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Research Article

Efficacy of Carbamide Peroxide Assisted by Er,Cr:YGSS Laser Induced Photoacoustic Streaming Technique for Enhancing the Color of Internally Stained Teeth

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Abstract

Objective: To evaluate the impact of photon-induced photoacoustic streaming (PIPS) technique for enhancing tooth color changes using Er,Cr:YSGG (2780 nm) laser with carbamide peroxide.
Materials and methods: A total of 42 sound premolars were included in this study. All teeth were endodontically treated then stained artificially utilizing sheep blood followed by placement of a 3mm layer of resin-reinforced GIC 2 mm apical to the CEJ on the buccal aspect. Such stained teeth were bleached conventionally with 37% carbamide peroxide or treated by PIPS using Er,Cr:YSGG laser (25 Hz frequency, 0.1 W power, 60 µs pulse duration) with 37% carbamide peroxide. The results were evaluated after 1, 2, and 3 weeks, resulted color changes were measured by using a spectrophotometer.
Results: Both techniques resulted in a significant color change at the endpoint of the study. However, intergroup comparison demonstrated that PIPS with 37% carbamide peroxide was significantly ($p < 0.05$) more effective than walking bleaching using 37% carbamide peroxide in bleaching outcomes over all time intervals of the study.
Conclusion: The current study showed that the PIPS technique used to activate bleaching agents containing 37% carbamide peroxide was more efficient in achieving desirable bleaching outcomes than the conventional walking-bleaching techniques.

Keywords: tooth discoloration, tooth bleaching, Er,Cr:YGSS laser, carbamide peroxide, endodontics.

1. Introduction

These days, aesthetics is a field that is becoming more and more important, particularly when it comes to getting a beautiful smile, this is due to the fact that it molds a person's opinion of their own appearance and has a profound psychosocial effect when teeth with pigmentation see a notable color shift, it stands out more because of the stark contrast it creates with the surrounding teeth. [1-3]. When using restorative materials, one should take into account that the crown, which is the visible portion of the tooth in the oral cavity, gets its color from the biomechanical combination of two primary tissues: dentin and enamel. [4].

Numerous reasons, including trauma to the pulp or pulp removal, can result in internal discolorations by allowing blood products and their byproducts to infiltrate into the dentinal tubules. As a result, as hemolysis continues, iron compounds are created that can eventually transform into black ferric sulphide. which represents the most common cause of intrinsic discoloration as stated by Grossman and associates [5], however, discoloration can also be caused by protein degradation, as was the case with pulp necrosis [6,7]. Significantly, dental restoration materials in particular, those used for root fillings also play a significant role in internal discoloration [8]. Remnants of root filling materials and some root canal medications could infiltrate the surrounding dentinal tubules and discolor them if they are left in the pulp chamber. Additionally, the presence of residual tissues in the root canal system not only diminish dentinal permeability but also act as a barrier, preventing the effective penetration of intracanal medications and various bleaching agents into the dentin [9].

Generally, there are three main methods for lightening tooth color; over-the-counter solutions, in-office treatments, and at-home bleaching [10]. The walking-bleaching approach is the most often used technique in dental clinics for teeth that have undergone root canal therapy[11]. The bleaching chemicals sodium perborate, carbamide peroxide, and hydrogen peroxide are the most commonly mentioned in the literature. The mechanism of these agents relies mainly on oxidative processes which mediate reversal of the chromatic shift[12,13]. Such mechanism of whitening depends mainly on breaking down the stain chromatin molecules into smaller chain molecules by the action of the free oxygen radicles that are liberated as byproducts from the hydrogen peroxide agent, where such free radicles will attack the doble bonds of the large chromatine molecules to give the colorless short chromatin chains [12]. Using lasers, especially Er,Cr:YSGG, has become increasingly popular in the last ten years in many dental applications, including root canal therapy, cavity preparation and cleaning, and minor oral procedures, with promising results and safety[14–16]. Moreover, the Er,Cr:YGSS laser demonstrated the ability to both strengthen the resin's attachment to the tooth surface and lessen tooth sensitivity[17]. The efficiency of cement bonding increased when dental zirconia was treated with the Er,Cr:YSGG laser [18]. Photon-induced photoacoustic streaming (PIPS) is a new type of laser technique that was just introduced to enhance the activation process of the bleaching mechanism[11]. When agitating a 5.25% NaOCl solution in PIPS, the Er,Cr:YSGG laser produced better results than the traditional approach in eliminating mature bacterial biofilm from intricate root canal networks[19]. Using a sub ablative power level erbium:yttrium-aluminum-garnet(ER:YAG) laser with a radial or conical tip, this thermophotocatalytic method works. The unique characteristic of PIPS that sets it apart from other techniques is that the tip is positioned above the orifice within the coronal chamber without coming into touch with the dentinal walls [12]. It is noteworthy that (Er,Cr:YSGG) PIPS is frequently used to activate intracanal irrigation materials [20, 21], to de-bond extra coronal lithium disilicate [22,23], and improve the bonding of extra coronal repair of all sorts [21].

