




Tooth-Whitening with a Novel Phthalimido Peroxy Caproic Acid: Short Communication

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Abstract: Professional tooth whitening in the dental office is a popular cosmetic procedure and is performed under carefully monitored conditions. This allows the controlled application of a relatively high concentration of bleaching ingredients based on hydrogen peroxide or peroxide derivatives which produce reactive oxygen species, and consequently induce enamel erosion, alteration of the microhardness of the teeth, irritation of the gums, pain or post bleach sensitivity. This short communication describes the successful and reliable application of a new professional tooth whitening technique using a novel phthalimido peroxy caproic acid complex while avoiding reactive oxygen species.

Keywords: in-office bleaching, SEM, composite gel, hydrogen peroxide, esthetics

Introduction

Teeth whitening has a long tradition as a minimally invasive alternative to potentially destructive and harmful veneer or crown placements to camouflage the underlying discoloration. Media and public concern in smile aesthetics led to growing importance of not only dental health but also dental aesthetics and oro-facial appearance in people's daily lives.¹ The oral health-related quality of life, consisting of oral function, oro-facial pain, oro-facial appearance, and psychosocial impact, is progressively becoming a key measure of patients' oral health experiences.²

The etiology of tooth discoloration has many intrinsic (staining) or extrinsic factors or even a combination of both.³ Extrinsic discoloration occurs when external chromogens are precipitated on the tooth surface or in the pellicle layer. Intrinsic discoloration results when chromogens are deposited inside the tooth. The main reasons for discoloration of teeth can be attributed to individual behavior, diseases, injuries, as well as various physiological processes.⁴ Over time, new methods and materials have been selected to achieve a lasting whitening effect of the teeth. At the moment there are two types of dentist-supervised techniques: at-home or in-office bleaching.⁵

Home bleaching offers decisive advantages for patients, as the trip to the dentist can be saved and with it the costs and time. However, the whitening effect with this method is less distinct and persistent, because the concentration of bleaching agents and active ingredients is too low to have any markable color effect on teeth. Furthermore, soft tissue irritation during home bleaching as well as incorrectly fitting trays are common drawbacks.⁶

For this reason, in-office bleaching or power bleaching is a reliable alternative.⁷ Yet, the improved whitening effect is based on a more aggressive and invasive technique or higher concentrations of mostly hydrogen peroxide ingredients, which require appropriate protective measures. Hydrogen peroxide exposure to the gingiva can induce severe epithelial damage.

Acidic H₂O₂-based bleaching agents are always associated with reactive oxygen species (ROS) such as hydroxyl (OH•) and perhydroxyl (HO₂•) radicals. The free radicals diffuse through enamel and dentin and break the double bonds of pigmented molecules, causing the tooth color to be perceived as whiter.⁸ The disadvantage is that hydroxyl radicals (OH•) have certain local detrimental effects, such enamel erosion, alteration of the microhardness of the teeth, irritation

of the gums, post bleach hypersensitivity and burning sensation.⁹ In order to avoid these negative effects, an alternative approach is necessary.

Recently, it was described that the use of a peroxy caproic acid (PAP) based composite gel could be selected as an effective vehicle for tooth-whitening. Thereby, PAP proved nearly harmless to the teeth enamel with a safe and reliable bleaching effect.¹⁰ In the clinical application of PAP for tooth whitening, oxidation reactions also take place, as in the classic methods. The chromogens, which consist of conjugated double bonds, are decolorized by chemical-physical processes. However, the reaction takes place without the formation of free radicals. This is the major and decisive difference, as free radicals are the main cause of tooth sensitivity and gum irritation during conventional tooth whitening.¹¹

In this context it is the aim of this short communication to introduce a novel two-component bleaching method based on a phthalimido-peroxy-caproic acid formulation. Additionally, preliminary data of the efficacy and possible side effects are shown.

