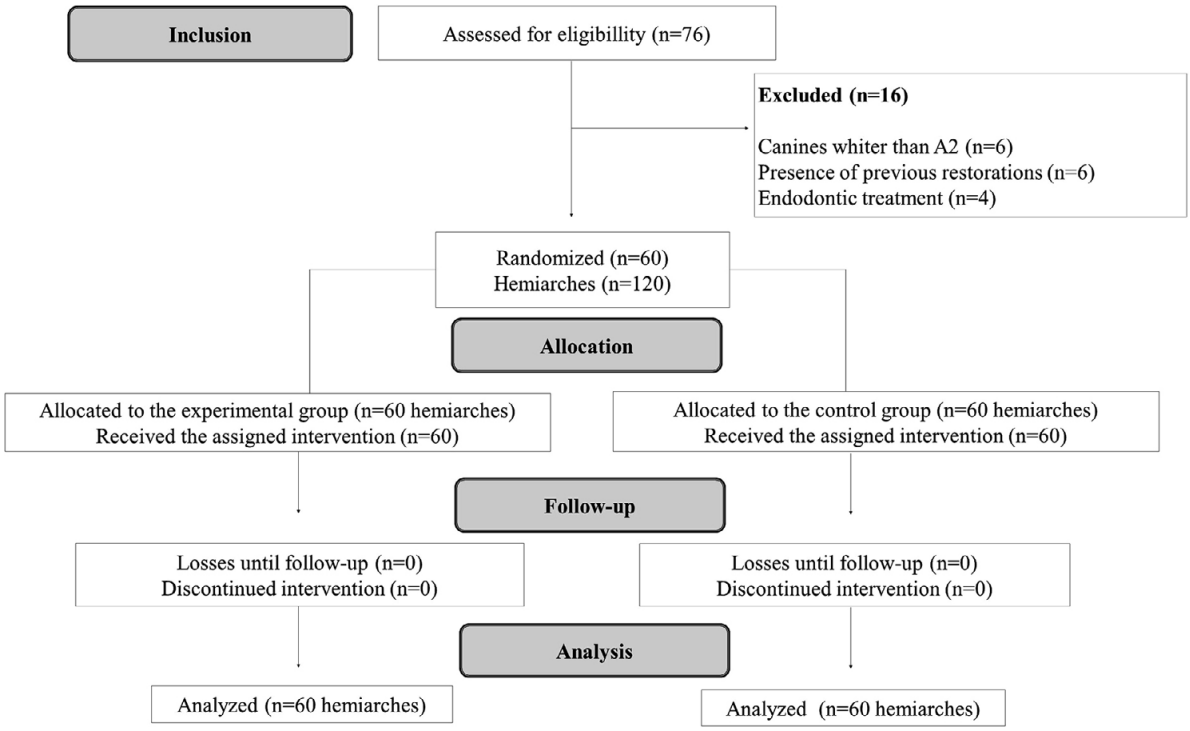


Table 6 - Baseline characteristics of the participants included in this clinical trial

Groups (number of patients)	Tip without brush (n=60)	Tip with a brush (n=60)
Baseline color (Classical SGU), median(minimum value:maximum value)*	10 (7:11)	11 (7:13)
Sex (women), %	40 (67%)	
Mean age (women/men), years old	14.6 ± 1.39	

*Abbreviations: SGU: shade guide unit measured by the VITA Classical scale.

Color evaluation

One month after the bleaching procedure, no significant differences were observed between the two groups in terms of the values obtained in the subjective scales (VITA Classical: MD 0.0; 95% CI -0.3 to 0.3; $p > 0.91$; and VITA Bleachedguide: MD −0.1; 95% CI−0.4 to 0.2; $p > 0.49$; Table 7) or the objective scales (ΔE_{ab}: MD −0.3; 95% CI −1.4 to 0.7; $p > 0.48$; and ΔE_{00}: MD −0.3; 95% CI −1. 1 to 0.4; $p > 0.38$; Table 8). This shows the equivalence of bleaching efficacy between the groups. In the results

determined by ΔWI_D, no statistical difference was observed between the groups after the first (MD 1.6; 95% CI -0.1 to 0.3; $p = 0.07$) and second weeks (MD 1.9; 95% CI-0.05 to 3.8; $p > 0.07$; Table 8). However, a significant difference was observed between the groups at the third week (MD 2.3; 95% CI 1.2 to 3.3; $p < 0.001$) and after one month (MD 1.6; 95% CI 0.6 to 2.6; $p < 0.03$; Table 8), favoring the tip without brush.

Table 7 - Means and standard deviations of the subjective assessment of color change and the mean difference (95% CI)

Color evaluation tool	Evaluated time	Group		Mean difference (95% CI)	Equivalence [p-value]*	*p*-value**
		Tip without brush	Tip with brush			
Vita Classical (ΔSGU)	Baseline vs. 1 week	0.6 ± 1.3	0.8 ± 1.5	-0.2 (-0.5 to 0.1)	Yes; p < 0.01	0.15
	Baseline vs. 2 weeks	2.1 ± 1.9	2.2 ± 2.1	-0.0 (-0.5 to 0.4)	Yes; p < 0.01	0.81
	Baseline vs. 3 weeks	3.6 ± 2.1	3.6 ± 2.4	-0.1 (-0.4 to 0.3)	Yes; p < 0.01	0.71
	Baseline vs. 1 month	3.7 ± 2.2	3.7 ± 2.3	0.0 (-0.3 to 0.3)	Yes; p < 0.01	0.91
Vita Bleachedguide (ΔSGU)	Baseline vs. 1 week	0.7 ± 1.3	0.8 ± 1.5	-0.2 (-0.4 to 0.04)	Yes; p < 0.01	0.10
	Baseline vs. 2 weeks	2.3 ± 2.0	2.6 ± 2.5	-0.3 (-0.6 to 0.04)	Yes; p < 0.01	0.09
	Baseline vs. 3 weeks	3.8 ± 2.2	3.9 ± 2.4	-0.1 (-0.5 to 0.2)	Yes; p < 0.01	0.51
	Baseline vs. 1 month	3.8 ± 2.2	3.9 ± 2.3	-0.1 (-0.4 to 0.2)	Yes; p < 0.01	0.49

*The p-value reported is the larger of the two p-values from the upper and lower one-sided tests (TOST-P test);**Paired t-test.

Table 8 - Means and standard deviations of the objective assessment of color change and the mean difference (95% CI)

Color evaluation tool	Evaluated time	Group		Mean difference (95% CI)	Equivalence [p-value]*	*p*-value**
		Tip without brush	Tip with brush			
CIELAB (ΔE_{ab})	Baseline vs. 1 week	6.0 ± 3.4	6.4 ± 4.4	−0.4 (−1.4 to 0.7)	Yes; p<0.01	0.50
	Baseline vs. 2 weeks	7.3 ± 3.2	7.3 ± 3.4	0.1 (−1.0 to 1.2)	Yes; p<0.01	0.88
	Baseline vs. 3 weeks	8.6 ± 3.2	8.5 ± 3.6	0.2 (−0.8 to 1.1)	Yes; p<0.01	0.73
	Baseline vs. 1 month	8.2 ± 2.8	8.5 ± 3.8	−0.3 (−1.4 to 0.7)	Yes; p<0.01	0.48
CIEDE (ΔE_{00})	Baseline vs. 1 week	4.2 ± 2.6	4.5 ± 3.3	−0.3 (−1.1 to 0.4)	Yes; p<0.01	0.41
	Baseline vs. 2 weeks	4.9 ± 2.5	5.0 ± 2.7	−0.1 (−0.8 to 0.6)	Yes; p<0.01	0.74

	Baseline vs. 3 weeks	5.7 ± 2.4	5.6 ± 2.7	0.1 (−0.6 to 0.8)	Yes; p<0.01	0.81
	Baseline vs. 1 month	5.5 ± 2.2	5.8 ± 2.9	−0.3 (−1.1 to 0.4)	Yes; p<0.01	0.38
Whiteness index (ΔWI_D)	Baseline vs. 1 week	5.5 ± 4.9	3.9 ± 5.9	1.6 (−0.1 to 0.3)	Yes; p<0.01	0.07
	Baseline vs. 2 weeks	8.9 ± 6.8	7.0 ± 6.6	1.9 (−0.05 to 3.8)	Yes; p<0.01	0.06
	Baseline vs. 3 weeks	9.5 ± 5.4	7.2 ± 5.8	2.3 (1.2 to 3.3)	Yes; p<0.01	0.00004
	Baseline vs. 1 month	10.5 ± 6.3	8.9 ± 6.4	1.6 (0.6 to 2.6)	Yes; p<0.01	0.03

*The p-value shown is the higher of the two p-values from the upper and lower one-sided tests (TOST-P test); **Paired t-test.

Tooth sensitivity

TS was transient up to 24 hours and was not recorded at 48 hours. The absolute risk of participantspresenting TS was 45% for the with brush group and 33.3% for the without brush group (Table 9). For TS,the odds ratio was 0.61 (95% CI 0.29 to 1.28) and, consequently, a statistical difference favoring the with brush group was detected ($p < 0.02$; Table 9). The Spearman correlation coefficient was moderate and significant for binary data pairs ($p < 0.0001$; r=0.78). Regarding the intensity of TS, the average for the worst-case scenario was less than one unit on a 10-unit scale for both groups. The mean difference between the groups was 0.05 (95% CI −0.06 to 0.17);therefore, there was no statistical difference ($p > 0.36$). The correlation coefficient was moderate and significant ($p < 0.0001$; 0.90).

Table 9 **-** Matched tabulation of the absolute risk of TS for both groups, along with the odds ratio and 95% CI

		Tip without brush			**Odds ratio (95% CI)**
		Positive	**Negative**	**Total**	
Tip with a brush	**Positive**	20	0	20	0.61 (0.29 to 1.28)
	Negative	7	33	40	
	Total	27	33	60	

McNemar test (p=0.023); Spearman correlation between paired data (r=0.78; p<0.0001).

Aesthetic self-perception

No significant difference was observed when comparing the two groups ($p > 0.05$). However,for all eight items evaluated, there was a statistical difference after the bleaching procedure ($p < 0.001$; Table 10), with the greatest mean difference with 95%

CI for the item “Color of your teeth”: −3.4 (−4.0 to −2.9) (Table 10).

Table 10 **-** Means and standard deviations of the orofacial aesthetic scale

Variable	Mean±SD		Mean difference (95% CI)	*p*-value*
	Before	After		
Facial appearance	7.7 ± 2.4	9.0 ± 2.1	−1.3 (−1.8 to −0.7)	<0.001
Facial profile appearance	6.9 ± 2.3	8.4 ± 1.7	−1.5 (−2.0 to −1.0)	<0.001
Lips appearance, smile, visible teeth	6.9 ± 2.2	8.7 ± 1.7	−1.8 (−2.4 to −1.1)	<0.001
Appearance of the tooth row	7.5 ± 2.3	8.8 ± 1.6	−1.2 (−1.8 to −0.7)	<0.001
Tooth shape	7.6 ± 2.4	8.9 ± 1.7	−1.3 (−1.9 to −0.7)	<0.001
Tooth color	5.3 ± 2.2	8.7 ± 1.7	−3.4 (−4.0 to −2.9)	<0.001
Appearance of the gums	8.2 ± 1.8	8.9 ± 1.5	−0.8 (−1.2 to −0.4)	<0.001
General feeling about the face, mouth, and teeth	7.5 ± 1.9	8.8 ± 1.9	−1.3 (−1.8 to −0.9)	<0.001

*Paired t-test.

Discussion

The results of this study showed that 6% HP, despite the difference between the tips used, promoted significant bleaching, with a lower TS pattern and a significant difference in aesthetic self-perception after the procedure among the adolescents evaluated. This finding is of significant importance, especially since, as explained in the Introduction section, a higher prevalence of TS is expected in younger patients due to the greater permeability of their teeth.[11,12]

The 6% HP applied in the study uses self-mixing tips that combine the two phases of the bleaching gel with different application tips and can be found in two ways. Considering these facts, regarding color change, this study used different evaluation parameters to better validate the results. Two subjective scales were used, the VITA Classical,[15,29,30,32] which has been used in clinical studies for a long time, allowing us to make more comparisons, and the VITA Bleachedguide 3D-MASTER, which is the proper scale for bleaching, with lighter color guides.[15,31] For the objective evaluation, the VITA Easyshade spectrophotometer was used, which also allowed us to compare with previous studies.[15,22,30,31]

Significant bleaching was detected for both study groups compared with baseline values. For the subjective (VITA Classical and VITA Bleachedguide) and objective (ΔE_{ab} and ΔE_{00}) scales, there was no statistical difference between the groups. The bleaching variations observed in this study are in line with other studies

that used 6% HP for bleaching and measured color change subjectively[15,30,31] or objectively.[15,30,31] However, it is worth mentioning that when the ΔWI_D (Whiteness Index for Dentistry) formula was used, a more significant bleaching was observed after three weeks and one month, favoring the without brush group. The ΔWI_D is a more recent formula recommended to assess the level of whiteness after tooth bleaching, with a lower probability of error than the previous one.[18]

The favorable bleaching results for the without brush group can be attributed to the amount of gel used. Figure 3 shows a noticeable difference in gel volume favoring the without brush group. This outcome is in line with expectations, since a previous *in vitro* study evaluating various application tips for 6% HP gel showed that the tip without brush significantly enhanced the bleaching effect.[8] This was largely due to the fact that it required three times as much gel as the tip with a brush, as previously observed.[8,9] In fact, the outcomes of this study are in line with the results of a recent clinical investigation that showed a more pronounced bleaching effect when a larger volume of bleaching gel was applied to the tooth surface, as opposed to a smaller volume of gel.[33] However, the absolute value of ΔWI_D should be analyzed carefully[18,19] and the perceptibility and acceptability thresholds of ΔWI_D should be verified to establish whether the difference is detected by the observer and whether it is clinically relevant.

When assessing the 50:50% perceptibility threshold for the ΔWI_D, the values observed in this study had an average difference of twice 0.72, a value that is perceptible to the average calibrated observer.[18,19] However, when the 50:50% acceptability threshold was assessed, this difference was not clinically important. In other words, the value obtained in this study was lower than 2.62, which means that this difference is lower than the acceptable value for a patient.[18,19] This leads the authors of this study to accept the first null hypothesis, since, although some significant differences were observed between the groups (ΔWI_D), they were below the acceptability threshold for bleaching procedures.[18,19]

One of the most common adverse effects observed during and after tooth bleaching is TS, and many alternatives have been studied to reduce this undesirable outcome, especially in adolescents, as aforementioned in the Introduction section. Since TS occurs due to the ability of HP to penetrate the tooth structure and cause an inflammatory response in the pulp,[7,8,9] it is expected that the higher the concentration of HP, the greater the TS.[23-27] This expectation was indirectly confirmed by the lower

absolute risk of TS observed in this study. On average, 38% of the study participants reported TS, compared with the 83% to 90% in previous studies that applied higher concentrations of HP.[23,24,27] However, the without brush group had a significantly higher absolute risk of TS, and these results led the authors to reject the second null hypothesis. These results are in line with an *in vitro* study[8] in which the application of 6% HP with a brush resulted in lower penetration of the bleaching gel compared with the without brush group, mainly because a smaller amount of gel was dispensed into the former. According to Fick's second law, the diffusion of HP is smaller when a small volume of bleaching gel is applied.[34] This was recently showed in a clinical study[33] that found a lower risk of TS when using a smaller volume of bleaching gel compared with a larger one.

Comparing the results of this study with the literature, some differences in terms of the absolute risk of TS can be observed.[31] For example, according to a study,[31] only 6.3% of participants reported TS when 6% HP was applied in in-office bleaching. These differences can be attributed to variations in the commercial brands evaluated, the technical application, and other aspects. However, from the authors' point of view, the most relevant factor is the age of participants. While this study evaluated young participants, the other study[31] included adult patients. Since younger participants have a larger pulp chamber[13] and more permeable teeth,[11,12] a low concentration is a good option for this age group. It is worth mentioning that the TS intensity recorded in this study was generally lower (below 1) in both groups, in line with the previous study,[31] which led the authors to accept the third null hypothesis.