The effects of lasers on dental hard tissues depend on a number of variables, such as the kind of tissue being treated, exposure time, irradiation mode, power density, and wavelength [9]. This study aimed to evaluate the PIPS technique impact enhancing tooth color changes using Er, Cr:YSGG laser with 37% carbamide peroxide

2. Theory

This in vitro study included a total of 42 sound premolars that were extracted for orthodontic reasons which were selected according to the following criteria:

1. Maxillary premolar with neither decay, abrasion, nor previous fillings.
2. Teeth that were extracted for orthodontic reasons.
3. Patients aged between 15-30 years old (approximately similar pattern of dentinal tubules).
4. No signs of internal resorption as examined by periapical x-ray.

This was followed by performing root canal treatment for these teeth that we did an access opening by handpiece using carbide round bur size 8.Stenderization of the buccal wall thickness of 2.5±0.3mm which was verified using a manual caliper(Figure 1).

Fig.1: Calibration of the thickness of the buccal wall.

By visual inspection of the root tip, we estimated the working length of the teeth before achieving instrumentation to size of X3 BY ProTaper technique. Root canals were then irrigated with 2.5% NaOCl and 17% EDTA, then distilled water before obturating by single cone technique (Figure 2).

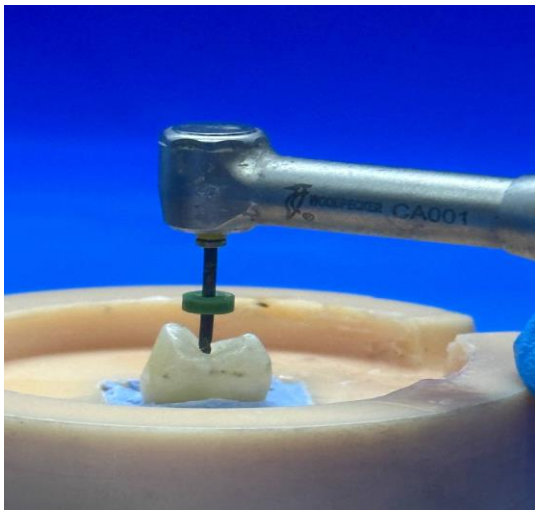

Fig.2: Using rotary instrumentation for the teeth.

2.1 Artificial staining

The method was originally introduced by Freccia and Peters (1982)[24], to artificially mimic internal staining of teeth and it was later modified by substituting human blood by sheep blood [10]. Briefly, each sample was put in an Eppendorf tube that contain 4 mL of sheep's blood. These tubes were centrifuged (PLC-03, Gemmy industrial corp., Taiwan) for 20 minutes at a speed of 3400 RPM and 37°C temperature. This process was repeated twice a day for three successive days, the teeth were rinsed under running tab water after each centrifugation, then returned to the tubes, and kept in 100% humidity at 37°C. Then we

put the blood and distilled water inside new tubes were centrifuged them to begin hemolysis, so, the supernatant layer was then removed away (Figure 3) after such teeth were removed from their original tubes to these new tubes on day 4 so after removing the supernatant layer, such teeth were put inside Eppendorf tubes before centrifuging them for 20 min o the 3 days. after six days, we repeated the same procedure as the first six days to create deep artificial staining of the teeth to get a total of 12 days of staining.

