CLINICAL EVALUATION OF SHADE IMPROVEMENT AFTER IN-OFFICE VITAL BLEACHING

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KEYWORDS

Colour Change

Vital bleaching

Hydrogen peroxide

Spectrophotometer

Tooth sensitivity

SUMMARY

Tooth discoloration has increased the demand by patients to pursue aesthetic treatment options. Bleaching is considered a conservative approach in performing an aesthetic treatment for discolored teeth; however colour rebound and post-operative sensitivity are among the adverse effects associated with vital bleaching. In-office bleaching systems employ the use of high hydrogen peroxide concentrations. The effects of in-office bleaching agents on the degree of colour change and the gender differences in relation to bleaching outcomes are questionable. Post-operative sensitivity can be considered a bleaching side effect and the number of patients that experience it is unknown.**Aim:** The aim of this study was to assess the outcome of an in-office vital bleaching technique. **Objectives:** The objectives of this study were to evaluate the degree of colour change after vital tooth bleaching using a 35% hydrogen peroxide gel (Yotuel® Special, Biocosmetics Laboratories, Spain), using a spectrophotometer (CM-2600d Konica, Minolta) to measure the colour change at each intervention during the bleaching process, to assess the post operative sensitivity during the first week of the intervention, to evaluate the patients' perception of the colour change and to compare it to the colour change (ΔE) expressed in numeric values and to investigate whether gender differences exist in relation to the outcome of the bleaching procedure. **Materials and Methods:** The maxillary anterior teeth of 22 patients comprising of 11 males and 11 females were bleached with a 35% hydrogen peroxide gel (Yotuel® Special, Biocosmetics Laboratories, Spain). Pre-treatment readings of the two maxillary central incisors using a spectrophotometer (CM-2600d Konica, Minolta) were obtained. Subsequent readings were obtained after scaling and polishing, before bleaching (which was used as a baseline reading), immediately after bleaching, one week and one month post-operatively. Patients were requested to complete a form regarding post-operative tooth sensitivity and their colour perception toward the bleaching treatment. **Results:** The quantitative effect of the bleaching material on tooth colour showed an increase in L* values and a decrease in a* and b* values, the changes were significant (p values ≤ 0.05) except for the mean value of b* one month after bleaching which was only significant between five and ten percent.

The mean values of colour change measured as ΔE between baseline and after bleaching was found to be 3.4 which did not exceed the visible colour change perceptible clinically at a difference of 3.7 units according to the literature. However nine patients exceeded the visible clinical colour change immediately after bleaching. There was no gender difference in the ΔE values in the entire bleaching process. Tooth sensitivity is considered a bleaching side effect and in this study sensitivity was traced until the fifth day after bleaching. The mean value of patients' tooth sensitivity was found to be 1.73 in the first day on a 4 point visual analog scale. The mean value of patients' colour perception was found to be 2.14 immediately after bleaching on a 3 point visual analog scale. Spearman correlation tests showed a positive relationship between ΔE values immediately and one week after bleaching and a weak relationship one week and one month after bleaching. There was significant consistency in the patients' colour perception data immediately and one week after the bleaching process and a weak relationship between ΔE values and patients' colour perception one month after bleaching. **Conclusion:** Yotuel® Special, Biocosmetics Laboratories, (Spain) an in-office bleaching material consisting of 35% hydrogen peroxide was able to bleach patients' teeth with a perceptible colour change however the chalky white teeth desired were not obtained for all the patients. Tooth sensitivity was a temporary side effect.

DECLARATION

I hereby declare that *Clinical Evaluation of Shade Improvement After In-Office Vital Bleaching* is my own work, that it has not been submitted before for any degree or examination in any university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Yousef Salem

June, 2010

Signed:.....

ETHICAL STATEMENT

In order to retain the impartiality of the study, no financial or material support was used from the Yotuel manufacturer or from any other commercial institution. The entire financial, material and technical support was ensured by the UWC.

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DEDICATION

To my Dad Mahmoud and my Mother Wafieh for their belief in my abilities and their constant support and sacrifices.

To my Sisters and Brothers.