One of the most important results of this study is the assessment of aesthetic self-perception, since it is a patient-reported outcome that characterizes specific influences of oral health on patients' lives and this assessment is already considered essential.[16] Although we found no significant differences between the groups in all parameters evaluated, participants showed great satisfaction after tooth bleaching, especially when they were asked about the color of their teeth. This led the authors to reject the fourth null hypothesis and is a strong indicator that tooth bleaching, even at low concentrations, should be considered a good option for young patients. Considering that young patients are concerned about the social aspect of their appearance;[17] tooth bleaching can improve their emotional well-being and self-esteem.[17]

Despite the favorable results in this study regarding in-office bleaching with 6% HP, it should be noted that the same level of bleaching efficacy should not be expected, especially when 6% HP is applied using a tip with a brush compared with more concentrated in-office bleaching gels, as previously tested in both *in vitro*[8] and in a clinical setting.[15,30]Therefore, we can hypothesize that conducting an additional session may improve the bleaching results, similar to what is achieved in high-concentration in-office bleaching. However, even with teeth that are not so white, participants still achieved aesthetic satisfaction, as shown by the results of the questionnaire. This outcome is significant,[16] especially considering the characteristics of the target population (children and adolescents).

Low-concentration in-office bleaching provided promising results. The use of 6% HP for the in-office technique has some advantages over at-home bleaching. In-office bleaching does not depend on the patient's collaboration and is easier to be performed, as it does not require individualized trays, which adolescents find difficult to use.[3] Moreover, in-office bleaching is completed in only three sessions of 50 minutes, whereas at-home bleaching with 6% HP usually requires daily application for 14 to 21 days, for one hour and 30 minutes.[9] The color change results in this study, regardless of the tip used, suggest that 6% HP is a good option for in-office bleaching, especially when used with a tip with a brush, which reduces the amount of gel used,[8] thus reducing treatment costs.

Some limitations need to be described. Our study evaluated only one commercial brand of bleaching gel, and future studies should evaluate different HP 6% bleaching gels available in clinical settings. Another limitation is the bleaching protocol, which made it difficult to compare this study with others, given the variability in application time or number of sessions, the association with light, and other factors,[15,22,25,30,31] requiring further studies to assess whether these factors could influence the results of this study.

Conclusion

The use of different tips (with or without brush) for the application of 6% hydrogen peroxide in in-office bleaching in adolescents resulted in a good bleaching,regardless of the tip. A lower risk of tooth sensitivity was observed for the tip with a brush and bleaching with 6% hydrogen peroxide improved patients' aesthetic self-perception.

Acknowledgments

The authors thank FGM Dental Group for generously donating the bleaching products used in this study. This study was partially funded by the National Council for Scientific and Technological Development (CNPq), under grants 304817/2021-0 and 308286/2019-7, and by the Coordination of Higher Education and Graduate Training (CAPES) – Brasil – Finance Code 001.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

The datasets generated and analyzed during this study are available from the corresponding author on reasonable request.

References

1 - Haywood VB, Sword RJ. Tray bleaching status and insights. J Esthet Restor Dent. 2021;33(1):27-38. doi: 10.1111/jerd.12688

2 - Bernardon JK, Sartori N, Ballarin A, Perdigão J, Lopes GC, Baratieri LN. Clinical performance of vital bleaching techniques. Oper Dent. 2010;35(1):3-10. doi: 10.2341/09-008CR

3 - Pinto MM, Gonçalves MLL, Mota ACC, Deana AM, Olivan SR, Bortoletto C, et al. Controlled clinical trial addressing teeth whitening with hydrogen peroxide in adolescents: a 12-month follow-up. Clinics (São Paulo). 2017;72(3):161-70. doi: 10.6061/clinics/2017(03)06

4 - Kihn PW. Vital tooth whitening. Dent Clin North Am. 2007;51(2):319- 31. doi: 10.1016/j.cden.2006.12.001

5 - Reis A, Silva LM, Martins L, Loguercio AD. In-office tooth whitening. Clin Dent Re. 2018;2:10. doi: 10.1007/s41894-018-0021-9

6 - Machado LS, Anchieta RB, Santos PH, Briso AL, Tovar N, Janal MN, et al. Clinical comparison of at-home and in-office dental bleaching procedures: a randomized trial of a split-mouth design. Int J Periodontics Restorative Dent. 2016;36(2):251-60. doi: 10.11607/ prd.2383

7 - Kwon SR, Wertz PW. Review of the mechanism of tooth whitening. J Esthet Restor Dent. 2015;27(5):240-57. doi: 10.1111/jerd.12152

8 - Carneiro TS, Favoreto MW, Bernardi LG, Bandeca MC, Borges CP, Reis A, et al. Application tip and concentration of a self-mixing bleach: hydrogen peroxide inside the pulp chamber, color change, and amount of bleaching gel used. Oper Dent. 2023;48(2):146-54. doi: 10.2341/21-053-L

9 - Bernardi LG, Favoreto MW, Carneiro TS, Mena-Serrano A, Borges CP, Reis A, et al. Use of an applicator brush with high concentration bleaching gels. Clin Oral Investig. 2022;26(10):6387-95. doi: 10.1007/ s00784-022-04594-8

10 - Parreiras S, Favoreto M, Cruz G, Gomes A, Borges CPF, Loguercio AD, et al. Initial and pulp chamber concentration of hydrogen peroxide using different bleaching products. Braz Dent Sci. 2020;23(2). doi: 10.14295/bds.2020.v23i2.1942

11 - Mjör IA. Dentin permeability: the basis for understanding pulp reactions and adhesive technology. Braz Dent J. 2009;20(1):3-16. doi: 10.1590/s0103-64402009000100001

12 - Pashley DH. Dentin-predentin complex and its permeability: physiologic overview. J Dent Res. 1985;64 Spec No:613-20. doi: 10.1177/002203458506400419

13 - Carvalho TS, Lussi A. Age-related morphological, histological and functional changes in teeth. J Oral Rehabil. 2017;44(4):291-8. doi: 10.1111/joor.12474

14 - Vallittu PK, Vallittu AS, Lassila VP. Dental aesthetics--a survey of attitudes in different groups of patients. J Dent. 1996;24(5):335-8. doi: 10.1016/0300-5712(95)00079-8

15 - Bersezio C, Martín J, Angel P, Bottner J, Godoy I, Avalos F, et al. Teeth whitening with 6% hydrogen peroxide and its impact on quality of life: 2 years of follow-up. Odontology. 2019;107(1):118-25. doi: 10.1007/s10266-018-0372-3

16 - John MT. Health outcomes reported by dental patients. J Evid Based Dent Pract. 2018;18(4):332-5. doi: 10.1016/j.jebdp.2018.09.001

17 - Ilyas N, Marshall S, Ahluwalia M. Dental bleaching: ‘Now I can smile for my selfies’ - paediatric patients’ perspectives. Prim Dent J. 2021;10(4):65-73. doi: 10.1177/20501684211066528

18 - Pérez Mdel M, Ghinea R, Rivas MJ, Yebra A, Ionescu AM, Paravina RD, et al. Development of a customized whiteness index for dentistry based on CIELAB color space. Dent Mater. 2016;32(3):461-7. doi: 10.1016/j.dental.2015.12.008

19 - Pérez MM, Herrera LJ, Carrillo F, Pecho OE, Dudea D, Gasparik C, et al. Whiteness difference thresholds in dentistry. Dent Mater. 2019;35(2):292-7. doi: 10.1016/j.dental.2018.11.022

20 - Monteiro J, Ashley P, Parekh S. Vital bleaching for children with dental anomalies: EAPD members' survey. Eur Arch Paediatr Dent. 2020;21(5):565-71. doi: 10.1007/s40368-019-00494-w

21 - Griffiths F, Parekh. Is it time to reconsider the use of vital teeth bleaching in children and adolescents in Europe? Eur Arch Paediatr Dent. 2021;22(4):759-63. doi: 10.1007/s40368-021-00609-2

22 - Ferraz NKL, Nogueira LC, Neiva IM, Ferreira RC, Moreira AN, Magalhães CS. Longevity, effectiveness, safety, and impact on quality of life of low-concentration hydrogen peroxides in-office bleaching: a randomized clinical trial. Clin Oral Investig. 2019;23(5):2061-70. doi: 10.1007/s00784-018-2607-7

23 - Lima SN, Ribeiro IS, Grisotto MA, Fernandes ES, Hass V, Tavarez RR, et al. Evaluation of several clinical parameters after bleaching with hydrogen peroxide at different concentrations: a randomized clinical trial. J Dent. 2018;68:9197. doi: 10.1016/j.jdent.2017.11.008

24 - Bortolatto JF, Pretel H, Floros MC, Luizzi AC, Dantas AA, Fernandez E, et al. Low concentration H(2)O(2)/TiO_N in office bleaching: a randomized clinical trial. J Dent Res. 2014;93(7 Suppl):66S-71S. doi: 10.1177/0022034514537466

25 - Bortolatto JF, Trevisan TC, Bernardi PS, Fernandez E, Dovigo LN, Loguercio AD, et al. A novel approach for in-office tooth bleaching with 6% H2O2/TiO_N and LED/laser system-a controlled, triple-blinded, randomized clinical trial. Lasers Med Sci. 2016;31(3):437-44. doi: 10.1007/s10103-016-1866-2

26 - Mena-Serrano AP, Garcia E, Luque-Martinez I, Grande R, Loguercio AD, Reis A. A single-blind randomized trial about the effect of hydrogen peroxide concentration on light-activated bleaching. Oper Dent. 2016;41(5):455-64. doi: 10.2341/15-077-C

27 - Pontes M, Gomes J, Lemos C, Leão RS, Moraes S, Vasconelos BC, et al. Effect of bleaching gel concentration on tooth color and sensitivity: a systematic review and meta-analysis. Oper Dent. 2020;45(3):265- 75. doi: 10.2341/17-376-L

28 - Bacaksiz A, Tulunoglu O, Tulunoglu I. Efficacy and stability of two in-office bleaching agents in adolescents: 12 months follow-up. J Clin Pediatr Dent. 2016;40(4):269-73. doi: 10.17796/1053-4628-40.4.269

29 - Gonçalves MLL, Tavares ACS, Mota ACC, Penna LAP, Deana AM, Bussadori SK. In-office tooth bleaching for adolescents using hydrogen peroxide-based gels: clinical trial. Braz Dent J. 2017;28(6):720-5. doi: 10.1590/0103-6440201701516

30 - Bersezio C, Estay J, Jorquera G, Peña M, Araya C, Angel P, et al. Effectiveness of dental bleaching with 37.5% and 6% hydrogen peroxide and its effect on quality of life. Oper Dent. 2019;44(2):146- 55. doi: 10.2341/17-229-C

31 - Vildósola P, Vera F, Ramírez J, Rencoret J, Pretel H, Oliveira OB Jr, et al. Comparison of effectiveness and sensitivity using two in-office bleaching protocols for a 6% hydrogen peroxide gel in a randomized clinical trial. Oper Dent. 2017;42(3):244-52. doi: 10.2341/16-043-C

32 - Martins I, Onofre S, Franco N, Martins LM, Montenegro A, Arana- Gordillo LA, et al. Effectiveness of in-office hydrogen peroxide with two different protocols: a two-center randomized clinical trial. Oper Dent. 2018;43(4):353-61. doi: 10.2341/17-128-C

33 - Esteves LM, Santos PH, Fagundes TC, Gallinari MO, Antonaccio GB, Cintra L, et al. Effect of bleaching gel volume on color change and postoperative sensitivity: a randomized clinical study. Clin Oral Investig. 2022;26(3):2527-36. doi: 10.1007/s00784-021-04220-z

34 - Crank J. The mathematics of diffusion. Oxford: Oxford University Press; 1979.

35 - Pandis N, Chung B, Scherer RW, Elbourne D, Altman DG. CONSORT 2010 statement: extension checklist for reporting within person randomised trials. Br J Dermatol. 2019;180(3):534-52. doi: 10.1111/bjd.17239

36 - International Organization for Standardization. ISO/TR 28642 dentistry: guidance on colour measurement. Geneva: ISO; 2011.

37 - CIE recommendations on uniform color spaces, color-difference equations, and metric color terms. Color Res Appl. 1977;2(1):5-6. doi: 10.1002/j.1520-6378.1977.tb00102.x

38 - Luo M, Cui G, Rigg B. The development of the CIE 2000 colour- difference formula: CIEDE2000. Color Res Appl. 2001;6(5):340-50. doi: 10.1002/col.1049

39 - Campos LA, Marôco J, John MT, Santos-Pinto A, Campos JA. Development and psychometric properties of the Portuguese version of the Orofacial Esthetic Scale: OES-Pt. PeerJ. 2020;8:e8814. doi: 10.7717/peerj.8814

40 - Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015;27 Suppl 1:S1-9. doi: 10.1111/jerd.12149

7 ARTIGO 4 - IN-OFFICE DENTAL BLEACHING IN ADOLESCENTS USING 6% HYDROGEN PEROXIDE WITH AND WITHOUT GINGIVAL BARRIER: RANDOMIZED DOUBLE-BLIND CLINICAL TRIAL

STATUS: Publicado em 2024

REVISTA: Journal of Applied Oral Science

DOI: 10.1590/1678-7757-2023-0416

Taynara de Souza CARNEIRO[1,2] Michael Willian FAVORETO[1] João Pedro Ferreira RODRIGUES[1] Elisama SUTIL[1] Gabrielle Gomes CENTENARO[1] Isabela de Matos de FREITAS[1] Alessandra REIS[1] Laura Ceballos GARCÍA[2] Alessandro Dourado LOGUERCIO[1].

[1]Universidade Estadual de Ponta Grossa, Departamento de Dentística Restauradora, Ponta Grossa, Brasil.

[2]Universidad Rey Juan Carlos, Facultad de Ciencias de la Salud, IDIBO, Madrid, España.

Corresponding address:

Prof. Dr. Alessandro D. Loguercio Universidade Estadual de Ponta Grossa - Curso de Odontologia - Avenida Carlos Cavalcanti, 4748 - Bloco M- Sala 64-A 84.030-900 - Ponta Grossa - PR - Brasil. Phone: +55 4232203740 e-mail: aloguercio@hotmail.com

Abstract

At low concentrations used for in-office bleaching gels, such as 6% HP, gingival barrier continues to be performed. If we take into account that, in the at-home bleaching technique, no barrier is indicated, it seems that theuse of a gingival barrier fails to make much sense when bleaching gel in low concentration is used for in-office bleaching. Objective: This double-blind, split-mouth, randomized clinical trial evaluated the gingival irritation (GI) of in-office bleaching using 6% hydrogen peroxide (HP) with and without a gingival barrier in adolescents, as well as color change and the impact of oral condition on quality of life. Methodology: Overall, 60 participants wererandomized into which side would or would not receive the gingival barrier. In-office bleaching was performed for 50 minutes with 6% HP in three sessions. The absolute risk and intensity of GI were assessed with a visual analogue scale. Color change was assessed using a digital spectrophotometer and color guides. The impact of oral condition on quality of life

was assessed using the Brazilian version of the Oral Health Impact Profile (α=0.05). Results: The proportion of patients who presented GI for the “with barrier” group was 31.6% and for the “without barrier” group, 30% (p=1.0). There is an equivalence for the evaluated groups regarding GI intensity (p<0.01). Color change was detected with no statistical differences (p>0.29). There was a significant impact of oral condition on quality of life after bleaching (p<0.001). Conclusions: The use or not of the gingival barrier for in-office bleaching with 6% HP was equivalent for GI, as well as for bleaching efficacy, with improvement in the impact of oral condition on quality of life.

Keywords: Tooth bleaching agents. Hydrogen peroxide. Gingiva. Clinical trial. Adolescent. RCT. Teeth whitening.