Materials and Methods

The novel bleaching technology (ALPINE WHITE, Cobea AG, Dänikon, Switzerland) is a stable liquid preparation based on phthalimido-peroxy-caproic acid crystals in an aqueous suspension and performs without release of hydrogen peroxide. The formulation consists of a two-component system. The main ingredients of the in-office whitening gel and the separate in-office activator are listed in Table 1. The product is sensitive to alkali and to solvents and should not be mixed to other chemicals without strong dilution in water or without a specific compatibility assessment. It can be stored for two years after production if stored in the original container and at room temperature. The material is intended for single use.

Overall, the present study consists of a retrospective clinical part and a preclinical trial on human teeth. The in-vitro data should support the clinical results accordingly. Case data from n=100 patients were evaluated retrospectively over a period of 3 months by one examiner (Table 2, Figures 1 and 2). No teeth with previous endodontic treatment or filling therapy were included in the analysis. The procedure for the case analysis consisted of the following.

Table 1 Ingredients of the in-Office Whitening Gel

Component 1	
Ingredient	Function
AQUA	Solvent
PHthalimido-PEROXY-CAPROIC ACID	Oxidising
GLYCERIN	Humectant
XANTHAN GUM	Binding
MONOSODIUM CITRAT	Buffering
PVM/MA COPOLYMER	Antistatic
SODIUM HYDROXIDE	Buffering
C12-15 PARETH-3	Emulsifying
Component 2	
Ingredient	Function
AQUA	Solvent
SODIUM HYDROXIDE	pH Regulator

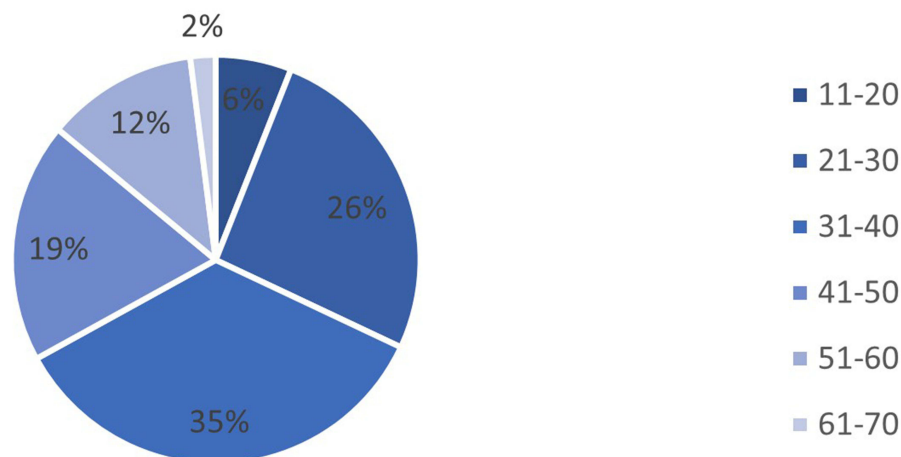
Table 2 Number of Patients and Number of Teeth Treated

Gender	Count	Prämolar-Prämolar	Total
Male	32	16	512
Female	68	16	1088
Total	100		1600

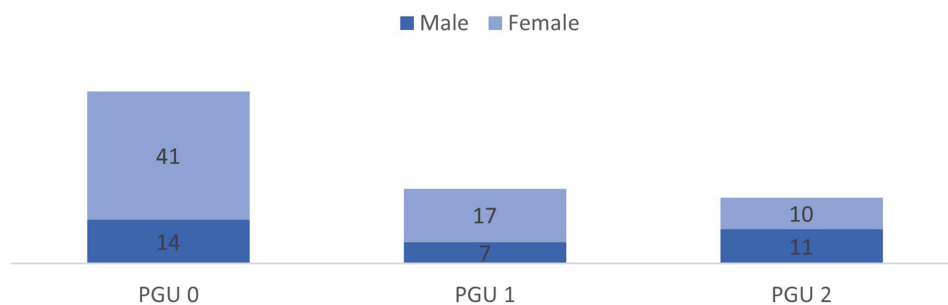
Before the whitening process a clinical examination of the oral and perioral region was conducted to reveal any signs of adverse changes to teeth or adjacent soft tissues. Further, all participants underwent a prophylaxis and oral hygiene guidance procedure. Certified dental hygienists performed the bleaching procedures by wearing protective goggles and gloves. In a period of 90 minutes, n=4 application cycles of 15 minutes each were performed.