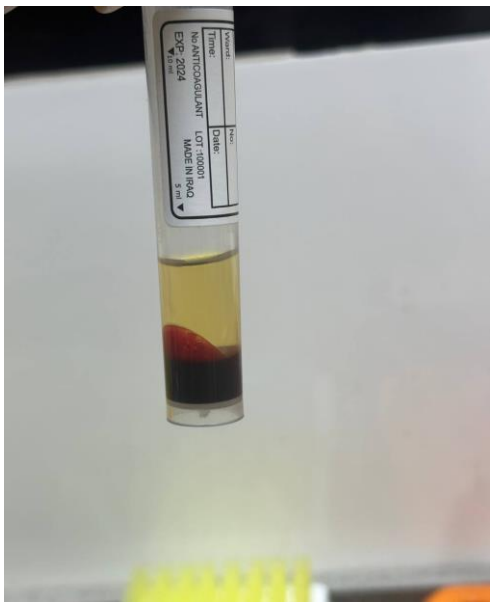

Fig. 3: Isolation supernatant layer from centrifuged stained teeth.

2.2 Color measurement

After finishing staining process, the teeth were rinsed under running water and air dried. This followed by placement of a 3 mm layer of GIC (Equia Forte, GC, Japan) that was placed 2 mm apical to the CEJ in order to prevent diffusion of the bleaching agent through the dentinal tubules, and to infiltrate through the root canal to the periapical region beside that it also prevent cervical root resorption [25]. The measurement of the photo properties of buccal area of the crown was done using a (Vita Easyshade Advance Spectrophotometer) (Vita Zahnfabrik, Germany) (figure 4). Where we repeat each measurement three times to take the average reading of them using the Commission International de l'Eclairage(CIELAB).These measurements were conducted by using the device was first was calibrated as follows: the probe tip was placed on the calibration port aperture as stated in the manufacturer's instructions. Following every measurement, the recorded values included ΔL* (representing brightness), Δa* (indicating redness), and Δb* (representing yellowness/blueness) of the specimen. After bleaching, repeated measurements were performed on specimen which were evenly distributed into two groups. Total color change (ΔE*) was determined by using the following formula:

$$\Delta E_{*2} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (1)$$

A. Group 1: PIPS with 37% carbamide peroxide

The pulp chamber was directly filled with 0.5 mL of 37% carbamide peroxide (Whiteness Super Endo, FGM, Brazil) using the tip of the delivery bleaching tube. Following the bleaching gel application, it was activated with PIPS using Er,Cr:YSGG laser 2780 nm (Biolase, WaterLase ®iPlus, USA)(Fig5).

According to the pilot study, the parameters of laser application were as follows: 1 minute exposure time, 60 µs pulse duration, 0.1W output power at a frequency of 25 Hz, dose of 500 J/cm^2 and o.333 J/cm^2 energy density using a 6mm tip diameter (Biolase, USA). The water and air systems remained closed during this process, avoiding any contact of the fiber optic tip with the pulp chamber walls. The fiber optic tip was placed within the endodontic access cavity and directly in the bleaching gel.

Following the aforementioned PIPS activation, the bleaching gel was replaced, and the PIPS device was left for 10 minutes to cool down. Once the PIPS tip had cooled down, the activation procedure was redone, resulting in a total of three 1-minute PIPS activations, amounting to 3 minutes in total. After 30 minutes had elapsed, tap water was used to thoroughly rinse away the bleaching gel. Next, a cotton pellet was inserted in the pulp chamber, and a provisional seal of the access cavity was done with the GIC. This bleaching process was repeated at 7-day intervals, lasting for 21 days total. Following every 7-day bleaching session, the teeth were stored in distilled water at 100% humidity and a temperature of 37°C, color measurements were taken on days 7, 14, and 21 as described above.

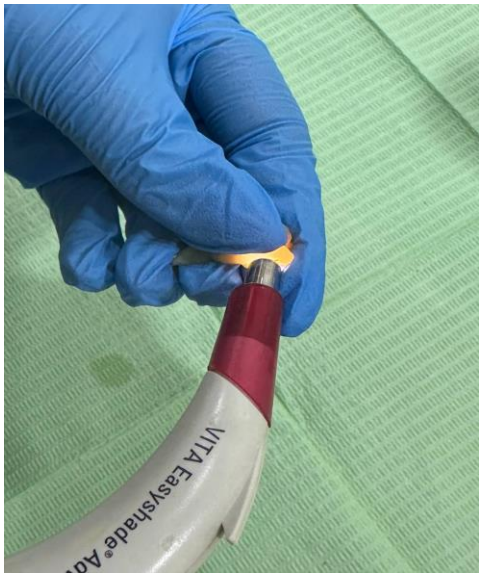

Fig. 4: Color Measurement by using VITA Easyshade.