Introduction

Adolescents are concerned about social acceptance and their emotional well-being and self-esteem can be improved by dental aesthetic procedures.[1] Among them, dental bleaching is considered a less invasive technique with positive effects on these patients’ quality of life and aesthetic self-perception.[2]

Dental bleaching is very effective both in the case of intrinsic and extrinsic discolorations[3,4,5] and can be done in various ways. In-office bleaching techniques that use high or medium concentrations of hydrogen peroxide (HP) (20% to 40%) provide faster results.[6,7] However, several adverse effects have been observed, among which are tooth sensitivity and gingival irritation (GI).[8]

GI is less prevalent and is directly related to the operator’s process. The operator should have complete mastery of the technique. Failure to correctly light-cure the gingival barrier or carelessness in application[8] may cause this adverse effect. GI can manifest itself as mild discomfort leading to burns and ulcerations[9] due to the direct contact of soft tissues with the bleaching gel, being exacerbated according to the time and concentration (Figure 5) of the bleaching gel in contact with the gingival area.[10] Because of this, when in-office bleaching with high concentrations of HP is performed, it is essential to use light-curing barriers to protect the soft tissue.[6]

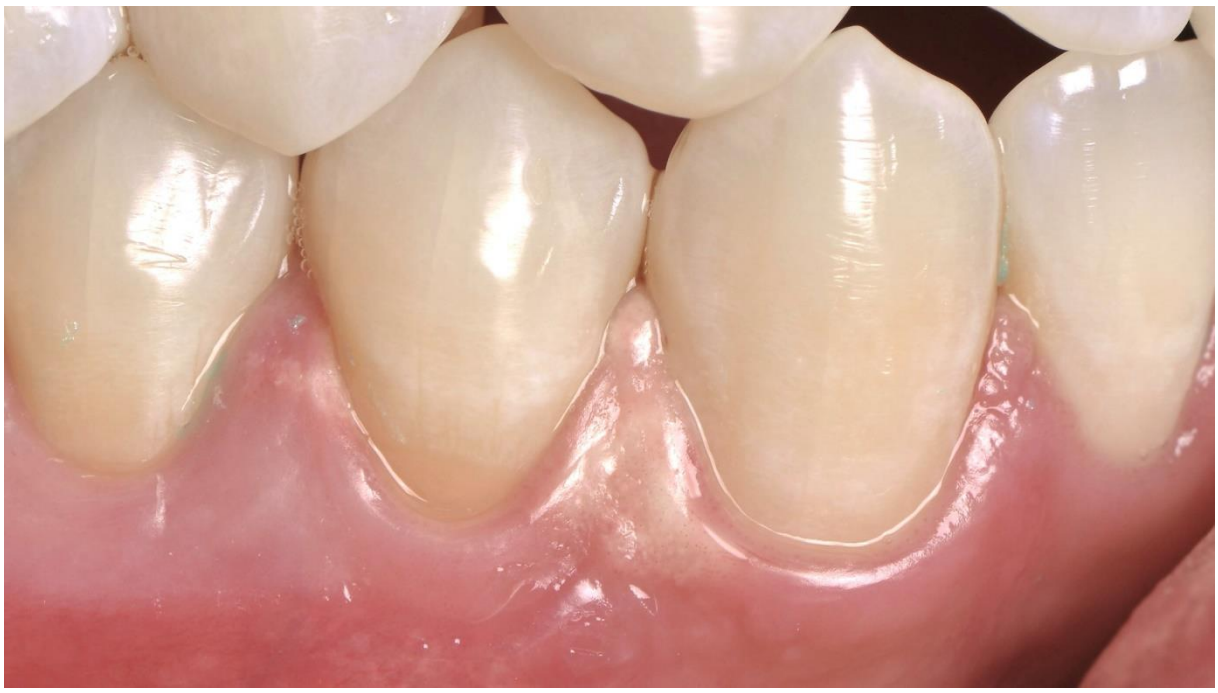
Low/medium[13] concentrations of bleaching gel (6-20%) have been developed

by manufacturers with the intention to reduce the adverse effects of in-office dental bleaching. Recently, several clinical studies have shown excellent bleaching efficacy and fewer adverse effects when low concentrations of HP were used.[2,12,13] These aspects appear particularly crucial in younger patients, such as adolescents. The most recommended technique for them thus far has been at-home bleaching due to its low concentration.[14] This is especially relevant because adolescents typically have more permeable teeth given their maturation level.[15] However, studies have indicated that adolescents encounter challenges in removing excess bleaching gel from trays and find them somewhat difficult to use,[16] making low concentration in-office bleaching a good option to avoid this problem. In light of these findings, low-concentration in-office bleaching emerges as a viable option to address these issues.

However, despite the low concentrations used for in-office bleaching gels, such as 6% HP, gingival barriers continue to be required.[12,13,17] No barrier is indicated for at-home bleaching techniques (up to 10% HP) regardless of the delivery method[18] because few patients have reported GI.[19,20] Therefore, it seems that the use of a gingival barrier fails to make much sense for the use of bleaching gel in low concentrations for in-office bleaching. However, to the extent of the authors' knowledge, no clinical studies have evaluated this hypothesis. Note that removing the application and light-curing step from the gingival barrier may make the clinical procedure faster, more practical, and, therefore, more economically viable.

Therefore, the aim of this double-blind, controlled, split-mouth, randomized equivalence clinical trial was to evaluate GI during in-office bleaching with 6% HP in adolescents with or without the use of the gingival barrier, as well as the efficacy of bleaching and the effect of the oral condition on patients' quality of life when subjected to low concentrations of in-office bleaching. The following null hypotheses were tested: 1) the use (or lack of use) of a gingival barrier will fail to affect the absolute risk and intensity of GI induced by in-office bleaching; 2) the use (or lack of use) of a gingival barrier for in-office bleaching will fail to affect color change; and 3) a low concentration of bleach will fail to affect the influence of oral condition on quality of life.

Figure 5 - Appearance of GI with burns in a patient subjected to 35% HP bleaching gel during in-office bleaching. This concentration of HP was not evaluated in the present study



Methodology

Study design

This was a randomized, double-blind (evaluators and participants), split-mouth, and equivalence study. After approval of this clinical trial by the ethics committee at the State University of Ponta Grossa, PR, Brazil (4.935.724), it was registered in the Brazilian Clinical Trials Registry (RBR-8q6mfhc). This study followed the Consolidated Standards of Reporting Trials protocol with the extension for noninferiority and equivalence trials and within-person designs,[21] and it was performed in the clinics of the school of dentistry at the State University of Ponta Grossa, PR, Brazil from September 2021 to February 2022.

Recruitment and eligibility criteria

Participants were recruited on social media. This approach was carried out by sharing posts on both the Instagram® feed and stories of the @bleachingbond research group user account. Additionally, the authors and other members of the research team reposted this content to further amplify its reach. Participants who met the eligibility criteria, before being included in the study, agreed to participate and their

guardians read and signed informed consent forms.

Inclusion criteria were adolescents aged from 12 to 16 years with vital teeth free from caries lesions, periodontal disease, and endodontic treatment, with both mandibular canines presenting A2 or darker color according to the VITA Classical guide (VITA Zahnfabrik, Bad Säckingen, Germany), and in good general and oral health. Participants who were on chronic medication, who had undergone previous tooth bleaching, had previous tooth sensitivity, used fixed orthodontic appliances or prostheses, had parafunction, gingival recession, discoloration due to fluorosis or tetracycline, were pregnant or breastfeeding, had visible cracks in the teeth, or were smokers were excluded.[2,12]

Sample size calculation

The primary outcome of this study was to assess the absolute risk of GI due to in-office bleaching with6% HP. Based on a pilot study (*data not shown*), a total of 10% GI was reported. For a control group with10% GI risk and an equivalence threshold of 20%, a minimum of 49 participants per group was required with 90% study power and 5% alpha. A sample size of 60 participants was used to compensate for any losses at follow-up.

Random sequence generation and allocation concealment

Simple randomization was performed in an online software (*www.sealedenvelope.com*) by a person outside the research protocol. Randomization was placed in a sealed and opaque envelope, sequentially numbered, and only revealed five minutes before the start of the bleaching procedure. Treatment of the lower right hemi-arch was decided based on the information within the envelope (with or without gingival barrier) while the alternative treatment was applied to the other hemi-arch. This procedure was conducted by a researcher indirectly involved in any of the experimental phases.

Blinding

This was a double-blind study in which the evaluator and the participant were unaware of group assignment. The color evaluator was kept from participating in the

process of randomization and implementation of the study and participant received a simulated application and photopolymerization of the gingival barrier in the hemiarch without treatment. Due to differences between bleaching procedures, the operator cannot be blinding.

Study intervention

Overall, three dentists with more than five years ofclinical experience performed the bleaching procedure. Before bleaching, participants underwent prophylaxis to remove extrinsic stains. The ArcFlex retractor (FGM,Joinville, SC, Brazil) was placed, which promotes retraction of the lips, cheeks, bite rest, and tongue control. Then, the operator opened the randomization envelope to visualize the group in which the patient's right hemi-arch was (with or without a gingival barrier). The procedure was performed with light-curing resin Top Dam (FGM, Joinville, SC, Brazil). Before performing the gingival barrier, the region in which the application would be performed was dried. The gingival barrier was applied to the corresponding teeth up to the second premolar region, being applied with a thickness of approximately 1 mm over the gingiva and gingival papillae, obtaining full coverage with a good protection field for the procedure. The barrier was light-cured for 20 seconds using an LED unit set at 1400 mW/cm^2 (Valo high power mode, Ultradent, South Jordan, UT, USA), and light-curing was performed immediately after application of the gingival barrier to prevent any possible irritation. Then, the bleaching gel WhitenessHP Automixx 6% (FGM, Joinville, SC, Brazil) was applied with a tip. Each session lasted 50 minutes, with three sessions with an interval of seven days between them.[2] Participants were instructed to use dentifrices without desensitizers and without bleaching agents for daily brushing.

Gingival irritation (GI) evaluation

To assess the absolute risk and intensity of GI, participants were instructed to record their GI using the Visual Analogue Scale (VAS; 0-10),[19] in which 0 = no irritation and 10 = severe irritation. Participants were instructed to record their GI even if there was no irritation, marking with a vertical line the value corresponding to the intensity of their GI, immediatelyafter, up to 1 hour after, up to 24 hours after, and up to 48 hours after the bleaching session, with the right and left hemiarches always being evaluated

separately, which was (the VAS with the marking) later measured in cm with the aid of a millimeter ruler. Regarding risk, any value greater than zero was considered as a presence of GI, described in percentages, and intensity was measured in cm (1^{st}, 2^{nd}, and 3^{rd} session and worst overall scenario [worst measured value for the three weeks]). Participants received all the guidelines for a better perception and greater description of results regarding GI, which may present pain and discomfort.

Color evaluation

Color was registered before and after 30 days of the end of treatment for all evaluated parameters, with a measurement being taken at each evaluation moment. The two evaluators were calibrated before the study, presenting superior color-matching competency according to the ISO/TR 28642.[22] In case of disagreement during the evaluation, they needed to reach a consensus before the participant was dismissed. Color evaluation was done in a room under artificial lighting conditions without interference from outside light.

Color evaluation was also performed using the objective method (VITA Easyshade spectrophotometer; VITA Zahnfabrik). The VITA Easyshade spectrophotometer (VITA Zahnfabrik) was used, according to the CIEL*a*b* system[2,12,13,17], where L* represents the lightness value from 0 (black) to 100 (white) and a* and b* represent the color, in which a* is the measurement along the green-red coordinate and b* is the measurement along the blue-yellow coordinate. These values were provided by a spectrophotometer that was calibrated before each measurement per patient. To standardize the measurement of objective color, an impression of the lower arch of participants, with condensation silicone (Perfil, Coltène, Altstätten, Switzerland), was performed to make a guide for the lower anterior teeth. The matrix was perforated with the aid of a 6-mm diameter circular scalpel (Biopsy Punch, Miltex, York, NJ, USA), similar to the active tip of the Vita Easyshade spectrophotometer, in the vestibular region and middle third of the lower right and left canines. In total, three measurements were performed for each tooth and average values were used for statistical purposes.

The difference between the colors registered before and 30 days after the end of the treatment was calculated using the formulas CIELab: $\Delta E_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 +$

$(\Delta b^*)^2]^{1/2}$,[23] CIEDE 2000 $\Delta E_{00} = [(\Delta L'/k_L S_L)^2 + (\Delta C'/k_C S_C)^2 + (\Delta H'/k_H S_H)^2 + R_T (\Delta C'/K_C S_C) (\Delta H'/ K_H S_H)]^{1/2}$,[24] where ΔL', ΔC', and ΔH' are the CIELab metric lightness, chroma, and hue differences, respectively, R_T is the rotation function that accounts for the interaction between chroma and hue differences. S_L, S_C, and S_H are the weighting functions for the lightness, chroma, and hue components, respectively.

The values calculated for these functions vary according to the positions of the sample pair being considered in CIELab color space. The k_L, k_C, and k_H values are the parametric factors to be adjusted according to different viewing parameters,[24] and Whiteness Index for Dentistry was calculated according to the following formula: $WI_D = 0.551 \times L - 2.324 \times a - 1.1 \times b$. Moreover, changes in WI_D caused by each step were calculated by subtracting the values observed at each assessment time from those calculated in the prior step (ΔWI_D).[25] The following color change acceptability limits were used: CIELab 2.7,[26] for CIEDE 2000 1.8,[26] and Whiteness Index for Dentistry 2.6.[27]

Also, color evaluation was performed by the subjective method (VITA Classical and VITA Bleachedguide 3D-MASTER; VITA Zahnfabrik). The value-oriented VITA Classical color scale (VITA Zahnfabrik) consists of 16 color guides arranged from highest (B1) to the lowest (C4)[2,12,17] and the VITA Bleachedguide 3D-MASTER scale (VITA Zahnfabrik) is a proper tooth bleaching scale containing lighter colored tabs arranged from the highest (0M1) to the lowest value (5M3).[2] The evaluation of color change was performed by the variation of VITA scale units (ΔSGU) subtracted from the initial color and the unit of color reached after bleaching, organized by value,[12,17] in the right and left canines.

Impact of oral condition on quality of life

The impact of oral condition on quality of life was evaluated by the Brazilian version of the abbreviated form of the Oral Health Impact Profile (OHIP-14), which contains 14 questions.[28] Participants were instructed to respond by marking the questions (0-4) with an X, where zero = never, one = rarely, two = sometimes, three = repeatedly, and four = always. The scale was delivered to be answered before the start

of bleaching and after the end of the whole treatment. Participants received the questionnaire and answered it without anyintervention from the evaluators and without a time limit for completion.

Statistical analysis

Analysis followed the intention-to-treat protocol and involved all participants (who were randomly assigned).[29] The statistician was blind to the assessmentof the groups. The absolute risk of gingival irritation of both groups was compared using the McNemar test. Odds ratios were also calculated, as were 95% confidence intervals and Spearman's correlation. Overall, two one-sided t-tests for paired samples(TOST-P) were used to test the equivalence of the study groups at the different assessment points for gingival irritation. The Student's paired t-test and Pearson's correlation were calculated for intensity of gingival irritation to detect differences between groups for each evaluation (1^{st}, 2^{nd}, and 3^{rd} sessions and worstoverall scenario). Color change between groups was compared using the Student's paired t-test for the different instruments. The impact of oral condition on quality of life was compared using Student's paired t-test before and after bleaching. In all statistical tests, alpha was preset to 5%.

Results

Characteristics of included participants

In total, 76 participants were examined, 60 of which were included in this clinical study (Figure 6). Table 11 describes the initial color of participants' teeth and the distribution of their genders and ages with no loss of participants in the follow-up of this study.