Initially, to each portion of the gel n=3 drops of activator were added. The ingredients were mixed homogeneously with a spatula for 60 seconds. After placement of a lip retractor (Cheek Retractor Black, Guangzhou GT Health Industry

Age distribution of the patients

**Figure 1** Age distribution of the patients.

Intraoral soft tissue situation (PGU)

**Figure 2** Intraoral soft tissue situation (PGU, Parodontale Grunduntersuchung). Grade 0 = healthy; Grade 1 = slight gingivitis; Grade 2 = progressed gingivitis.

Co. Ltd., Liantang Town, China) the ALPINE WHITE gel (ALPINE WHITE, Cobea AG, Dänikon, Switzerland) was applied manually on each tooth by a single-use brush. After 15 min, the bleaching gel was removed and teeth were cleaned with gauze, and washed with an air–water spray. Four bleaching sessions were performed with each client. The lip retractor was removed. All participants were instructed to brush their teeth regularly with fluoridated toothpaste afterwards. Efficacy (tooth color) and safety (possible side effects) such as tooth sensitivity and gingival irritation were documented at baseline and immediately after treatment. Tooth color was measured using the VITA classic shade guide (Vita Zahnfabrik, Bad Säckingen, Germany). The middle one-third of the facial surface of the upper and lower anterior teeth was measured to select the shade.

In addition to the retrospective clinical analysis, an in-vitro study was carried out on separate human teeth in the laboratory to evaluate the effects on the tooth surface. Healthy teeth were used without dental restorations or endodontic treatments. All patients gave their informed consent for their teeth to be used for the tests. The teeth were vertically cut into 3–4 pieces producing a as large as possible area of tooth surface in each piece. These pieces were placed on top of a PMMA block (Sigma Aldrich Chemie GmbH, Buchs/ Switzerland) in a glass container. Liquid MMA (Sigma Aldrich Chemie GmbH, Buchs/ Switzerland) was then added into the glass container so that only the surface of the tooth sample was free of PMMA. After polymerization of MMA the tooth samples could be examined. The enamel of teeth as poor conductive samples were sputtered with 8 nm conductive layer of Gold Palladium (Au/Pd) (Leica Microsystems, Leica EM ACE600 Sputter-Coater, Heerbrugg, Switzerland) and imaged with (SEM) (Thermo Scientific™ Axia™ ChemiSEM™, Reinach, Switzerland) operating at 20kV acceleration voltage.

Results

SEM analysis of the ALPINE WHITE group showed an unchanged surface morphology with no signs of damage to the enamel (Figure 3). After the teeth surface of the samples was treated with ALPINE WHITE Whitening 4 times for 15 min, both the smooth areas (A, B) and the rough areas (C/D) of the bleached samples show that the tooth enamel was not damaged compared to the control samples treated with deionized water (E, F, G, H). No destruction or roughening of the surface could be detected in the PAP samples. The micropores remained intact. Overall, no general smoothing or washing out of the tooth surface could be seen in the PAP group. The effect of PAP was similar to that of the control group with water in both the rough and smooth areas. Results from the SEM analysis were appropriately supported by preliminary case reports.

Baseline demographic and clinical characteristics are shown in Table 2 and Figures 1 and 2. For the analysis, only A2 and A3 on the VITA scale were selected as the initial shades. A clear improvement to the lighter shade was observed for both the A2 and A3 shades (Figures 4 and 5). In addition, only a small percentage in these preliminary cases showed a change to a different color quality (color range B). In the present preliminary cases, no side effects or other problems were noted on the part of the clinicians or patients.