To my Supervisor whose guidance, encouragement and constant support made this project successful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF GRAPHS

CHAPTER ONE

INTRODUCTION

Tooth discoloration results in an increased number of patients demanding aesthetic treatment. The proper diagnosis of the original cause of the discoloration can dramatically change the treatment options (Watts and Addy, 2001).

There are many treatment modalities for discolored teeth and they vary from bleaching, microabrasion of enamel using abrasive materials, veneers, all ceramic crowns and a combination of treatment options depending on the degree of staining (Griffiths *et al*, 2008). Bleaching is considered a conservative approach in performing an aesthetic treatment for discolored teeth, unlike laminated veneers and all ceramic crowns which require irreversible tooth preparation (Bello and Jarvis, 1997).

Currently there are numerous methods that can be used to achieve the bleaching effect. Dentists supervised nightguard bleaching, in-office bleaching and over the counter bleaching products are basically the main approaches used for vital tooth bleaching (Heymann, 2005).

Due to a busy lifestyle; patients usually prefer to have quick results in a relatively short time and with minimal effort. Therefore, in-office vital bleaching is considered to be the quickest way to get white teeth. The whitening effect can be achieved after one visit (Tavares *et al*, 2003) or sometimes it needs multiple visits (Sulieman, 2005).

In-office bleaching systems use a high concentration of hydrogen peroxide (Goldstein, 1997) that can be activated using a light source such as Quartz–

tungsten–halogen (QTH) lamps, plasma arc lamps (xenon short arc lamps), laser sources and light emitting diodes (LED) (Buchalla and Attin, 2007).
Further modifications of the in-office vital bleaching systems include the introduction of chemically activated systems which do not need light units for their activation (Christensen, 2000).

However, colour rebound (Garber, 1997), post-operative sensitivity and the effect of bleaching agents on enamel and different types of restorations, are possible complications associated with vital tooth bleaching (Tredwin *et al*, 2006).

Therefore the aim of this clinical study was to assess the outcome of in-office vital bleaching using a chemically activated bleaching material. In addition an assessment was to be made of the dental sensitivity experienced during the first week of intervention. The material that was tested in this study had been recently launched commercially with limited independent research.

CHAPTER TWO

LITERATURE REVIEW

2. 1- Introduction

Generalized staining, dark tooth colour due to aging, fluorosis and tetracycline stained teeth are among the indications to bleach teeth (Sulieman, 2004).

In-office vital bleaching has proved to be an effective treatment modality for discoloured teeth. It has offered quick results in a relatively short time with minimal effort from the patient (Tavares *et al*, 2003).

In-office bleaching systems employ the use of a high concentration hydrogen peroxide solution of 35% or greater strength, or lesser if it is a concentrated gel (Goldstein, 1997). These systems can be activated using heat or light (Greenwall, 2001).
Currently, chemically activated systems which do not need light activation have been introduced commercially. The Yotuel (SPAIN) bleaching system is one of these systems that involves a mixing process that results in a thick hydrogen peroxide gel that can be applied onto the tooth surface to achieve the bleaching effect (Pretty *et al*, 2006).

The bleaching effect can be reversible and colour rebound can occur (Bello and Jarvis, 1997). In addition, post-operative sensitivity is considered one of the adverse effects associated with vital tooth bleaching (Tredwin *et al*, 2006).

2.2- Tooth Colour and Colour Perception

The natural tooth colour depends mainly on the underlying dentin; however the enamel thickness and its translucency can affect the overall tooth colour.
Teeth become darker with age. Canines are darker than the central and lateral incisors. This difference is not only between teeth, but even in the same tooth where the gingival third is darker than the incisal third (Sulieman, 2005 b).

The perception of colour depends mainly on the interaction between the object, the light and the observer. The object will reflect, absorb or transmit the light to the observer while the light is the illumination source. If the object has been illuminated with different light sources, the colour will be changed. The same is applied to the observer; if we change the observer the colour perception will be different (Burkinshaw, 2004).

Three variables are measured to describe the perception of light reflected from a tooth. These variables are the hue which is the dominant wavelength (red, green or blue colour), the value which represents darkness or lightness and the chroma that represents colour saturation (Anusavice, 2001).