Figure 6 - The CONSORT Flow Diagram of study design phases, including enrollment and allocation criteria

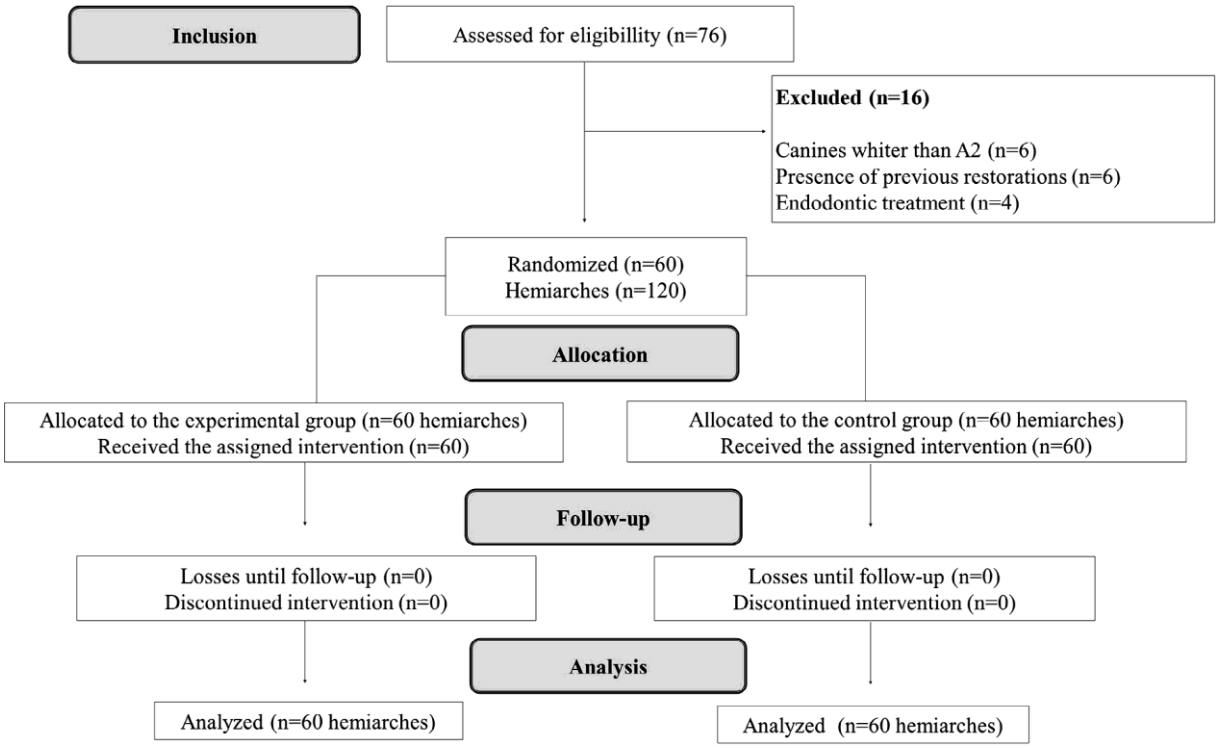


Table 11 - Baseline characteristics of the participants included in this clinical trial

Groups (number of patients)	With barrier (n = 60)	Without barrier (n = 60)
Baseline color (SGU; mean ± SD)*	10.0±2.7	10.6±2.1
Baseline color (WID; mean ± SD)*	15.5±6.7	14.9±6.6
Gender (female; %)	40 (67%)	
Average age (years; female/male)	14.6	

*Abbreviations: SGU, shade guide unit measured by VITA Classical scale; WI_D, Whiteness index measured by VITA Easyshade spectrophotometer.

Gingival irritation

GI (Figure 7) was reported by 30.8% of participants. While for the group with barrier, 31.6% of participants felt some discomfort, for the group without barrier, this discomfort was reported by 30% of participants. In relative terms, the odds ratio for irritation was 0.9 (0.4 to 2.0; Table 12), thus failing to reach statistical significance (p=1.0). Spearman's correlation coefficient for pairs of binary data was moderate and significant (r=0.75; p<0.001).

Regarding intensity of GI, no significant difference between both groups was observed in the first (p=0.67), second (p=0.79), and third sessions (p=0.29), as well as in the overall worst-case scenario(p=0.77; Table 13). The mean difference in intensity of GI averaged below 0.3, which was far from clinically important. Irritation was positively correlated in both groups (Table 13). Pearson's correlation was 0.83 (p<0.001) for the worst-case scenario in the first and second sessions, 0.75 (p<0.001) for the worst-case scenario for the third session, and 0.84 (p<0.001) forthe overall worst-case scenario (Table 13).

Figure 7 - Appearance of GI in a patient subjected to 6% HP bleaching gel during in-office bleaching. Despite the nearly imperceptible nature of GI, the patient reported experiencing irritation in the gingival area below teeth #31 and 41

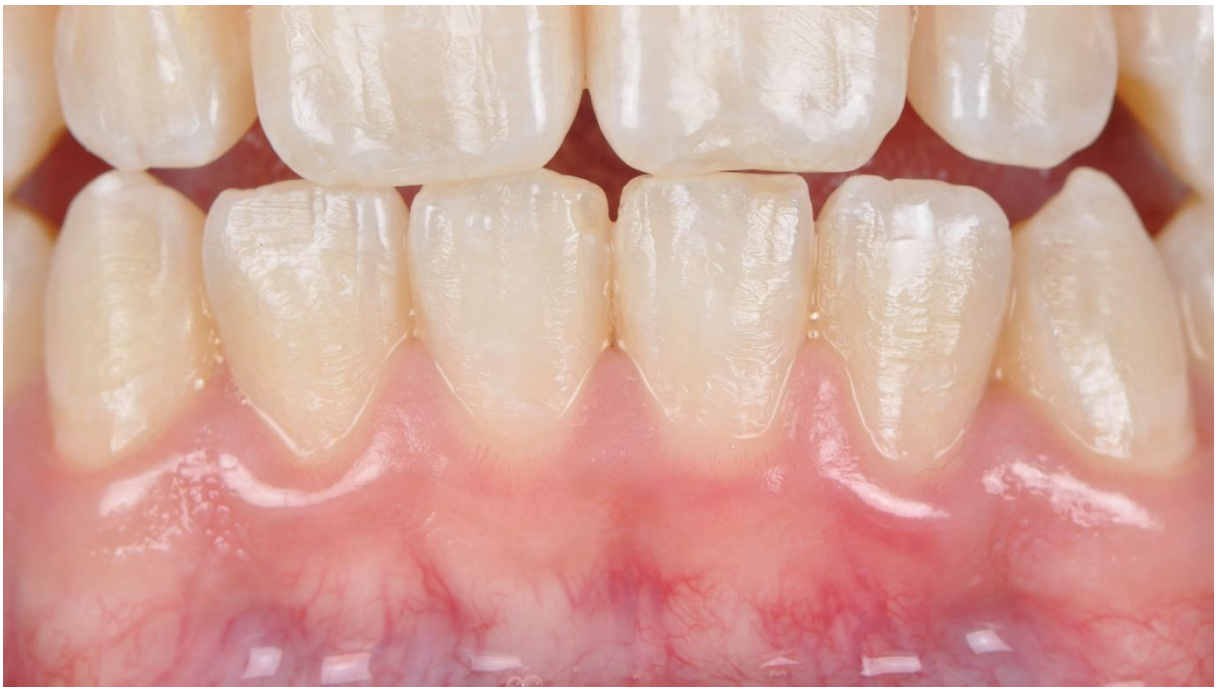


Table 12 **-** Matched tabulation of the absolute risk of GI for both groups along with the odds ratio and 95% confidence interval (CI)

		Without barrier			Odds ratio
		Positive	**Negative**	**Total**	**(95% CI)**
With barrier	**Positive**	15	4	19	0.9 (0.4 to 2.0)
	Negative	3	38	41	
	Total	18	42	60	

*Mc Nemar's test (p = 1.0); Spearman correlation between paired data (r = 0.75; p-value < 0.001).

Table 13 - Means and standard deviations of the intensity of GI for both groups, mean differences (95% confidence interval [CI]), and correlation coefficients

Main factor time	With barrier	Without barrier	Mean difference (95% CI)	Equivalence [p-value]	p-value **	Correlation coefficient [p-value]
First Session	0.2±0.6	0.2±0.7	0.0 (-0.1 to 0.1)	Yes; p<0.01	0.67	0.83; p<0.0001
Second Session	0.1±0.3	0.1±0.3	0.0 (0.0 to 0.0)	Yes; p<0.01	0.79	0.83; p<0.0001
Third Session	0.0±0.2	0.0±0.1	0.0 (0.0 to 0.0)	Yes; p<0.01	0.29	0.75; p<0.0001
Worst overall scenario	0.3±0.7	0.3±0.7	0.0 (-0.1 to 0.1)	Yes; p<0.01	0.77	0.84; p<0.0001

* The p-value reported is the larger of the two p-values from the upper and lower one-sided tests (TOST test); **Paired t-test.

Color change

Table 11 demonstrates that the initial tooth color averages in both groups were similar. After bleaching (Table 14), color change was detected for all evaluated parameters. Approximately, four units in the VITA Classical and VITA Bleachedguide scale, eight units in the ΔE_{ab}, five units in ΔE_{00}, and 10 units in the ΔWI_D were observed, regardless of groups (Table 14). Comparison of both groups showed no significant difference in bleaching for none of the evaluated parameters (p>0.46; Table 14).

Table 14 - Means and standard deviations in color change and mean differences (95% confidence intervals [CI]) baseline vs. one month

Color evaluation tool	Groups		Mean difference (95% CI)	p -value*
	With barrier	Without barrier		
CIELab (ΔE_{ab})	8.5±6.2	8.1±4.9	0.3 (-1.1 to 1.8)	0.64
CIEDE 2000 (ΔE_{00})	5.6±4.4	5.2±3.0	0.4 (-0.7 to 1.5)	0.46
Whiteness Index for Dentistry (ΔWI_D)	10.4±6.1	10.1±5.9	0.3 (-1.3 to 2.0)	0.68
Vita Classical (ΔSGU)	3.8±2.3	3.7±2.3	0.0 (0.0 to 0.1)	0.56
Vita Bleachedguide (ΔSGU)	3.7±2.1	3.6±2.1	0.0 (-0.1 to 0.1)	0.48

*Paired t-test.

Impact of oral condition on quality of life

When the impact of oral condition on quality oflife was evaluated before and after the bleaching procedure, there was a significant impact of oral condition on quality of life after bleaching (p<0.001;Table 15).

Table 15 - Medians and standard deviations of the Oral Health Impact Profile

	Means ± SD		Mean Difference (95% CI)	p-value*
	Before	After		
OHIP-14	9.4 ± 6.4	5.2 ± 6.0	4.2 (2.7 to 5.8)	<0.001

*Paired t-test.

Discussion

Dental bleaching using a gingival barrier is routine in dental offices. In a clinical scenario with in-office bleaching using high concentrations of HP, there is no doubt about the effectiveness of using gingival barriers to control GI or even gingival burns in patients. This study was carried out to verify whether GI occurred when a gingival barrier for in-office bleaching with 6% HP was not placed. This is a new scenario, occurring during the popularization of low bleach concentrations in several parts of the world,[2,12,13,30] mainly in Europe, in which 6% HP is the maximum allowed to be used whether in-office or at-home treatment.[31]

As far as the authors are aware, this is the first study concerned with evaluating GI in relation to the presence or absence of a gingival barrier for low concentrations of bleaching gel. In concentrations up to 10% for at-home bleaching, the gingival barrier may be avoided,[19,32] and eliminating the step of placing the barrier for in-office bleaching makes the procedure simpler, faster, and less expensive.

GI is of great importance in the evaluation of clinical studies of tooth bleaching. Depending on the degree of GI, it can even manifest ulcerations and burns, being initially described as direct discomfort or pain in the gingival tissue.[9,33] Unfortunately, in-office bleaching studies rarely assess GI because it is directly associated with the operator's care for the patient. However, despite several studies having evaluated 6% HP for in-office bleaching,[2,12,17,34-36] only Ferraz, et al.[17] (2019) evaluated GI. In that study, the authors reported GI in 57.7% of participants, differing from this study, which obtained a total of 30.8%. Some methodological differences between Ferraz's study and this one could help to explain the results in the latter.[17] The percentage difference can be attributed to the used protocol; the former[17] used light activation, and light activation of in-office bleaching can increase the operatory temperature,[37,38]

thus burning soft tissue.[38]

As previously described, the use of a gingival barrier is effective in controlling GI. However, it isimportant to note that GI can still occur despite its use. For instance, Al Shethri, et al.[39] (2003) demonstrated the presence of GI even with the use of the barrier, as did Bruzzell, et al.[9] (2013) suggesting that this may be attributed to the use of highly concentrated bleaching gels. Notably, one study demonstrated genotoxic potential when bleaching agents in higher concentrations were tested,[40] whereas 6% HP neither affected nor altered cell morphology.[41]

GI intensity in both groups was less than 0.3 on a scale of 10, considered clinically insignificant. Unlike the absolute risk of GI, the intensity of GI was similar to that reported in the literature. For instance,in a study by Ferraz, et al.[17] (2019) low intensity was detected when the gingival barrier was used. Additionally, GI intensity without a gingival barrier was similar to levels determined during at-home bleaching, which uses low concentrations.[19,20] This leads us to accept the first null hypothesis, facilitating the clinical day-to-day process and possibly reducing costs for the bleaching procedure. It is important to note that our study focused on evaluating GI in the patient's lower arch. This constitutes part 2 of the research,with part 1 having been previously published.[2] Part 1was conducted in the upper arch at a different time.

Various methods were employed for color evaluationin this study, a critical aspect given that the absence of a gingival barrier may lead to contact between the bleaching gel and saliva. It has been previously noted that saliva can interfere with the degradation of HP.[42] Therefore, evaluating color changes becomes essential in understanding the potential impact of these interactions.[42] For the objective method, a spectrophotometer was used, which is the least affected by the observer's training and variability.[43] For the subjective method, the VITA Classical and VITA Bleachedguide 3D-MASTER scales were used, which facilitate comparisons with previous studies as they were the most used in previous bleaching studies.[12,30,34] There was no difference between groups in all evaluated parameters, prompting us to accept the second null hypothesis. The results are similar to the study by Carneiro, et al.[2] (2023) who used the same protocol as the present study in adolescents, even in teeth assessed in different arches. Other studies that evaluated, by the same methods,

6% HP (objective[12,30,34] and subjective methods,[12,30,34,35]) demonstrated similar bleaching efficacy. However, it is worth mentioning that the protocol used in this study, as well as that by Carneiro, et al.[2] (2023) and Bersezio, et al.[34] (2019) used no light and obtained similar results to the studies that used it.[12,30] The bleaching pattern was acceptable when compared to studies that used higher concentrations of HP.[36,44] However, one more session could be undertaken to achieve better results since the use of HP products in low concentrations can produce the same efficacy of color change with the advantage of having fewer adverse effects.[11]

Assessing patients' quality of life in clinical studies is of great importance. Due to the fact that it is a result reported by the patient, its evaluation is already considered essential because it demonstrates how much oral health influences patients' lives.[45] Adolescents are concerned about social acceptance and appearance, and negative psychosocial judgments have been demonstrated in children and adolescents from the age of 11.[46] Thus, aesthetic procedures, such as tooth bleaching, can increase a patient's self-esteem and emotional well-being,[1] as well as quality of life. This study demonstrated a significant improvement in the effects of the oral condition on patients' quality of life after bleaching, thus prompting us to reject the third null hypothesis. The results presented are in line with other studies that used 6% HP.[12,34,35]

It is crucial to emphasize that there is a significant demand for orthodontic treatments, including tooth bleaching, in the adolescent age group.[47] Therefore, following the bleaching procedure in these patients, it is essential to consider waiting for bracket bonding to avoid potential inconveniences. Changes occurring in the dental substrate could lead to bracket detachment.[47,48,49] However, it is important to note that there is a lack of clinical studies in the literature to confirm these hypotheses.

Some limitations of the study need to be described. The sample size for detecting a difference smaller than the proposed one was relatively small. Additionally, this study included no visual assessment by the clinician evaluating GI. It tested only one brand of bleaching gel available on the market. Moreover, this research employed only one protocol for the use of HP 6% in in-office bleaching, strictly adhering to the manufacturer's recommendations. Results are unable to be directly applied for the over-the-counter or at- home bleaching materials based on 6% HP, mainly because

protocols related to the use of 6% HP vary widely.[12,17,30,34-36] Therefore, future clinical studies with larger designs need to be done to evaluate if GI is affected at the same level if different brands and/or application protocols of bleaching materials are used.