B. Group 2: Walking bleaching using 37% carbamide peroxide:

Around 0.5 mL of the 37% carbamide peroxide walking-bleaching gel (Whiteness Super Endo, FGM, Brazil) was directly placed into the pulp chamber by the delivery tip of the bleaching tube. Following the bleaching gel application and packing, a cotton pellet was positioned over the gel. Resin-reinforced GIC was used as a filling to temporarily seal the access cavity. Then the gel was washed away, after each 7-day treatment session, followed by thorough cleaning of the teeth before conducting the color measurements. This sequence was repeated over three 7-day intervals over 21 days of treatment. At the end of each 7-day session, the teeth were stored in distilled water in 100% humidity and at 37°C. Color measurements were taken on days 7, 14, and 21, as previously outlined.

Fig. 4: Activation of carbamide peroxide.

2.3 Statistical analysis

The distribution of data was first checked by Shapiro-Wilk's test. Descriptive statistics were expressed as mean and standard deviation (SD) which showed normal distribution of data. Intragroup comparisons for color changes over the time intervals of the study were conducted by using two-ANOVA. If the results were significant, *post hoc* analysis was performed to highlight changes within the same group. Intergroup comparison for the mean of ΔE was performed by unpaired t-test. A p-value < 0.05 was considered significant. All analyses were conducted by using SPSS software (version 26, IBM, USA).

3. Results

The data were normally distributed, therefore, parameter statistical assays were used for analyses. Results of the two-way ANOVA revealed that the whitening of the discolored teeth was significant (p-value 0.05) when treated with PIPS with 37% carbamide peroxide (Group 1). These changes followed a time-dependent manner as shown by further analysis using LSD post hoc which demonstrated that the mean value of ΔE was significantly increasing considering the following up of the progress in the color variation until the end of the third week. Table 1 shows the mean value of (ΔE) of this group at the three-week intervals.

In Group 2, it is observed that there is a highly statistically significant difference between the baseline color measurements (ANOVA p-value 0.001). Similar to Group 1, there was an observable change over time interval as the impact of bleaching on color variations was noticed from the LSD test. Table 2 shows the mean value of (ΔE) of Group 2 at the three-week intervals. The results indicated that there was a highly significant difference between the two bleaching methods as shown in Figure 4. At the end of the first, second, and third weeks we compared the change of ΔE of the two groups, where there was Statistical differences in ΔE were observed between Groups 1 and 2 after the collection of the results for the 21 days of bleaching procedure. The mean bleaching values of Group 1 (PIPS +37% carbamide peroxide) were statistically different from those of Group 2 (walking bleaching 37% carbamide peroxide) with reported p values of 0.01, 0.001, and p 0.01 respectively in Table 3 and Figure 6.

Table 1. Mean Color Differences (ΔE) in pips with 37% carbamide peroxide group at 7, 14, and 21 Days.

	1st w/Δ E	2nd w/Δ E	3rd w/Δ E	
Mean	**C** 13.55	**B** 18.93	**A** 24.64	
Median	14.43	17.60	25.01	
SD	2.24	3.46	1.38	0.05
MIN	11.01	16.33	23.11	
MAX	15.22	22.85	25.79	

*LSD test was used to calculate the significant differences between tested mean, the letters (A, B, and C) LSD represented the levels of significant, highly significant start from the letter (A) and decreasing with the last one. Similar letters mean there are no significant differences between the tested mean. p≤0.05 were considered significantly different

Table 2. Mean Color Differences (ΔE) in walking bleaching 37% carbamide peroxide group at 7, 14, and 21 Days.

Statistics	1st w/Δ E	2nd w/Δ E	3rd w/Δ E	*P-VALUE
Mean	C 7.81	B 11.90	A 17.43	
Median	7.38	11.83	16.69	
SD	3.24	4.35	4.44	0.001
MIN	2.89	6.59	11.21	
MAX	13.14	19.60	23.52	

*LSD test was used to calculate the significant differences between tested mean, the letters (A, B, and C) LSD represented the levels of significant, highly significant start from the letter (A) and decreasing with the last one. Similar letters mean there are no significant differences between the tested mean. p≤0.05 were considered significantly different.