Visible light wavelength lies in the range of 360 nm and 780 nm. Light at the shorter wavelengths (400 nm) appears blue while it appears to be red at the longer wavelength (700 nm). (Joiner *et al*, 2008).

The Commission International De l'Eclairage (CIE) defined a three-dimensional colour space (L*a*b*). The three coordinates are L*, a* and b*, where L* refers to the lightness coordinate (with 0 being perfect black and 100 being perfect white), a* represents the red–green axis (+a red and -a green) and b* represents the yellow–blue axis (+b yellow and -b indicates blue) (Seghi *et al,* 1986, Uchida *et al*, 1998) (Appendix I).

Using colour measuring devices such as the spectrophotometer and the colorimeter makes it possible to express colour in an objective way implementing the CIE Lab system (Russell *et al*, 2000).

2.3- Tooth Discoloration

Depending on the origin of the stain, tooth discoloration can be classified into extrinsic, intrinsic and internalized stains.

"Extrinsic stains are formed within enamel defects or when dentin is exposed following dental development" (Addy and Moran, 1995). Extrinsic stains are associated with materials incorporated into the acquired pellicle on the enamel surface (Joiner *et al*, 1995), including the dietary intake of tannin-rich foods (red

wine), smoking and the use of chlorhexidine (Vogel, 1975). The stains can be removed by using whitening toothpastes or scaling and polishing (Sarrett, 2002).

Intrinsically discolored teeth occur during tooth development and affect light absorption and the scattering of light through both enamel and dentine (Ten Bosch and Coops, 1995). Conditions which result in intrinsically discolored teeth include fluorosis, trauma, iatrogenic stains, systemic conditions, hereditary conditions and dental caries (Goldstein, 1997).

Internalized stains are formed when extrinsic stains become trapped within enamel or dentinal developmental defects or due to trauma (Sulieman, 2005 b).

Proper diagnosis of the original cause of tooth discoloration can affect the treatment modality used to remove the stain. Treatment can be achieved by simple scaling and polishing as in the case of extrinsic stains to bleaching or more invasive treatment options including veneers and crowns for marked staining of the teeth (Sulieman, 2005 b).

2.4- Bleaching History

2.4.1- Non-Vital Bleaching History

Bleaching was described in 1864 for the treatment of non-vital and discolored teeth (Truman, 1864). The bleaching material was placed on the buccal surface for the treatment of non-vital teeth. In this technique, the success rate was limited; untill 1958, when Pearson placed the bleaching material directly into the pulp chamber (Goldstein and Garber, 1995).

In 1961 Spasser described what is known as the "walking bleach technique" in which a mixture of sodium perborate and water was sealed into the pulp chamber and left in place for one week. Nutting and Poe in their study replaced the water with 30% hydrogen peroxide. The combination of sodium perborate and hydrogen peroxide improved the whitening of the discoloured non-vital teeth (Nutting and Poe, 1963).

2.4.2- Vital Bleaching History

Night-Guard Vital Bleaching

Vital bleaching started when, Dr Klusmier, an orthodontist prescribed an antiseptic mouthwash containing 10% carbamide peroxide to be used in a tray for the treatment of gum irritation and accidentally noticed that this material caused lightening of the adjacent teeth (Haywood, 1991a).

In 1989 Haywood and Heymann introduced night-guard vital bleaching using 10% carbamide peroxide in a custom fabricated tray.

In-Office Vital Bleaching

For over a century, in office bleaching techniques have been available. In 1991, the availability of hydrogen peroxide gels in a high concentration led to the innovation of the power bleaching technique, in which conventional light curing units were used to activate the gel (Sulieman, 2008). Light and heat are considered as activation methods in the power bleaching technique (Sulieman, 2004).

Modification of this technique included the introduction of the halogen curing light, plasma arc or xenon power arc light activated units which did not generate heat during the bleaching process (Greenwall, 2001).

Further modifications included the introduction of the chemically activated systems which did not need light units to initiate the bleaching process (Christensen, 2000).