Conclusions

The use or not of the gingival barrier for in-office bleaching with 6% HP in adolescents proved to be equivalent for gingival irritation. A significant color change was observed in both groups. Bleaching with 6% HP improved the impact of oral condition on patients' quality of life. Therefore, the step of applying the gingival barrier for 6% HP in in-office bleaching can be disregarded.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

The datasets generated and analyzed in this study are available from the corresponding author upon reasonable request.

References

1. Ilyas N, Marshall S, Ahluwalia M. Dental bleaching: 'now I can smile for my selfies' - paediatric patients' perspectives. Prim Dent J. 2021;10(4):65-73. doi: 10.1177/20501684211066528
2. Carneiro TS, Favoreto MW, Wendlinger M, Bernardi LG, Andrade HF, Bandeca MC, et al. In-office dental bleaching with different tips: randomized clinical trial. J Appl Oral Sci. 2023;31:e20230216. doi:10.1590/1678-7757-2023-0216
3. Brookes ZL, Belfield LA, Ashworth A, Casas-Agustench P, Raja M, Pollard AJ, et al. Effects of chlorhexidine mouthwash on the oral microbiome. J Dent. 2021;113:103768. doi: 10.1016/j. jdent.2021.103768
4. Butera A, Folini E, Cosola S, Russo G, Scribante A, Gallo S, et al. Evaluation of the efficacy of probiotics domiciliary protocols for the management of periodontal disease, in adjunction of non-surgical periodontal therapy (nspt): a

systematic literature review. Appl Sci. 2023;13(1):663. doi: 10.3390/app13010663

5. Rodríguez-Martínez J, Valiente M, Sánchez-Martín MJ. Tooth whitening: from the established treatments to novel approaches to prevent side effects. J Esthet Restor Dent. 2019;31(5):431-40. doi:10.1111/jerd.12519
6. Reis A, da Silva LM, Martins L, Loguercio AD. In-office tooth whitening. Clin Dent Rev. 2018;2:10. doi: 10.1007/s41894-018- 0021-9.
7. Machado LS, Anchieta RB, Santos PH, Briso AL, Tovar N, Janal MN, et al. Clinical comparison of at-home and in-office dental bleaching procedures: a randomized trial of a split-mouth design. Int J Periodontics Restorative Dent. 2016;36(2):251-60. doi: 10.11607/ prd.2383
8. Li Y, Greenwall L. Safety issues of tooth whitening using peroxide- based materials. Br Dent J. 2013;215(1):29-34. doi: 10.1038/ sj.bdj.2013.629
9. Bruzell EM, Pallesen U, Thoresen NR, Wallman C, Dahl JE. Side effects of external tooth bleaching: a multi-centre practice-based prospective study. Br Dent J. 2013;215(9):E17. doi: 10.1038/sj.bdj.2013.1047
10. Li Y. Safety controversies in tooth bleaching. Den Clin of North Am. 2011;55(2):255-63. doi: 10.1016/j.cden.2011.01.003
11. Maran BM, Matos TP, Castro AD, Vochikovski L, Amadori AL, Loguercio AD, et al. In-office bleaching with low/medium vs. high concentrate hydrogen peroxide: a systematic review and meta-analysis. J Dent. 2020;103:103499. doi: 10.1016/j.jdent.2020.103499
12. Bersezio C, Martín J, Angel P, Bottner J, Godoy I, Avalos F, et al. Teeth whitening with 6% hydrogen peroxide and its impact on quality of life: 2 years of follow-up. Odontology. 2019;107(1):118-25. doi: 10.1007/s10266-018-0372-3
13. Martín J, Vildósola P, Bersezio C, Herrera A, Bortolatto J, Saad JR, et al. Effectiveness of 6% hydrogen peroxide concentration for tooth bleaching - a double-blind, randomized clinical trial. J Dent. 2015;43(8):965-72. doi: 10.1016/j.jdent.2015.05.011
14. Griffiths F, Parekh S. Is it time to reconsider the use of vital teeth bleaching in children and adolescents in Europe? Eur Arch Paediatr Dent. 2021;22(4):759-63. doi: 10.1007/s40368-021-00609-2

15. Mjör IA. Dentin permeability: the basis for understanding pulp reactions and adhesive technology. Braz Dent J. 2009;20(1):3-16. doi: 10.1590/s0103-64402009000100001
16. Pinto MM, Gonçalves ML, Mota AC, Deana AM, Olivan SR, Bortoletto C, et al. Controlled clinical trial addressing teeth whitening with hydrogen peroxide in adolescents: a 12-month follow-up. Clinics. 2017;72(3):161-70. doi: 10.6061/clinics/2017(03)06
17. Ferraz NK, Nogueira LC, Neiva IM, Ferreira RC, Moreira AN, Magalhães CS. Longevity, effectiveness, safety, and impact on quality of life of low-concentration hydrogen peroxides in-office bleaching: a randomized clinical trial. Clin Oral Investig. 2019;23(5):2061-70. doi: 10.1007/s00784-018-2607-7
18. Cordeiro D, Toda C, Hanan S, Arnhold LP, Reis A, Loguercio AD, et al. Clinical evaluation of different delivery methods of at-home bleaching gels composed of 10% hydrogen peroxide. Oper Dent. 2019;44(1):13- 23. doi: 10.2341/17-174-c
19. Carneiro TS, Favoreto MW, Bernardi LG, Sutil E, Wendlinger M, Centenaro GG, et al. Gingival irritation in patients submitted to at-home bleaching with different cutouts of the bleaching tray: a randomized, single-blind clinical trial. Clin Oral Investig. 2022;26(6):4381-90. doi: 10.1007/s00784-022-04401-4
20. Mailart MC, Sakassegawa PA, Santos KC, Torres CR, Palo RM, Borges AB. One-year follow-up comparing at-home bleaching systems outcomes and the impact on patient's satisfaction: randomized clinical trial. J Esthet Restor Dent. 2021;33(8):1175-85. doi: 10.1111/ jerd.12814
21. Pandis N, Chung B, Scherer RW, Elbourne D, Altman DG. CONSORT 2010 statement: extension checklist for reporting within person randomised trials. Br J Dermatol. 2019;180(3):534-52. doi: 10.1111/ bjd.17239
22. International Organization for Standardization. Technical Report - ISO TR 28642 Dentistry: guidance on colour measurement. Geneva: ISO; 2011.
23. De L'Eclairage. CIE Recommendations on uniform color spaces, color-difference equations, psychometric color terms. Color Res Appl. 1978;2(1):5-6. doi: 10.1002/j.1520-6378.1977.tb00102.x
24. Luo M, Cui G, Rigg B. The development of the CIE 2000 colour- difference formula: CIEDE2000. Color Res Appl 2001;26(5):340-50. doi: 10.1002/col.1049

25. Pérez MM, Ghinea R, Rivas MJ, Yebra A, Ionescu AM, Paravina RD, at al. Development of a customized whiteness index for dentistry based on CIELAB color space. Dent Mat. 2016;32(3):461-7. doi: 10.1016/j. dental.2015.12.008
26. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry.J Esthet Restor Dent. 2015;27:S1-S9. doi:10.1111/jerd.12149
27. Pérez MM, Herrera LJ, Carrillo F, Pecho OE, Dudea D, Gasparik C, et al. Whiteness difference thresholds in dentistry. Dent Mater. 2019;35(2):292-7. doi:10.1016/j.dental.2018.11.022
28. Oliveira BH, Nadanovsky P. Psychometric properties of the Brazilian version of the Oral Health Impact Profile-short form. Community Dent Oral Epidemiol. 2005;33(4):307-14. doi: 10.1111/j.1600- 0528.2005.00225.x
29. Schulz KF, Altman DG, Moher D, CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. BMJ. 2010;340:c332. doi: 10.1136/bmj.c332
30. Vildósola P, Vera F, Ramírez J, Rencoret J, Pretel H, Oliveira OB Jr., et al. Comparison of effectiveness and sensitivity using two in-office bleaching protocols for a 6% hydrogen peroxide gel in a randomized clinical trial. Oper Dent. 2017;42(3):244-252. doi: 10.2341/16-043-C 31-
31. The Scientific Committee on Consumer Products. Public consultation on a preliminary opinion on hydrogen peroxide in tooth whitening products. [place unknown]: Eurpean Comission; 2005 [cited 2024 Feb 2]. Available from: https://ec.europa.eu/health/archive/ph_risk/committees/04_sccp/docs/sccp_cons_01_en.pdf
32. Haywood VB, Sword RJ. Tray bleaching status and insights. J Esthet Restor Dent. 2021;33(1):27-38. doi: 10.1111/jerd.12688
33. Briso AL, Rahal V, Gallinari MO, Soares DG, Souza Costa CA. Complications from the use of peroxides. In: Perdigão, J (ed). Tooth whitening: an evidence-based perspective. Berlin, Springer; 2016. 45-79.
34. Bersezio C, Estay J, Jorquera G, Peña M, Araya C, Angel P, et al. Effectiveness of dental bleaching with 37.5% and 6% hydrogen peroxide and its effect on quality of life. Oper Dent. 2019;44(2):146- 55. doi: 10.2341/17-229-C

35. Fernández E, Bersezio C, Bottner J, Avalos F, Godoy I, Inda D, et al. Longevity, esthetic perception, and psychosocial impact of teeth bleaching by low (6%) hydrogen peroxide concentration for in-office treatment: a randomized clinical trial. Oper Dent. 2017;42(1):41-52. doi: 10.2341/15-335-c
36. Bortolatto JF, Trevisan TC, Bernardi PS, Fernandez E, Dovigo LN, Loguercio AD, et al. A novel approach for in-office tooth bleaching with 6% H2O2/TiO_N and LED/laser system-a controlled, triple-blinded, randomized clinical trial. Lasers Med Sci. 2016;31(3):437-44. doi: 10.1007/s10103-016-1866-2
37. Klaric E, Rakic M, Sever I, Tarle Z. Temperature rise during experimental light-activated bleaching. Lasers Med Sci. 2015;30(2):567- 76. doi: 10.1007/s10103-013-1366-6
38. Boksman L. Current status of tooth whitening: literature review. Dent Today. 2006;25(9):76-9.
39. Al Shethri S, Matis BA, Cochran MA, Zekonis R, Stropes M. A clinical evaluation of two in-office bleaching products. Oper Dent. 2003;28(5):488-95.
40. Klaric E, Par M, Profeta I, Kopjar N, Rozgaj R, Kasuba V, et al. Genotoxic effect of two bleaching agents on oral mucosa. Cancer Genomics Proteomics. 2013;10(5):209-15.
41. Almeida LC, Soares DG, Azevedo FA, Gallinari MO, Costa CA, Santos PH, et al. At-home bleaching: color alteration, hydrogen peroxide diffusion and cytotoxicity. Braz Dent J. 2015;26(4):378-383. doi: 10.1590/0103-6440201300380
42. Matis BA, Yousef M, Cochran MA, Eckert GJ. Degradation of bleaching gels *in vivo* as a function of tray design and carbamide peroxide concentration. Oper Dent. 2002;27(1):12-8.
43. Paul S, Peter A, Pietrobon N, Hämmerle CH. Visual and spectrophotometric shade analysis of human teeth. J Dent Res. 2002;81(8):578-82. doi: 10.1177/154405910208100815
44. Martins I, Onofre S, Franco N, Martins LM, Montenegro A, Arana- Gordillo LA, et al. Effectiveness of in-office hydrogen peroxide with two different protocols: a two-center randomized clinical trial. Oper Dent. 2018;43(4):353-61. doi: 10.2341/17-128-c

45. John MT. Health outcomes reported by dental patients. J Evid Based Dent Pract. 2018;18(4):332-5. doi: 10.1016/j.jebdp.2018.09.001
46. Rodd HD, Marshman Z, Porritt J, Bradbury J, Baker SR. Oral health- related quality of life of children in relation to dental appearance and educational transition. Br Dent J. 2011;211(2):E4-E4. doi: 10.1038/ sj.bdj.2011.574
47. Boccuzzi M, Nota A, Cosola S, De Simone G, Iozzo R, Pittari L, et al. Effect of bleaching treatments on the adhesion of orthodontic brackets: a systematic review. BMC Oral Health. 2023;23(1):758. doi: 10.1186/s12903-023-03418-9
48. Lanteri V, Segu M, Doldi J, Butera A. Pre-bonding prophylaxis and brackets detachment: an experimental comparison of different methods. Int J Clin Dent. 2014;7(2):191-7.
49. Cossellu G, Lanteri V, Butera A, Laffi N, Merlini A, Farronato G. Timing considerations on the shear bond strength of orthodontic brackets after topical fluoride varnish applications. J Orthod Sci. 2017;6(1):11-5. doi: 10.4103/2278-0203.197392

8 DISCUSSÃO

O presente trabalho foi o primeiro a abordar as diferentes estratégias de uso mais recentemente desenvolvidas para o PH a 6%, uma concentração que cada vez mais vem sendo difundida quando o assunto é baixa concentração, tanto para clareamento caseiro quanto para clareamento de consultório. Visando isto, buscando um copilado de evidências do PH a 6% e observando a falta de estudos na literatura, além de estudos *in vitro*, foram realizados estudos clínicos, uma vez que estudos *in vitro* geram hipóteses e os estudos clínicos são essenciais para recomendações clínicas.

Em relação ao primeiro estudo *in vitro*, ele introduz a tese abordando o uso do PH a 6% que está disponível para vernizes clareadores utilizados como clareamento caseiro. Conforme descrito na sessão “Introdução”, os fabricantes indicam a aplicação de uma fina camada de gel clareador [49; 66], e a SD pode não depender apenas da concentração do gel clareador, mas também da quantidade de produto que é aplicado na superfície [50; 67] e que de acordo com a segunda lei de Fick, quanto maior o volume aplicado, maior é a difusão [52]. Desta forma, os vernizes clareadores de baixa concentração parecem promissores, uma vez que uma fina camada é aplicada devido ao seu pincel aplicador, bem como são usados rapidamente e também não requerem o uso de moldeiras [53], facilitando o dia a dia dos pacientes e dos clínicos. Diferentes vernizes clareadores estão disponíveis no mercado, e poucos haviam sido descritos na literatura [68; 69; 70]. Portanto, o estudo 1 é o primeiro que comparou *in vitro* diferentes vernizes clareadores.

Quando diferentes tempos de aplicação foram comparados, um aumento na quantidade de PH dentro da câmara pulpar foi registrado para três dos quatro vernizes clareadores quando aplicados por 30 minutos. Quanto maior é o tempo que o agente clareador permanece em contato com a superfície do dente, maior penetração foi observada quando o peróxido ainda está disponível [44; 71], o que pode ser explicado pela dinâmica de difusão do PH nos tecidos dentais [72].

A exceção única foi o Pola Luminate, que não mostrou diferenças significativas ao comparar os dois tempos de aplicação. O pH pode explicar isso. A maioria dos fabricantes de agentes clareadores apresenta seus produtos com pH ácido para manter a vida útil dos produtos alta [73]. Apesar de isso parecer benéfico para esse propósito, infelizmente, o pH mais baixo do agente clareador está associado a uma

maior quantidade de PH dentro da câmara pulpar quando comparado a géis clareadores de pH menos ácido ou neutro [74; 75]. Quando géis clareadores de pH mais ácido são aplicados na superfície do dente, ocorrem alterações morfológicas com a diminuição da dureza do esmalte devido à desmineralização superficial [76; 77; 78]. Esses fatores aumentam a permeabilidade do dente e, consequentemente, aumentam a quantidade de penetração do PH dentro da câmara pulpar, conforme observado anteriormente [79; 80]. Além disso, géis clareadores com pH mais ácido levam mais tempo para completar a decomposição do PH quando comparados a géis clareadores menos ácidos [7]. Isso significa que os géis clareadores se tornam ativos por mais tempo, o que aumenta a chance do PH penetrar na câmara pulpar. Deve-se notar que o Pola Luminate exibiu um pH mais alto (5,7) em comparação com os outros vernizes clareadores avaliados.