Table 3. Intergroup comparison of means of Δ E at 7, 14, and 21 Days.

	First week		Second week		Third week	
Statistics	G1/Δ E	G2/Δ E	G1/Δ E	G2/Δ E	G1/Δ E	G2/Δ E
Mean	13.55	7.81	18.93	11.90	24.64	17.43
Median	14.43	7.38	17.60	11.83	25.01	16.69
SD	2.24	3.24	3.46	4.35	1.38	4.44
MIN	11.01	2.89	16.33	6.59	23.11	11.21
MAX	15.22	13.14	22.85	19.60	25.79	23.52
P value	0.01 H.Sig		0.001 H. sig		0.01 H. sig	

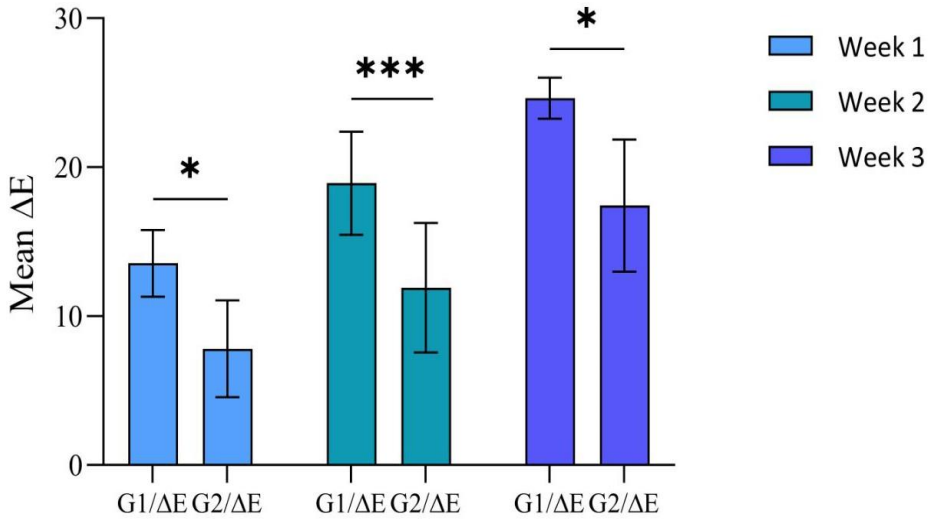

Fig. 6: Mean Color Differences (ΔE) between Group 1 (PIPS +37% carbamide peroxide) and Group 2 (walking bleaching Sodium perborate- 20% H_2O_2) at 7, 14, and 21 Days. Group 1 exhibited significantly higher color change throughout the study period as compared to Group 2. G: Group. P value * <0.05, *** <0.001 by using unpaired t-test.

4. Discussion

Teeth discolored due to endodontic treatment can vary in its density due to many factors like the age of the patient, type of tooth, type of root canal medicaments, age of filling, patient habits, etc. so for that our statistical results of the teeth pigmentation were varied accordingly which was in a good agreement with the study of Nandita et al. [26].The pigmented teeth could be lightened via various methods and materials, carbamide peroxide is one of most common bleaching agents used. In our experiment we have used such agent either with or without PIPS. It is known that PIPS produced shock wave that virtually able to facilitate the penetration of the bleaching agent by reducing the surface tension and heating of this material also enhanced the effectiveness of the peroxide agent[27]. The amount of H_2O_2 liberated as a result of the bleaching agent's byproduct is positively correlated with the effectiveness of any bleaching process [26]. The oxidative impact of free radicals produced from H_2O_2 breakdown which is the basic factor for the bleaching process, where such mechanism of bleaching depend on breaking down the lengthy chromatin molecules that of the stain which have unsaturated double bonds that make them susceptible to be distracted, this results in the creation of shorter molecules [11]. In our experiment we have chosen carbamide peroxide which achieved significant whitening for intrinsic pigmented teeth in a manner of results that were in a good agreement with studies of Cooper etal and Mokhlis [28, 29]. Since the amount of H_2O_2 produced is directly related to the bleaching agent's efficacy, as was previously noted, this quantity is crucial to understanding the study's findings, which demonstrated that using PIPS boosted the effectiveness of carbamide peroxide by stimulating more than H_2O_2 conventional carbamide peroxide alone , while Senem in 2021 found different results due to use of different laser [11]. According to research by Warren et al.[30], carbamide peroxide at15% releases 5.4% H_2O_2, 20% releases 7% H_2O_2, and at 35%, 10% H_2O_2. Nevertheless, Rokaya found that only an estimated 12.3% H_2O_2 was produced after 37% carbamide peroxide underwent a chemical reaction in Groups 1 and 2, bleaching gels which gave accepted agreement with such study [31]. Water has a strong absorption of the Er,Cr:YSGG wavelength of light, therefore an increased water ratio in the bleaching gel would increase the agent's activity. The laser is a crucial part of the bleaching process because it ionizes the H_2O_2 in the bleaching substance, which decreases pigmentation and results in the desired color shift [32]. This work used the PIPS technique at sub ablative power settings with an Er,Cr:YGSS laser. The bleaching agent is easily heated when exposed to the laser beam because