2.5- Bleaching Mechanism

Hydrogen peroxide is the backbone material currently used in the bleaching process, even when other bleaching materials such as sodium perborate or carbamide peroxide are used; hydrogen peroxide is the effective end-product in the chemical reaction (Sulieman, 2008).

Sodium perborate in the presence of water, warm air or acid breaks down into sodium metaborate, hydrogen peroxide and oxygen (Greenwall, 2001).

Hydrogen peroxide is an oxidizing agent that breaks down into unstable free radicals, which penetrate the enamel and diffuse into the dentin (Fuss *et al*, 1989).

The breakdown of hydrogen peroxide into free radicals occurs according to the steps illustrated below.

1. Hydrogen peroxide forms free radicals like hydroxyl and perhydroxyl radicals and superoxide anions

$$H_2O_2 \rightarrow 2HO^{\cdot} \longrightarrow \text{Hydroxyl radical}$$

$$HO^{\cdot} + H_2O_2 \rightarrow H_2O + HO^{\cdot}_2 \longrightarrow \text{Perhydroxyl radical}$$

$$HO^{\cdot}_2 \leftrightarrow H^+ + O^{\cdot}_2 \longrightarrow \text{Superoxide anion}$$

2. Unstable reactive oxygen molecules are transformed into oxygen

$$2\,H_2O_2 \leftrightarrow 2H_2O + \underbrace{2\{O\}}_{\text{Reactive oxygen}} \leftrightarrow 2H_2O + O_2$$

3. And also into hydrogen peroxide anions

$$H_2O_2 \leftrightarrow H^+ + HOO^- \longrightarrow \text{Hydrogen peroxide anion}$$

Free radicals, reactive oxygen molecules and hydrogen peroxide anions (Sulieman, 2008) attack the organic pigmented molecules breaking them down (Goldstein and Garber, 1995) and resulting in less pigmented smaller molecules. The whitening effect occurs due to less light being reflected from these smaller molecules (Mccaslin *et al*, 1999).

Carbamide peroxide produces urea (Budavari *et al*, 1989), which breaks down into ammonia and carbon dioxide. The urea elevates the pH (Greenwall, 2001), which expedites the bleaching reaction (Sun, 2000).

Raising the temperature by light or heat accelerates the release of hydroxyl radicals from the peroxide that may lead to an increase in the efficacy of the bleaching material (Buchalla and Attin, 2007).

2.6- Tooth Bleaching Techniques

Tooth bleaching can be classified into non vital and vital tooth bleaching. In the literature, there are a number of methods and approaches that have been used to bleach discolored and stained teeth.

2.6.1- Techniques for Non-Vital Tooth Bleaching

Under this category, walking bleach, non-vital power bleaching (thermo and / or photo bleaching), and inside / outside bleaching will be discussed (Sulieman, 2008, Greenwall, 2001).

Walking Bleach Technique

Using this technique in combination with external bleaching produces rapid and better results, but the technique is contraindicated as it may cause external cervical root resorption (Attin *et al.*, 2003).

Radiographs are used to assess the quality of the endodontic treatment and periodontal tissues. Prior to the treatment a shade assessment and photographs should be taken to have a colour record. Isolation using a rubber dam is mandatory when performing a bleaching procedure.

The access cavity should be modified to ensure the removal of all the pulpal remnants especially from the pulp horns. The dentine should be exposed and any stains or restorative remnants should be removed. Gutta percha should be removed up to 2-3mm below the cemento-enamel junction. The coronal end of the obturation must be sealed using a glass ionomer base to reduce the risk of external root resorption. The sodium perborate is mixed with saline and packed into the pulp chamber. Excess liquid is removed using cotton pellets. The access cavity is sealed using a zinc oxide eugenol or glass ionomer temporary restoration. The patient is recalled two weeks after the procedure.

The combination walking bleach technique differs from the main walking bleach procedure in that the sodium perborate is mixed with hydrogen peroxide (30% or lower concentration) instead of saline and packed into the pulp chamber and the recall visit, should be in one week's time (Sulieman, 2006).

Internal Non-Vital Power Bleaching

The procedure is the same as the walking bleach procedure except for the bleaching material and the method of activation.