Apesar de algumas diferenças entre os vernizes clareadores e tempo de aplicação, quando a mudança de cor foi avaliada por ΔE_{ab} ou ΔE_{00}, para todos os grupos experimentais, a mudança de cor foi maior do que o limite de aceitabilidade (AT) de 50:50 para ΔE_{ab} (AT = 2,7) ou ΔE_{00} (AT = 1,8). O valor AT representa uma diferença existente aceitável para a maioria das pessoas. Isso significa que uma diferença perceptível ocorre de mudança de cor, e os resultados são semelhantes aos observados em um estudo publicado [44]. No entanto, uma visão mais próxima sobre o ΔWI_D mostrou que, para todos os vernizes clareadores aplicados por 10 minutos e para Cavex e Aligner White aplicados por 30 minutos, os valores observados não atingiram o valor limite AT (2,6) para ΔWI_D [81]. Isso significa que, apesar de ocorrer algum clareamento, ele não deve ser considerado clinicamente aceitável. No entanto, quando um tempo de aplicação maior (30 minutos) é realizado para Pola Luminate e Viva Style, os valores de clareamento excedem o valor limite AT. Esse achado parece ser o mais importante para a mudança de cor, uma vez que o Whiteness Index é usado recentemente especificamente para avaliar o quanto os dentes ficaram mais brancos [82].

É essencial esclarecer que, apesar de um melhor efeito clareador observado para Pola Luminate e Viva Style quando aplicados por 30 minutos, apenas o fabricante do primeiro indica a aplicação por 30 minutos. Além disso, Viva Style apresentou duas vezes mais PH na câmara pulpar que Pola Luminate, principalmente quando avaliado

por 30 minutos. Portanto, considerando ambas as propriedades, Pola Luminate parece ser melhor que os outros vernizes clareadores avaliados.

Embora, até onde sabemos, este seja o primeiro estudo a avaliar diferentes vernizes clareadores em tempos diferentes, uma das limitações do estudo 1 pode ser atribuída ao uso de apenas quatro marcas comerciais. Uma vez que as diferenças na composição de vernizes clareadores de outras marcas podem diferir dos resultados apresentados neste estudo, além disso, futuros estudos clínicos necessitam ser realizados testando suas aplicações.

Seguindo a mesma linha de estudos voltados para aplicação de um fina camada de gel conforme descrito anteriormente, e observando que fabricantes desenvolveram diferentes ponteiras de aplicação para clareamento de consultório, o estudo *in vitro* 2 foi desenvolvido para testar as diferentes ponteiras disponíveis para o clareamento de consultório, ponteira convencional (sem pincel) e ponteira com pincel e verificar se as quantidades de géis aplicadas na superfície dental poderiam influenciar na penetração e mudança de cor comparando o PH a 6% com a alta concentração (PH 35%), uma vez que, mais frequentemente é utilizada para clareamento de consultório.

Os resultados do estudo 2 mostraram uma alta quantidade de PH observada dentro da polpa para PH a 35% quando comparado com PH a 6%. Isso era esperado porque vários estudos mostraram que quanto maior a concentração de PH, maior a quantidade de PH dentro da câmara pulpar [83; 84; 85]. No entanto, a quantidade excessiva de PH que atinge o tecido pulpar quando o PH a 35% é aplicado promove uma resposta inflamatória intensa [9]. Por exemplo, estudos clínicos mostraram que mais de 80% dos pacientes submetidos ao clareamento relataram SD durante e logo após uma sessão no consultório com PH a 35% [86; 87; 88; 89]. Embora esse efeito adverso seja geralmente considerado temporário e moderado, ele pode produzir desconforto considerável ao paciente e, em alguns casos, danos pulpares consideráveis podem ser vistos em estudos histológicos [90; 91; 92].

No entanto, uma quantidade significativamente menor de PH foi observada dentro da câmara pulpar quando os géis clareadores PH a 35% e PH a 6% foram aplicados com uma ponteira com pincel, em vez da ponteira convencional (sem pincel). Parece que a menor quantidade de PH dentro da câmara pulpar está diretamente relacionada ao volume aproximado de 50% menor de gel clareador usado

com uma ponteira com pincel quando comparado com a aplicação da ponteira sem pincel.

Na maioria dos países da União Europeia, é totalmente proibido usar PH a 35%. O Comitê Científico de Produtos de Consumo da União Europeia considera apenas produtos clareadores com concentrações de até 6% de PH como seguros para uso [48]. Esta é uma das razões, para usar um gel de baixa concentração para clareamento de consultório.

Como esperado, baixas quantidades de PH dentro da polpa [84; 93], bem como um menor efeito clareador, foram observados para o PH a 6% quando comparado com concentrações mais altas [94; 95]. Uma visão mais detalhada dos resultados da mudança de cor mostrou que a aplicação do PH a 6% causou um bom padrão de efeito clareador, com apenas 12-32% a menos em comparação com a aplicação do PH a 35%, apesar de uma enorme diferença na concentração de PH, uma vez que, o PH a 6% contém apenas 17% da quantidade de PH quando comparado com o PH a 35%.

Na realidade, diferentemente dos grupos de PH a 35%, um efeito clareador significativamente maior (ΔE_{ab} e ΔWI_D) foi observado para o PH a 6% quando aplicado com a ponteira convencional (sem pincel) em oposição à ponteira com pincel. Da mesma forma, um volume significativamente maior de gel clareador foi gasto quando a ponteira convencional foi usada. Observando bons resultados para o PH a 6% no clareamento de consultório e devido as diferenças detectadas em todos os parâmetros avaliados, o estudo 3 foi desenvolvido para testar o PH a 6% clinicamente com as diferentes ponteiras de aplicação.

O estudo 3 foi desenvolvido voltado para pacientes adolescentes, uma vez que é a mais baixa concentração disponível para clareamento de consultório. Os resultados mostraram que o PH a 6%, apesar da diferença entre as pontas utilizadas, obteve clareamento significativo, com menor risco e intensidade de SD quando comparada a alta concentração [33; 34] e com diferença significativa na autopercepção estética após ser submetido ao clareamento para os adolescentes avaliados. Essa descoberta tem importância significativa, principalmente porque, uma maior prevalência de SD é esperada em pacientes mais jovens devido à maior permeabilidade de seus dentes [37; 38].

Clareamento significativo foi detectado para ambos os grupos em comparação com os valores iniciais. Para as escalas subjetiva (VITA Classical e VITA Bleachedguide) e objetiva (ΔE_{ab} e ΔE_{00}), não houve diferença estatística entre os grupos. As variações de clareamento observadas no presente estudo estão de acordo com outros estudos que utilizaram PH a 6% para fins de clareamento e mediram a mudança de cor subjetivamente [1; 58; 96] ou objetivamente [1; 58; 96]. No entanto, vale ressaltar que quando a fórmula ΔWI_D foi usada, o clareamento mais significativo foi observado nas recordações de terceira semana e um mês, favorecendo o grupo ponteira sem pincel. O ΔWI_D é uma fórmula mais recente recomendada para avaliar o nível de brancura após o clareamento dental, com menor probabilidade de erro do que a anterior [82].

Resultados favoráveis de clareamento para o grupo da ponteira sem pincel podem ser atribuídos à quantidade de volume de gel utilizado. Observe na Figura 2 uma diferença notável no volume de gel que favorece o grupo da ponteira sem pincel. Este resultado está alinhado com as expectativas, pois o estudo 2 anterior avaliando as diferentes ponteiras de aplicação para gel de PH a 6% indicou que a ponteira sem pincel melhorou significativamente o efeito de clareamento. Isso se deve em grande parte ao fato de que exigiu quase três vezes mais gel em comparação com a ponteira com pincel, bem como observado anteriormente no estudo 2. De fato, os resultados do estudo atual estão alinhados com os de uma investigação clínica recente que demonstrou um efeito de clareamento mais pronunciado quando um volume maior de gel clareador foi aplicado à superfície do dente, em oposição a um volume menor de gel [50]. No entanto, o valor de ΔWI_D deve ser analisado cuidadosamente [81; 82], pois os limites de perceptibilidade e aceitabilidade de ΔWI_D devem ser verificados para estabelecer se a diferença é detectada pelo observador e é clinicamente relevante.

Ao avaliar o limite de perceptibilidade de 50:50% para o ΔWI_D, os valores observados no presente estudo apresentaram uma diferença média duas vezes maior que 0,72, valor perceptível ao observador médio calibrado [8;, 82]. No entanto, quando o limite de aceitabilidade de 50:50% foi avaliado, essa diferença não foi considerada clinicamente importante. Em outras palavras, o valor obtido no presente estudo foi menor que 2,62, o que significa que essa diferença é menor que o valor aceitável para um paciente [81; 82]. Desta forma, apesar de algumas diferenças significativas

observadas entre os grupos (ΔWI_D), esta estava abaixo do limiar de aceitabilidade para procedimentos de clareamento [81; 82].

Como a SD ocorre devido à capacidade do PH de penetrar na estrutura dentária e causar uma resposta inflamatória da polpa [9], espera-se que quanto maior a concentração de PH utilizada, mais SD seja observada [88; 89; 95; 97]. Essa expectativa foi indiretamente confirmada pelo menor risco absoluto de SD observado no presente estudo 3. Em média, 38% dos participantes do presente estudo relataram SD, em comparação com os 83-90% registrados em estudos anteriores que aplicaram concentrações maiores de PH [89; 97]. No entanto, o grupo de pacientes para os quais o clareador foi aplicado com a ponteira sem pincel apresentou um risco absoluto significativamente maior de SD. Esses resultados estão de acordo com os do estudo 2, que mostrou que a aplicação de PH a 6% no grupo da ponteira com pincel resultou em uma menor penetração do agente clareador quando comparado ao grupo da ponteira sem pincel, principalmente porque uma quantidade menor de gel foi dispensada para o primeiro. Isso pode ser demonstrado recentemente em um estudo clínico [50] que obteve um menor risco de SD ao usar um volume menor de gel clareador em comparação a um maior.

Um dos resultados mais importantes do presente estudo é a avaliação da autopercepção estética, pois é um desfecho relatado pelo paciente que caracteriza influências específicas da saúde bucal na vida dos pacientes, e sua avaliação já é considerada essencial [98]. Apesar de não encontrar diferenças significativas entre os grupos em todos os parâmetros avaliados, os participantes indicaram grande satisfação após o clareamento dental, principalmente quando questionados sobre a cor dos dentes. Este é um forte indicador de que o clareamento dental, mesmo em baixas concentrações, deve ser considerado uma boa opção para pacientes jovens. Considerando que pacientes jovens se preocupam com o aspecto social de sua aparência [99], o clareamento dental pode melhorar o bem-estar emocional e a autoestima dos pacientes [99].

Apesar dos resultados favoráveis descritos no estudo 3 sobre o clareamento no consultório com PH a 6%, deve-se notar que o mesmo nível de eficácia do clareamento não deve ser esperado, principalmente quando o PH a 6% foi comparado com géis para clareamento de consultório mais concentrados, como demonstrado anteriormente no estudo *in vitro* 2 e em estudos clínicos [1; 58]. Portanto, poderíamos

levantar a hipótese de que conduzir uma sessão adicional poderia produzir melhores resultados de clareamento para os participantes, semelhante ao que é alcançado ao usar o clareamento de alta concentração no consultório. No entanto, não devemos desconsiderar o fato de que, mesmo com os dentes não tão claros, os participantes ainda alcançaram satisfação estética, conforme indicado pelos resultados do questionário. Isso deve ser considerado um resultado significativo [98], principalmente ao levar em consideração as características da população-alvo (adolescentes).

O clareamento de consultório com baixa concentração forneceu resultados promissores. O uso de PH a 6% para a técnica de consultório oferece algumas vantagens sobre o clareamento em casa. O clareamento de consultório não depende da colaboração do paciente e é mais fácil de ser realizado porque não são necessárias moldeiras individualizadas, o que os adolescentes acham um pouco difícil de usar [65]. Além disso, o clareamento de consultório é concluído em apenas três sessões de 50 minutos, enquanto o clareamento em casa com PH a 6% geralmente requer aplicação diária por 14 a 21 dias, por 1 hora e 30 minutos. Os resultados de mudança de cor do estudo, independentemente da ponteira usada, sugerem que PH a 6% é uma boa opção para clareamento em consultório, especialmente quando usado com a ponteira com pincel que reduz a quantidade de gel usado conforme o estudo 2, reduzindo assim os custos do tratamento.

Algumas limitações precisam ser descritas, uma que o estudo 3 avaliou apenas uma marca comercial de gel clareador, e estudos futuros devem avaliar diferentes géis clareadores de PH a 6% disponíveis em cenários clínicos. Outra limitação é o protocolo de clareamento, o que dificultou a comparação deste estudo 3 com outros, tendo em vista a variabilidade no tempo de aplicação ou no número de sessões, associação com a luz e outros fatores [1; 58; 60; 95; 96], sendo necessários estudos posteriores para avaliar se esses fatores poderiam influenciar os resultados do estudo 3.

E em relação a IG, o estudo 4 foi realizado para verificar se IG ocorre quando uma barreira gengival para clareamento de consultório com PH a 6% não for colocada. Este é um cenário novo, ocorrendo durante a popularização de baixas concentrações de clareador em várias partes do mundo [58; 59; 96]. O clareamento dental usando uma barreira gengival é rotina em consultórios odontológicos. Em um cenário clínico, com clareamento de consultório usando altas concentrações de PH, não há dúvidas sobre

a eficácia do uso de barreiras gengivais para controlar IG ou mesmo queimaduras gengivais em pacientes. Em concentrações de até 10% para clareamento caseiro, a barreira gengival é dispensada [27; 61], e a eliminação da etapa de colocação da barreira para clareamento em consultório torna o procedimento mais simples, rápido e econômico.

A IG tem grande importância na avaliação de estudos clínicos de clareamento dental. Dependendo do grau de IG, pode até se apresentar como ulcerações e queimaduras, sendo inicialmente descrito como desconforto ou dor diretamente no tecido gengival [54; 77]. Infelizmente, estudos de clareamento de consultório raramente avaliam a IG, pois ele está diretamente associado ao cuidado do operador com o paciente. No entanto, apesar de vários estudos terem avaliado PH a 6% para clareamento de consultório [1; 58; 60; 95; 100], apenas Ferraz, et al [60] avaliou a IG. Neste estudo, os autores relataram IG em 57,7% dos participantes, diferindo do presente estudo, que obteve um total de 30,8%. Algumas diferenças metodológicas entre o estudo de Ferraz, et al [60] e o presente podem ajudar a explicar os resultados atuais. A diferença percentual pode ser atribuída ao protocolo usado; o primeiro [60] usou ativação de luz, e a ativação de luz do clareamento no consultório pode aumentar a temperatura operatória [101; 102], queimando assim o tecido mole [102].

A intensidade de IG em ambos os grupos foi menor que 0,3 em uma escala de 10, não sendo considerada clinicamente significativa. Diferentemente do risco absoluto de IG, a intensidade de IG foi semelhante à relatada na literatura. Por exemplo, em um estudo de Ferraz, et al [60], foi detectada baixa intensidade quando a barreira gengival foi utilizada. Além disso, a intensidade de IG sem barreira gengival foi semelhante aos níveis determinados durante o clareamento caseiro, que utiliza baixas concentrações [61; 62], vale ressaltar que nosso estudo 4 avaliou a IG na arcada inferior do paciente, por ser um estudo parte 2, pois a parte 1 do estudo foi publicada anteriormente (estudo 3), sendo realizado na arcada superior em um momento diferente.

Os resultados são semelhantes ao estudo 3 que utilizou o mesmo protocolo do estudo 4 em adolescentes, mesmo em dentes avaliados em arcadas diferentes. Outros estudos que avaliaram pelos mesmos métodos para PH a 6% (método objetivo [1; 58; 96] e método subjetivo [1; 58; 96; 100]) demonstraram eficácia de clareamento semelhante. No entanto, vale ressaltar que o protocolo utilizado no presente estudo,

assim como o do estudo 3 e Bersezio, et al [1], não utilizou luz e obteve resultados semelhantes aos estudos que a utilizaram [58; 96]. O padrão de clareamento foi aceitável quando comparado aos estudos que utilizaram maiores concentrações de PH [49; 95], no entanto, assim como descrito para o estudo 3, uma sessão a mais poderia ser realizada para atingir melhores resultados, uma vez que o uso de produtos de PH em baixas concentrações pode produzir a mesma eficácia de mudança de cor com a vantagem de ter menos efeitos adversos [103].