Discussion

Given that bleaching is one of the most frequently applied aesthetic procedure in dentistry, the demand for innovative and safe products is on the rise. In particular, the elimination of hydrogen peroxide (HP) and its free radicals is increasingly sought after due to concerns regarding its ability to penetrate enamel and dentin, and thus access to the pulp tissue. The reactive inflammatory response leads to bleaching-induced tooth sensitivity over time. Although this is only temporary, it is a barrier for many patients who subsequently refrain from bleaching.

The Introduction of a new PAP-based method offers a promising solution to reach significant tooth whitening with negligible side effects, as demonstrated by SEM analysis and initial case data, highlighting its effectiveness in achieving significant tooth whitening with negligible side effects. This new bleaching technology is much gentler compared to conventional methods and shows no toxic effects on human tissue. It also leads to fewer problems and hypersensitivity after bleaching. In the present test, however, no attempt was made to analyze dental materials or restorative materials using the new method.¹² Yet own unpublished data revealed no negative effect on dental restorations.

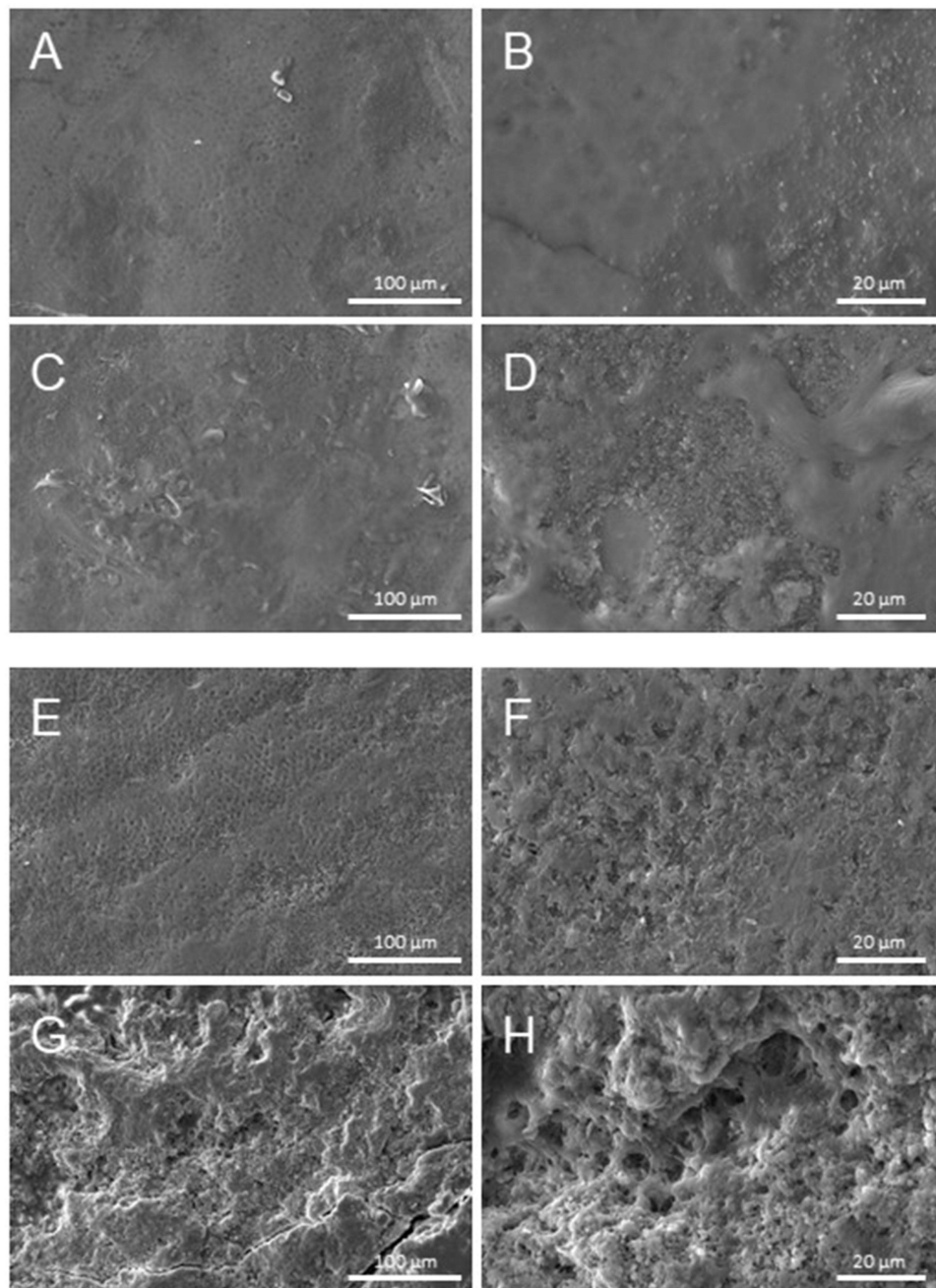