The material used is a hydrogen peroxide gel (30 to 35%) which is placed in the pulp chamber and activated using a light or heat source. The tip of the heat-producing instrument is placed directly onto the cotton pellet saturated with the bleaching gel. The temperature should be between 50° and 60°C for five minutes, allowing the tooth to cool down for five minutes and then removing the gel by washing it off with water for a minute. The tooth is then dried and the conventional walking bleach technique is used between recall visits. At the recall visit in two weeks time, the tooth is assessed to determine if further treatment is necessary.

The light activation technique includes using a conventional halogen curing light, plasma arc lamp or laser beam which can quickly activate the high concentration of the 35% hydrogen peroxide gel (Greenwall, 2001).

Inside/Outside Bleaching

This technique is a combination of the walking bleach technique and the home bleaching techniques. The procedure includes checking the custom-made trays for fit as this is the carrier for the home bleaching technique.

This technique depends on the patient in a way that he/she should place a cotton pellet in the cavity in the tooth when not undergoing the bleaching procedure to keep the cavity closed. The procedure involves insertion of the bleaching material (10% carbamide peroxide) into the cavity in the tooth using a syringe followed by applying the bleaching material in the tray over the tooth.

The patient should wear the tray for a two-hour session then irrigate the cavity with water using a syringe and finally replace the cotton pellet to seal the cavity. The recall visit can be within three to seven days depending on the number of two-hour applications done by the patient with optimum five to eight applications necessary to achieve a desirable colour change (Sulieman, 2006).

2.6.2- Vital Tooth Bleaching

Dentists supervised night-guard bleaching, in-office bleaching and over the counter bleaching products are basically the main approaches used for vital tooth bleaching (Heymann, 2005).

Dentist-Supervised Night-Guard Bleaching

In 1997, nightguard vital bleaching had been used by Haywood *et al* in treating tetracycline stained teeth for a period of six months. They considered it a safe and efficient approach. Even though the sample size was small, Leonard *et al* (2003), reported after seven and a half years that no significant problems were noted with the procedure.

Night-guard vital bleaching is considered an effective technique in treating stained teeth with a high success rate of 98% for non-tetracycline-stained teeth, and 86% for tetracycline-stained teeth (Leonard, 2000).

The patient's lifestyle determines the bleaching time and the concentration of the material to be used. For instance, concentration of the bleaching material depends on whether tooth sensitivity exists or not; with higher concentrations it is more likely to cause thermal sensitivity (Sulieman, 2006). 5% to 36% carbamide peroxide, 6%, 7.5%, 9.5%, 14% or 15% hydrogen peroxide are all available commercially as whitening products without significant side-effects (Kihn, 2007).

Fabrication of the bleaching tray, baseline shade assessment and written instructions must be discussed with the patient prior to the bleaching procedure. 10% carbamide peroxide is worn for 8 hours overnight for 2 weeks

per arch, bearing in mind that patients may not be able to wear both trays simultaneously, thereby prolonging the treatment.

Higher concentrations of carbamide peroxide (15% to 20%) can be used depending on the baseline shade of the tooth and the sensitivity experienced during treatment.

Patients should be recalled after 10 days to 2 weeks time for an assessment of the shade and any soft tissue or other problems encountered by the patient immediately post-operatively (Sulieman, 2006).

In-Office Bleaching Technique

In 1970, Cohen and Parkins introduced bleaching of tetracycline stained-teeth, using 30% hydrogen peroxide and a heating source.

In-office bleaching systems employ the use of high concentrations of hydrogen peroxide 35% solution or greater, or lesser if it is a concentrated gel (Goldstein, 1997). The procedure can be heated, non-heated or light activated (Kihn, 2007).

Currently, chemically activated systems which do not need light activation have been introduced (Christensen, 2000). *Opalescence Xtra-Boost* (Ultradent Products, South Jordan, Utah, USA) is a chemically activated in-office bleaching material which is a two syringe system activated by mixing both syringes. In 2005, Sulieman suggested that when these syringes were mixed together the pH increased to 7. Ultradent has recently replaced this material with *Opalescence Boost,* which is also a chemically activated double syringe system.