Para as limitações do estudo 4, ele avaliou apenas uma marca de gel clareador disponível no mercado, bem como utilizou apenas um protocolo para uso do PH a 6% no clareamento de consultório, utilizando as recomendações do fabricante. Os resultados não podem ser aplicados diretamente para materiais de clareamento de venda livre ou caseiros baseados em PH a 6%, principalmente porque os protocolos relacionados ao uso de PH a 6% variam muito [1; 58; 60; 95; 96; 100]. Portanto, estudos clínicos futuros precisam ser feitos para avaliar se a IG é afetada no mesmo nível em diferentes marcas e/ou protocolos.

9 CONCLUSÃO

De acordo com a metodologia aplicada e os resultados obtidos, as conclusões dos trabalhos realizados são as seguintes:

1. Uma menor quantidade de PH dentro da câmara pulpar foi detectada quando todos os vernizes clareadores com PH a 6% foram aplicados por 10 min em um período de 14 dias em comparação com 30 minutos. No entanto, nenhum desses tratamentos atingiu uma mudança de cor clinicamente aceitável (conforme limite de aceitabilidade para Whiteness Index) após o clareamento dental. Apenas dois dos vernizes clareadores testados, Pola Luminate PH a 6% e VivaStyle Paint On Plus PH a 6%, exibiram uma mudança de cor clinicamente aceitável após o clareamento quando aplicados por 30 min em um período de 14 dias. No entanto, Pola Luminate PH a 6% demonstrou uma menor quantidade de peróxido de hidrogênio dentro da câmara pulpar em comparação com VivaStyle Paint On Plus PH a 6% quando ambos foram aplicados por 30 minutos.
2. Quando avaliadas as diferentes ponteiras de aplicação (com pincel e sem pincel) para baixa (PH a 6%) e alta (PH a 35%) concentração, menor penetração na câmara pulpar foi encontrada para a ponteira com pincel utilizada no clareamento de consultório independente da concentração de gel clareador; porém, o uso da ponteira sem pincel para PH a 6% apresentou uma melhora significativa na mudança de cor (ΔE_{ab} e ΔWI_D) em comparação com a ponteira com pincel, uma vez que utilizou uma quantidade de gel significativamente maior.
3. Clinicamente, eficácia clareadora (VITA Classical, VITA Bleachedguide e espectrofotômetro VITA Easyshade) foi observada para ambas as ponteiras de aplicação (ponteira com pincel e sem pincel) quando avaliadas em adolescentes no clareamento de consultório com PH a 6%. Baixo risco e intensidade (EVA) de SD foram presenciados para PH a 6%, entretanto a ponteira com pincel deve ser considerada como primeira opção, uma vez que apresentou menor risco de SD. Melhora da autopercepção estética (EEO) foi detectada após o clareamento dental independentemente da ponteira de aplicação.

4. Clinicamente, foi presenciado baixo risco e intensidade (EVA) de IG para clareamento de consultório com PH a 6% em adolescentes com o uso ou não da barreira gengival apresentando equivalência entre os grupos. Eficácia clareadora foi observada (VITA Classical, VITA Bleachedguide e espectrofotômetro VITA Easyshade) e a necessidade da etapa de aplicação da barreira gengival pode ser desconsiderada. Melhora do impacto da condição bucal na qualidade de vida dos pacientes (OHIP-14) foi detectada após o clareamento dental.

REFERÊNCIAS

1.BERSEZIO, C. *et al.* Effectiveness of Dental Bleaching With 37.5% and 6% Hydrogen Peroxide and Its Effect on Quality of Life. **Oper Dent**, v. 44, n. 2, p. 146-155, 2019.

2.JIANG, N. W. *et al.* Correlation between patient satisfaction and color changes after tooth bleaching. **J Esthet Restor Dent**, v. 36, n. 3, p. 437-444, 2024.

3.NIE, J. *et al.* Comparison of efficacy and outcome satisfaction between in-office and home teeth bleaching in Chinese patients. **J Oral Sci,** v. 59, n. 4, p. 527-532, 2017.

4.RODRIGUEZ-MARTINEZ, J. *et al.* Tooth whitening: From the established treatments to novel approaches to prevent side effects. **J Esthet Restor Dent***,* v. 31, n. 5, p. 431-440, 2019.

5.MAZILU MOLDOVAN, A. *et al.* Various Aspects Involved in the Study of Tooth Bleaching Procedure: A Questionnaire-Based Study. **Int J Environ Res Public Health,** v. 19, n. 7, p. 3977, 2022.

6.HEYMANN, H.O. Tooth whitening: facts and fallacies, **Br Dent J,** v. 198, n. 8, p. 514, 2005.

7.REIS, A.; LOGUERCIO, A.D. Materiais dentários diretos: dos fundamentos à aplicação clínica. **Santos**, 2021.

8.KIHN PW.Vital tooth whitening. **Dent Clin North Am**, v. 51, n. 2, p. 319-331, 2007.

9.KWON, S. R.; WERTZ, P.W. Review of the Mechanism of Tooth Whitening. **J Esthet Restor Dent**, v. 27, n. 5, p. 240-257, 2015.

10.HAYWOOD, V.; HEYMANN, H. Nightguard vital bleaching. **Quintessence Int,** v. 20, n. 3, p. 173-176, 1989.

11.PEREIRA, R. *et al.* Dental prophylaxis influence in tooth color assessment—Clinical study. **J Esthet Restor Dent**, v. 32, n. 6, p. 586-592, 2020.

12.JOINER, A.; LUO, W. Tooth colour and whiteness: A review. **J Dent**, v. 67, p. S3-S10, 2017.

13.DE GEUS, J. L. *et al.* Effects of At-home Bleaching in Smokers: 30-month Follow-up. **Oper Dent**, v. 42, n. 6, p. 572-580, 2017.

14.SULIEMAN, M. J. An overview of bleaching techniques: 2. Night Guard Vital Bleaching and non-vital bleaching. **Dent Update**, v. 32, n. 1, p. 39-46, 2005.

15.ALQAHTANI, M. Q. Tooth-bleaching procedures and their controversial effects: A literature review. **Saudi Dent J**, v. 26, n. 2, p. 33-46, 2014.

16.CAREY, C. M. Tooth whitening: what we now know. **J Evid Based Dent Pract**, v. 14, p. 70-76, 2014.

17.EIMAR, H. *et al.* Hydrogen peroxide whitens teeth by oxidizing the organic structure. **J Dent**, v. 40, n. 2, p. e25-33, 2012.

18.KAWAMOTO, K.; TSUJIMOTO, Y. Effects of the hydroxyl radical and hydrogen peroxide on tooth bleaching. **J Endod**, v. 30, n. 1, p. 45-50, 2004.

19.WATTS, A.; ADDY, M.Tooth discolouration and staining: a review of the literature. **Br Dent J**, v. 190, n. 6, p. 309-316, 2001.

20.SULIEMAN, M. An overview of bleaching techniques: I. History, chemistry, safety and legal aspects. **Dent Update**, v. 31, n. 10, p. 608-610, 612-604, 616, 2004.

21.JOINER, A. The bleaching of teeth: a review of the literature. **J Dent**, v. 34, n. 7, p. 412-419, 2006.

22.FATTIBENE, P. *et al.* A comparative EPR, infrared and Raman study of natural and deproteinated tooth enamel and dentin. **Phys Med Biol**, v. 50, n. 6, p. 1095-1108, 2005.

23.EIMAR, H. *et al.* The role of enamel crystallography on tooth shade. **J Dent**, v. 39, Suppl 3, p. e3-10, 2011.

24.DE GEUS, J. L. *et al.* At-home vs In-office Bleaching: A Systematic Review and Meta-analysis. **Oper Dent**, v. 41, n. 4, p. 341-356, 2016.

25.TREDWIN, C. J. *et al.* Hydrogen peroxide tooth-whitening (bleaching) products: review of adverse effects and safety issues. **Br Dent J**, v. 200, n. 7, p. 371-376, 2006.

26.REIS, A. *et al.* In-office tooth whitening. **Clin Dent Rev**, v. 2, n. 1, p. 10, 2018.

27.HAYWOOD, V. B.; SWORD, R. J. Tray bleaching status and insights. **J Esthet Restor Dent**, v. 33, n. 1, p. 27-38, 2021.

28.CORDEIRO, D. *et al.* Clinical Evaluation of Different Delivery Methods of At-Home Bleaching Gels Composed of 10% Hydrogen Peroxide. **Oper Dent**, v. 44, n. 1, p. 13-23, 2019.

29.DOURADO PINTO, A.V. *et al.* At-home, in-office and combined dental bleaching techniques using hydrogen peroxide: Randomized clinical trial evaluation of effectiveness, clinical parameters and enamel mineral content. **Am J Dent**, v. 32, n. 3, p. 124-132, 2019.

30.HOSSAIN, M. Z. *et al.* The Role of Transient Receptor Potential (TRP) Channels in the Transduction of Dental Pain. **Int J Mol Sci**, v. 20, n. 3, 2019.

31.CHEN, C. *et al.* TRPA1 triggers hyperalgesia and inflammation after tooth bleaching. **Sci Rep**, v. 11, n. 1, p. 17418, 2021.

32.MARKOWITZ, K. Pretty painful: why does tooth bleaching hurt? **Med Hypotheses**, v. 74, n. 5, p. 835-840, 2010.

33.TAY, L. Y. *et al.* Long-term efficacy of in-office and at-home bleaching: a 2-year double-blind randomized clinical trial. **Am J Dent**, v. 25, n. 4, p. 199-204, 2012.

34.MOUNIKA, A. *et al.* Clinical evaluation of color change and tooth sensitivity with in-office and home bleaching treatments. **Indian J Dent Res**, v. 29, n. 4, p. 423-427, 2018.

35.ALONSO DE LA PEÑA, V., LÓPEZ RATÓN, M. Randomized clinical trial on the efficacy and safety of four professional at-home tooth whitening gels. **Oper Dent**, v. 39, n. 2, p. 136-143, 2014.

36.CHEMIN, K. *et al.* Effectiveness of and Dental Sensitivity to At-home Bleaching With 4% and 10% Hydrogen Peroxide: A Randomized, Triple-blind Clinical Trial. **Oper Dent,** v. 43, n. 3, p. 232-240, 2018.

37.MJÖR, I. A. Dentin permeability: the basis for understanding pulp reactions and adhesive technology. **Braz Dent J**, v. 20, n. 1, p. 3-16, 2009.

38.PASHLEY, D.H. Dentin-predentin complex and its permeability: physiologic overview. **J Dent Res**, v. 64, p. 613-620, 1985.

39.CARVALHO, T. S.; LUSSI, A. Age-related morphological, histological and functional changes in teeth. v. 44, n. 4, p. 291-298, 2017.

40.MARTINI, E. *et al.* Topical application of a desensitizing agent containing potassium nitrate before dental bleaching: a systematic review and meta-analysis**. Clin Oral Investig**, v. 25, n. 7,p. 4311-4327, 2021.

41.LOGUERCIO, A. D. *et al.* Effect of acidity of in-office bleaching gels on tooth sensitivity and whitening: a two-center double-blind randomized clinical trial. **Clin Oral Investig**, v. 21, n. 9, p. 2811-2818, 2017.

42.COPPLA, F. *et al.* Combination of acetaminophen/codeine analgesics does not avoid bleaching-induced tooth sensitivity: a randomized, triple-blind two-center clinical trial. **Oper Dent**, v. 43, n. 2, p. E53-E63, 2018.

43.FAVORETO, M. W. *et al.* Topical application of Otosporin® before in-office bleaching: a split mouth, triple-blind, multicenter randomized clinical trial. **Clin Oral Investig**, v. 26, n. 3, p. 2555-2564, 2021.

44.ALMEIDA, L. C. *et al.* At-home bleaching: color alteration, hydrogen peroxide diffusion and cytotoxicity. **Braz Dent J**, v. 26, n. 4, p. 378-383, 2015.

45.SOARES, D. G. *et al.* Immediate and late analysis of dental pulp stem cells viability after indirect exposition to alternative in-office bleaching strategies. **Clin Oral Investig**, v. 19, n. 5, p. 1013-1020, 2015.

46.DE ALMEIDA, L. C. *et al.* Color alteration, hydrogen peroxide diffusion, and cytotoxicity caused by in-office bleaching protocols. **Clin Oral Investig**, v. 19, n. 3, p. 673-680, 2015.

47.DE LIMA, A. F. *et al.* Cytotoxic effects of different concentrations of a carbamide peroxide bleaching gel on odontoblast-like cells MDPC-23. **J Biomed Mater Res B Appl Biomater**, v. 90, n. 2, p. 907-912, 2009.

48. Scientific Committee on Consumer Products. Public consultation on a preliminary opinion on hydrogen peroxide in tooth whitening products In: Products, **European commission health & consumer protection directorate-general**, 2005.

49.MARTINS, I. *et al.* Effectiveness of In-office Hydrogen Peroxide With Two Different Protocols: A Two-center Randomized Clinical Trial. **Oper Dent**, v. 43, n. 4, p. 353-361, 2018.

50.ESTEVES, L. M. B, *et al.* Effect of bleaching gel volume on color change and postoperative sensitivity: a randomized clinical study. **Clin Oral Investig**, v. 26, n. 3, p. 2527-2536, 2022.

51.BERNARDI, L. G. *et al.* Use of an applicator brush with high concentration bleaching gels. **Clin Oral Investig**, v. 26, n. 10, p. 6387-6395, 2022.

52.CRANK, J. The mathematics of diffusion. **Oxford university press**. 1979.

53.GREENWALL, L. J. Tooth whitening: the last 25 years. **Aesthetic Dent Today,** v. 6, n. 2, p. 15-19, 2016.

54.BRUZELL, E. M. *et al.* Side effects of external tooth bleaching: a multi-centre practice-based prospective study. **Br Dent J**, v. 215, n. 9, p. E17, 2013.

55.LI, Y. Safety controversies in tooth bleaching. **Dent Clin North Am**, v. 55, n. 2, p. 255-263, 2011.
.
56.POWELL, L. V.; BALES, D. J. Tooth bleaching: its effect on oral tissues. **J Am Dent Assoc**, v. 122,n. 11, p. 50-54, 1991.

57.LI, Y.; GREENWALL, L. Safety issues of tooth whitening using peroxide-based materials. **Br Dent J**, v. 215, n. 1, p. 29-34, 2013.

58.BERSEZIO, C. *et al.* Teeth whitening with 6% hydrogen peroxide and its impact on quality of life: 2 years of follow-up. **Odontology**, v. 107, n. 1, p. 118-125, 2019.

59.MARTÍN, J. *et al.* Effectiveness of 6% hydrogen peroxide concentration for tooth bleaching—A double-blind, randomized clinical trial. **J Dent**, v. 43, n. 8, p. 965-972, 2015.

60.FERRAZ, N. K. L. *et al.* Longevity, effectiveness, safety, and impact on quality of life of low-concentration hydrogen peroxides in-office bleaching: a randomized clinical trial. **Clin Oral Investig**, v. 23, n. 5, p. 2061-2070, 2019.

61.CARNEIRO, T. S. *et al.* Gingival irritation in patients submitted to at-home bleaching with different cutouts of the bleaching tray: a randomized, single-blind clinical trial. **Clin Oral Investig**, v. 26, n. 6, p. 4381-4390, 2022.

62.MAILART, M. C. *et al.* One-year follow-up comparing at-home bleaching systems outcomes and the impact on patient's satisfaction: Randomized clinical trial. **J Esthet Restor Dent**, v. 33, n. 8, p. 1175-1185, 2021.