Figure 3 SEM images show the teeth surface of the samples treated with ALPINE WHITE Whitening on a smooth (**A** and **B**) and rough (**C** and **D**) section of enamel area. For comparison control samples were treated only with deionized water for smooth (**E** and **F**) and rough regions (**G** and **H**). Left panels show images at low magnification (500x) and right panels show the same region taken at higher magnification (2000x).

For a deeper statistical evaluation, a larger number of cases is planned in the course of an explorative study. In the present case, the aim was only to introduce the SEM method including the first positive results and to use it as a starting point for further statistical evaluation. Another limit of the present application is still the number of treatment cycles. For the current procedure, 4 application cycles within 90 minutes are necessary to achieve the desired effect. This means that a visit to the specialist is still necessary. Nevertheless, further development steps are already directed towards a faster and home-based method. Future clinical studies must then also prove the long-term effect of the new method.

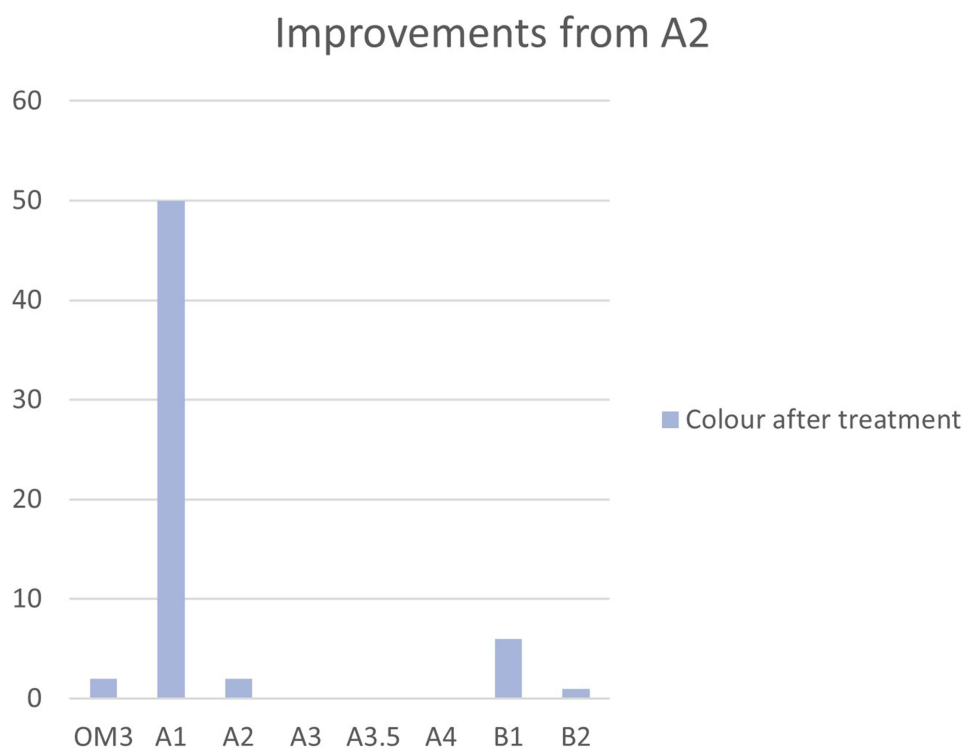


Figure 4 Analysis of tooth shade based on A2 after treatment with ALPINE WHITE.