the Er,Cr:YGSS laser is substantially absorbed by water [33]. Sheep's blood was used by Arslan et al. to artificially stained teeth, which were subsequently bleached using various liquid and gel forms of H_2O_2 with or without the application of PIPS, they found that employing the liquid form of H_2O_2 allowed for greater color shift when the PIPS approach was applied. They proposed that the use of PIPS raised the pulp chamber's temperature and allowed H_2O_2 to permeate deeper, improving internal bleaching which was somehow agreed to the study of Arsalan et al.[34], in order to consider the whitening procedure's effectiveness, we should have a change of a minimum of 5 units of the ΔE [35]. Despite the fact that DiVito demonstrated that the PIPS approach only raised temperatures by 1.2–1.4°C during the course of 20–40 seconds of activation, there was no thermal side effect on the dentin walls [36].

5. Conclusions

The current study showed promising results when PIPS technique was used to activate bleaching agents containing 37% carbamide peroxide in achieving desirable bleaching outcomes. Although the walking-bleaching method was also capable of altering tooth color change, but combination of PIPS technique with 37% carbamide peroxide emerged as a more efficient technique for reversing severely discolored teeth.

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كفاءة مادة البيروكسايد كاربمايد في ازالة التصبغات اللونية الداخلية للاسنان بمساعدة تقنية ليزر Er,Cr:YSSG المحتث بالأمواج الضوئية الصوتية

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الخلاصة

هدف البحث: تقييم تأثير تقنية الليزر المحتث بالامواج الضوئية الصوتية (PIPS) في تعزيز تغييرات لون الأسنان باستخدام الليزرEr ، Cr:YSGGمع بيروكسيد الكارباميد.

مواد وطرائق البحث: مجموعة من 42 سنًا سليمًا تم تضمينها في هذه الدراسة. تمت معالجة جميع الأسنان لبياً ثم تم تلوينها بشكل صناعي باستخدام دم الخروف ثم وضعت طبقة بسمك 3 مم من إسمنت الأيونومر الزجاجي (GIC) المعزز بالراتنج على مسافة 2 مم تحت المَوصِلُ المِلاَطِيُّ المينائِيّ (CEJ) من جانب السن الخارجي. بعد ذلك، تم تبييض الأسنان بواسطة تقنية PIPS باستخدام بيروكسيد الكارباميد بتركيز 37% أو باستخدام التبييض المشي التقليدي بواسطة بيروكسيد الكارباميد بتركيز 37%. تم تقييم النتائج بعد 1 و 2 و 3 أسابيع. تم قياس التغييرات في لون النتائج باستخدام جهاز الطيف اللوني.

النتائج: أدت كلتا التقنيتين إلى تغيير لون كبير في نهاية الدراسة. ومع ذلك، أظهرت المقارنة بين المجموعات أن تقنية PIPS باستخدام بيروكسيد الكارباميد بتركيز 37% كانت أكثر فعالية بشكل ملحوظ ($p < 0.05$) من التبييض المشي التقليدي باستخدام بيروكسيد الكارباميد بتركيز 37% فقط في نتائج التبييض على مدى جميع فترات الدراسة.

الاستنتاج: أظهرت الدراسة الحالية أن تقنية PIPS المستخدمة لتنشيط عوامل التبييض التي تحتوي على بيروكسيد الكارباميد بتركيز 37% كانت أكثر فعالية في تحقيق نتائج التبييض المرغوبة من تقنيات التبييض التقليدية.