63.VALLITTU, P. K.; VALLITTU, A. S.; LASSILA, V. P. Dental aesthetics--a survey of attitudes in different groups of patients. **J Dent**, v. 24, n. 5, p. 335-338, 1996.

64.GRIFFITHS, F.; PAREKH, S. J. Is it time to reconsider the use of vital teeth bleaching in children and adolescents in Europe? **Eur Arch Paediatr Dent**, v. 22, n. 4,p. 759-763, 2021.

65.PINTO, M. *et al.* Controlled clinical trial addressing teeth whitening with hydrogen peroxide in adolescents: A 12-month follow-up. **Clinics**, v. 72, n. 3,p. 161-170, 2017.

66.KOSSATZ, S. *et al.* Tooth sensitivity and bleaching effectiveness associated with use of a calcium-containing in-office bleaching gel. **J Am Dent Assoc**, v. 143, n. 12, p. e81-87, 2012.

67.TORRES, C. R. *et al.* Influence of chemical activation of a 35% hydrogen peroxide bleaching gel on its penetration and efficacy--in vitro study. **J Dent**, v. 38, n. 10, p. 838-846, 2010.

68.YILDIRIM, E. *et al.* Effects of Different Over - the - Counter Whitening Products on the Microhardness, Surface Roughness, Color and Shear Bond Strength of Enamel. **Acta Stomatol Croat**, v. 56, n. 2, p. 120-131, 2022.

69.KIELBASSA, A. M. *et al.* In vitro comparison of visual and computer-aided pre- and post-tooth shade determination using various home bleaching procedures. **J Prosthet Dent**, v. 101, n. 2, p. 92-100, 2009.

70.PESSANHA, S. *et al.* Evaluation of the effect of fluorinated tooth bleaching products using polarized Raman microscopy and particle induced gamma-ray emission Spectrochim. **Acta A Mol Biomol Spectrosc,** v. 236, p. 118378, 2020.

71.MARSON, F. C. *et al.* Penetration of hydrogen peroxide and degradation rate of different bleaching products. **Oper Dent**, v. 40, n. 1, p. 72-79, 2015.

72.UBALDINI, A. L. *et al.* Hydrogen peroxide diffusion dynamics in dental tissues. **J Dent Res,** v. 92, n. 7, p. 661-665, 2013.

73.TORRES, C. R. *et al.* Influence of pH on the effectiveness of hydrogen peroxide whitening. **Oper Dent**, v. 39, n. 6, p. E261-268, 2014.

74.ACUÑA, E. D. *et al.* In-office bleaching with a commercial 40% hydrogen peroxide gel modified to have different pHs: Color change, surface morphology, and penetration of hydrogen peroxide into the pulp chamber. **J Esthet Restor Dent**, v. 34, n. 2, p. 322-327, 2019.

75.BALLADARES, L. *et al.* Effects of pH and Application Technique of In-office Bleaching Gels on Hydrogen Peroxide Penetration into the Pulp Chamber. **Oper Dent**, v. 44, n. 6, p. 659-667, 2019.

76.DAHL, J. E.; PALLESEN, U. Tooth bleaching--a critical review of the biological aspects. **Crit Rev Oral Biol Med**, v. 14, n. 4, p. 292-304, 2003.

77.BRISO, A. L. F. *et al.* Complications from the use of peroxides Tooth Whitening. **Springer**, p. 45-79, 2016.

78.PINTO, C. F. *et al.* Peroxide bleaching agent effects on enamel surface microhardness, roughness and morphology. **Braz Oral Res**, v. 18, n. 4, p. 306-311, 2004.

79.CAVALLI, V. *et al.* High-concentrated carbamide peroxide bleaching agents effects on enamel surface. **J Oral Rehabil**, v. 31, v. 2, p. 155-159, 2004.

80.BISTEY, T. *et al.* In vitro FT-IR study of the effects of hydrogen peroxide on superficial tooth enamel. **J Dent**, v. 35, n. 4, p. 325-330, 2007.

81.PÉREZ. M. M. *et al.* Whiteness difference thresholds in dentistry. **Dent Mater**, v. 35, n. 2, p. 292-297, 2019.

82.PÉREZ, M. M. *et al.* Development of a customized whiteness index for dentistry based on CIELAB color space. **Dent Mater**, v. 32, n. 3, p. 461-467, 2016.

83.SOARES, D. G. *et al.* Concentrations of and application protocols for hydrogen peroxide bleaching gels: effects on pulp cell viability and whitening efficacy. **J Dent**, v. 42, n. 2, p. 185-198, 2014.

84.PARREIRAS, S. *et al.* Initial and pulp chamber concentration of hydrogen peroxide using different bleaching products. **Braz Dent Sci**, v. 23, n. 2, p. 8, 2020.

85.CINTRA, L. T. A. *et al.* Penetration Capacity, Color Alteration and Biological Response of Two In-office Bleaching Protocols. **Braz Dent J**, v. 27, n. 2, p. 169-175, 2016.

86.MARTINI, E. C. *et al.* Bleaching-induced tooth sensitivity with application of a desensitizing gel before and after in-office bleaching: a triple-blind randomized clinical trial. **Clin Oral Investig**, v. 24, n. 1, p. 385-394, 2020.

87.PAULA, E. *et al.* The effect of perioperative ibuprofen use on tooth sensitivity caused by in-office bleaching. **Oper Dent**, v. 38, n. 6, p. 601-608, 2013.

88.MENA-SERRANO, A. P. *et al.* A Single-Blind Randomized Trial About the Effect of Hydrogen Peroxide Concentration on Light-Activated Bleaching. **Oper Dent**, v. 41, n. 5, p. 455-464, 2016.

89.LIMA, S. N. L. *et al.* Evaluation of several clinical parameters after bleaching with hydrogen peroxide at different concentrations: A randomized clinical trial. **J Dent**, v. 68, p. 91-97, 2018.

90.CINTRA, L. T. *et al.* The number of bleaching sessions influences pulp tissue damage in rat teeth. **J Endod**, v. 39, n. 12, p. 1576-1580, 2013.

91.RODERJAN, D. A. *et al.* Response of Human Pulps to Different In-Office Bleaching Techniques: Preliminary Findings. **Braz Dent J**, v. 26, n. 3, p. 242-248, 2015.

92.COSTA, C. A. *et al.* Human pulp responses to in-office tooth bleaching. **Oral Surg Oral Med Oral Pathol Oral Radiol Endod**, v. 109, n. 4, p. e59-64, 2010.

93.JOINER, A.; THAKKER, G. In vitro evaluation of a novel 6% hydrogen peroxide tooth whitening product. **J Dent**, v. 32, Suppl 1, p. 19-25, 2004.

94.ESTAY, J. *et al.* The change of teeth color, whiteness variations and its psychosocial and self-perception effects when using low vs. high concentration bleaching gels: a one-year follow-up. **BMC Oral Health**, v. 20, n. 1, p. 255, 2020.

95. BORTOLATTO, J. F. *et al.* A novel approach for in-office tooth bleaching with 6% H2O2/TiO_N and LED/laser system-a controlled, triple-blinded, randomized clinical trial. **Lasers Med Sci**, v. 31, n. 3, p. 437-444, 2016.

96.VILDÓSOLA, P. *et al.* Comparison of Effectiveness and Sensitivity Using Two In-Office Bleaching Protocols for a 6% Hydrogen Peroxide Gel in a Randomized Clinical Trial. **Oper Dent**, v. 42, n. 3, p. 244-252, 2017.

97.BORTOLATTO, J. F. *et al.* Low Concentration H(2)O(2)/TiO_N in Office Bleaching: A Randomized Clinical Trial. **J Dent Res**, v. 93, 7 Suppl, p. 66s-71s, 2014.

98.JOHN, M. T. Health Outcomes Reported by Dental Patients. **J Evid Based Dent Pract**, v. 18, n. 4, p. 332-335, 2018.

99.ILYAS, N.; MARSHALL, S.; AHLUWALIA, M. Dental Bleaching: 'Now I can Smile for my Selfies' - Paediatric Patients' Perspectives. **Prim Dent J**, v. 10, n. 4, p. 65-73, 2021.

100.FERNÁNDEZ, E. *et al.* Longevity, Esthetic Perception, and Psychosocial Impact of Teeth Bleaching by Low (6%) Hydrogen Peroxide Concentration for In-office Treatment: A Randomized Clinical Trial. **Oper Dent**, v. 42, n. 1, p. 41-52, 2017.

101.KLARIC, E. *et al.* Temperature rise during experimental light-activated bleaching. **Lasers Med Sci**, v. 30, n. 2, p. 567-576, 2015.

102.BOKSMAN, L. Current status of tooth whitening: literature review. **Dent Today**, v. 25, n. 9, p. 74, 76-79; 2006.

103.MARAN, B. M. *et al.* In-office bleaching with low/medium vs. high concentrate hydrogen peroxide: A systematic review and meta-analysis. **J Dent**, v. 103, p. 103499, 2020.

ANEXO A
DIVULGAÇÃO DOS RESULTADOS

CONGRESSOS

Título: Clareamento de consultório com peróxido de hidrogênio 6% com diferentes ponteiras
Formato: Pôster
Autores: CARNEIRO, T. S.; FAVORETO, M. W.; FERREIRA, M. W. C.; ÑAUPARI-VILLASANTE, ROMINA ; BORGES, CHRISTIANE P. F. ; REIS, A; CEBALLOS, L; LOGUERCIO, A. D.
Congresso: 40º Reunião Anual da Sociedade Brasileira de Pesquisa Odontológica
Organizador: Sociedade Brasileira de Pesquisa Odontológica - SBPqO
Data e lugar: 2023 Campinas-SP

Título: Clareamento dental de consultório em adolescentes usando peróxido de hidrogênio a 6% com e sem barreira gengival: ensaio clínico randomizado
Formato: Pôster
Autores: RODRIGUES, J. P. F.; CARNEIRO, T. S.; FAVORETO, M. W.; SUTIL, E.; CENTENARO, G. G.; REIS, A.; CEBALLOS, L.; LOGUERCIO, A. D.
Congresso: 25º Encontro do Grupo Brasileiro de Professores de Dentística
Organizador: GBPD
Data e lugar: 2023 Gramado-RS

Título: Efeitos de diferentes vernizes clareadores: penetração de peróxido de hidrogênio na câmara pulpar e mudança de cor
Formato: Pôster
Autores: DIAS, R. M.; CARNEIRO, T. S.; ANDRADE, H. F.; MENA-SERRANO, A.; FAVORETO, M. W.; REIS, A; CEBALLOS, L.; LOGUERCIO, A. D.
Congresso: 25º Encontro do Grupo Brasileiro de Professores de Dentística
Organizador: Grupo Brasileiro de Professores de Dentística - GBPD
Data e lugar: 2023 Gramado-RS

Título: Eficácia do clareamento em consultório com peróxido de hidrogênio 35% utilizando diferentes ponteiras de aplicação
Formato: Pôster

Autores: FAVORETO, M. W.; CENTENARO, G. G.; CARNEIRO, T. S.; COCHINSKI, G. D.; CORDEIRO, D.; GUMY, F.; LOGUERCIO, A. D.; REIS, A
Congresso: 40º Reunião Anual da Sociedade Brasileira de Pesquisa Odontológica
Organizador: Sociedade Brasileira de Pesquisa Odontológica - SBPqO
Data e lugar: 2023 Campinas-SP

Título: Clareamento de consultório em odontohebiatria com um novo agente clareador com diferentes ponteiras: ensaio clínico randomizado
Formato: Pôster
Autores: CARNEIRO, T. S.; FAVORETO, M. W.; FERREIRA, M. W. C.; ANDRADE, H. F.; BERNARDI, L. G.; BANDECA, M. C.; REIS, A.; LOGUERCIO, A. D.
Congresso: 39º Reunião Anual da Sociedade Brasileira de Pesquisa Odontológica
Organizador: Sociedade Brasileira de Pesquisa Odontológica - SBPqO
Data e lugar: 2022 Campinas-SP

Título: Avaliação das diferentes técnicas de clareamento utilizando peróxido de hidrogênio 6%
Formato: Pôster
Autores: CENTENARO, G. G.; FAVORETO, M. W.; CARNEIRO, T. S.; WENDLINGER, M; BORGES, C. P. F.; GALVAO, L. C. C.; REIS, A.; LOGUERCIO, A. D.
Congresso: 39º Reunião Anual da Sociedade Brasileira de Pesquisa Odontológica
Organizador: Sociedade Brasileira de Pesquisa Odontológica - SBPqO
Data e lugar: 2022 Campinas-SP

Título: Efeito da ponteira de aplicação em diferentes géis clareadores de automistura no clareamento de consultório
Formato: Pôster
Autores: CARNEIRO, T. S.; FAVORETO, M. W.; BERNARDI, L. G.; BANDECA, M. C.; BORGES, C. P. F.; REIS, A.; LOGUERCIO, A. D.
Congresso: 38º Reunião Anual da Sociedade Brasileira de Pesquisa Odontológica
Organizador: Sociedade Brasileira de Pesquisa Odontológica - SBPqO
Data e lugar: 2021 Campinas-SP

TEXTOS EM REVISTAS

Título: O impacto do percentual de peróxido de hidrogênio no clareamento dental
Autores: CARNEIRO, T. S.; FAVORETO, M. W.; LOGUERCIO, A. D.
Revista e ano: FGM News 2024
Páginas: 30-33

Título: Clareamento em consultório sem sensibilidade dental
Autores: FAVORETO, M. W.; CENTENARO, G. G.; CARNEIRO, T. S.; REIS, A.; LOGUERCIO, A. D.
Revista e ano: FGM News 2024
Páginas: 34-36

Título: Clareamento de Consultório com Whiteness HP Automixx 6% com Ponteira Brush
Autores: REIS, A.; LOGUERCIO, A. D.; FAVORETO, M. W.; CARNEIRO, T. S.
Revista e ano: FGM News 2023
Páginas: 34-37

ARTIGOS

Título: In vitro evaluation of the effect of different bleaching varnishes: Hydrogen peroxide penetration into the pulp chamber and color change
Autores: CARNEIRO, T. S.; FAVORETO, M. W.; MENA-SERRANO, A.; WENDLINGER, M.; FORVILLE, H.; REIS, A.; CEBALLOS, L.; LOGUERCIO, A. D.
Revista e ano: Journal of Esthetic and Restorative Dentistry 2023
Volume, número e páginas: v. 36, n. 2, p. 402-409
DOI: 10.1111/jerd.13133

Título: Application Tip and Concentration of a Self-mixing Bleach: Hydrogen Peroxide Inside the Pulp Chamber, Color Change, and Amount of Bleaching Gel Used

Autores: CARNEIRO, T. S.; FAVORETO, M. W.; BERNARDI, L. G.; BANDECA, M. C.; BORGES, C. P. F.; REIS, A.; LOGUERCIO, A. D.
Revista e ano: Operative Dentistry 2023
Volume, número e páginas: v. 48, n. 2, p. 146-154
DOI: 10.2341/21-053-L

Título: In-office dental bleaching in adolescents using 6% hydrogen peroxide with different application tips: randomized clinical trial
Autores: CARNEIRO, T. S.; FAVORETO, M. W.; FERREIRA, M. W.; BERNARDI, L. G.; ANDRADE, H. F.; BANDECA, M. C.; REIS, A.; CEBALLOS L.; LOGUERCIO, A. D.
Revista e ano: Journal of Applied Oral Science 2023
Volume, número e páginas: v. 31, e20230216, p. 1-10
DOI: 10.1590/1678-7757-2023-0216

Título: In-office dental bleaching in adolescents using 6% hydrogen peroxide with and without gingival barrier: a randomized double-blind clinical trial
Autores: CARNEIRO, T. S.; FAVORETO, M. W.; RODRIGUES, J. P. F. ; SUTIL, E.; CENTENARO, G. G.; FREITAS, I. M.; REIS, A.; CEBALLOS, L.; LOGUERCIO, A. D.
Revista e ano: Journal of Applied Oral Science 2024
Volume, número e páginas: v. 32, e20230416, p. 1-10
DOI: 10.1590/1678-7757-2023-0416