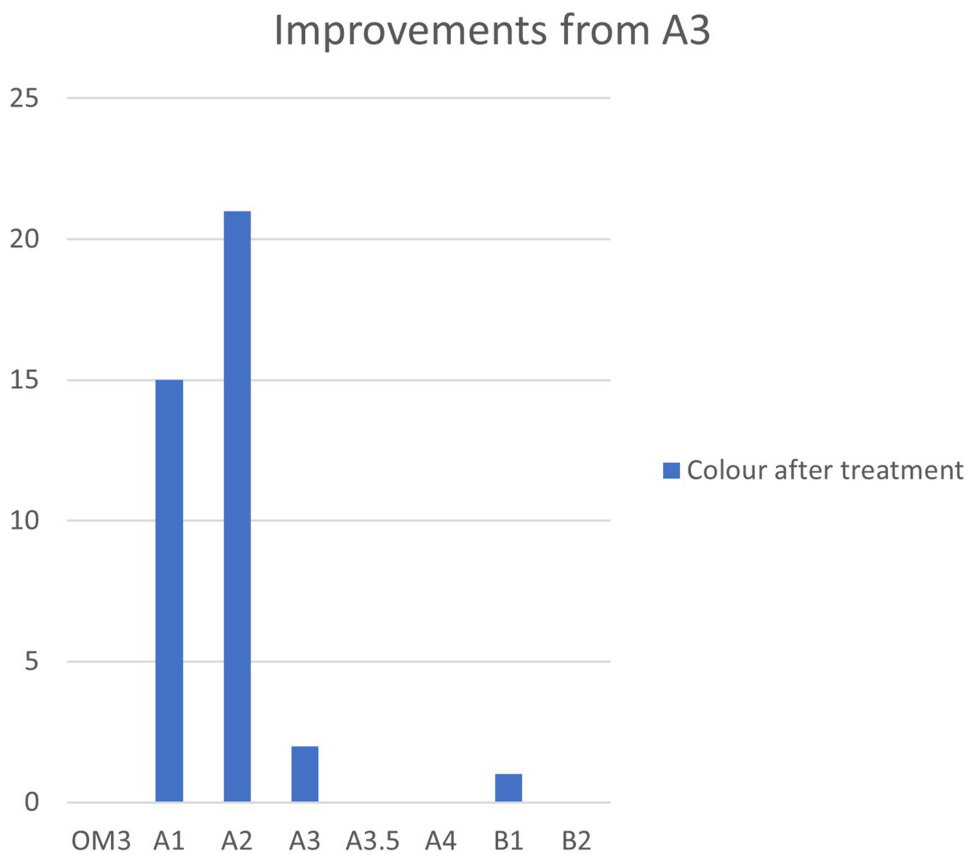


Figure 5 Analysis of tooth shade based on A3 after treatment with ALPINE WHITE.

Conclusion

This short communication introduces the successful application of a new-type two-component bleaching method based on a phthalimido-peroxy-caproic acid formulation without the release of hydrogen peroxide. In contrast to conventional hydrogen peroxide tooth whitening gels,¹⁰ phthalimide peroxy caproic acid (PAP) significantly reduced damage to teeth with minimal impairment to surface morphology and hardness. Also bleaching-induced tooth sensitivity after in-office bleaching using PAP is reduced. Importantly, PAP exhibits a notable whitening effect without causing irritation to oral mucosa and dentin. In Conclusion, this short communication underscores the promising and innovative nature of PAP-based tooth whitening technology, marking a significant advancement in the field of dental aesthetics and patient care.

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Disclosure

Dr Stefan Stübinger reports personal fees from COBEA AG, outside the submitted work. The authors report no other conflicts of interest in this work.

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