The Yotuel® Special, Biocosmetics Laboratories, (Spain) bleaching system is another system that involves the mixing process in which the powder should be introduced into the liquid found in the same bottle by pressing the release cap down. The bottle then has to be shaken gently. The activator should then be added to the bleaching material and mixed until it forms a thick hydrogen peroxide gel that can be applied onto the tooth surface (Pretty *et al*, 2006).

In light activated bleaching materials Quartz–tungsten–halogen (QTH) lamps, plasma arc lamps (xenon short arc lamps), laser sources and light emitting diodes (LED) can be used to activate the peroxide (Buchalla and Attin, 2007).

However in 2010 Bernardon *et al* did not recommend the use of a light source in the in-office vital bleaching technique, after they found that the light source did not enhance the bleaching effect.

The whitening effect can be achieved for patients after one visit (Tavares *et al*, 2003) or sometimes it needs multiple visits (Sulieman, 2005).

Procedure

The patient should be assessed clinically and radiologically. Photographic records should be taken prior to the tooth bleaching procedure. The teeth must be cleaned with a pumice prophylaxis paste. The bleaching gel is applied to the teeth after isolating the soft tissue by means of a rubber dam or the use of a light-cure isolating paste (Powell and Bales, 1991).

The peroxide is activated by heat (Goldstein, 1997), light (Buchalla and Attin, 2007) or chemically activated (Kugel *et al*, 2006).

In the case of a conventional light source; the light is placed close to the teeth, while in the case of the plasma arc; the light source should be placed 6 to 7 mm away from the gel (Greenwall, 2001).

It is important to follow the manufacturer's instructions in relation to the number of applications and the timing for each application session. The bleaching material is removed after finishing the procedure. The teeth are then washed and rinsed. The gingival isolating material or the rubber dam is removed and the tooth assessed for shade change. Post-operative photographs are obtained for record purposes (Greenwall, 2001).

In-Office Bleaching Materials Commercially Available

Illumine, (DENTSPLY Professional) 15% hydrogen peroxide
Office White, (Life-Like Cosmetic Solutions) 40% hydrogen peroxide
Perfection White, (Premier Dental Products) 35% hydrogen peroxide
Niveous, (Shofu Dental) 25% hydrogen peroxide
Opalescence boost, (Ultradent Products) 38% hydrogen peroxide
Yotuel® Special, (Biocosmetics Laboratories) 35% hydrogen peroxide

Light Activated Bleaching Materials Commercially Available

LaserSmile, (Biolase Technology) 37% hydrogen peroxide
ArcBrite, (Biotrol) 30% hydrogen peroxide
BriteSmile, (BriteSmile) 15% hydrogen peroxide
Lightening Plus, (Johnson and Johnson) 35% hydrogen peroxide
Zoom, (Discus Dental) 20% hydrogen peroxide
Luma White Plus, (Luma Lite) 35% hydrogen peroxide

Over-the-counter (OTC) Bleaching Materials Commercially Available

The whitening effect of toothpastes, mouth rinses, and paint-on products is questionable; there is only limited research available to support their effectiveness as bleaching agents (Greenwall, 2001).

Products that use carbamide peroxide have user modified trays available for use in the bleaching process (Li, 1996).

OTC products that contain peroxide vary in their concentration of peroxide from 5.9% to 6.5% (Kihn, 2007) or it could be as high as 13% to 16% (Gŏtz *et al*, 2007).

Whitening toothpastes mainly polish stains; there is no evidence that even peroxide containing toothpastes actually remove internal stains (Sarrett, 2002). In 2007, Gŏtz *et al* evaluated 13% and 16% hydrogen peroxide strips and concluded that these systems were well tolerated by the patient with no side effects except for mild reversible sensitivity.

2.6.3- Combination Technique

The combination technique involves the use of an in-office bleaching technique using 35% to 50% hydrogen peroxide followed by the application of a less concentrated hydrogen peroxide or carbamide peroxide gel in a night-guard for 30 to 45 minutes at night for two weeks followed by a once a week application until the colour is stable (Garber, 1997).

2.6.4- Ultrasonic Technique

This technique involves the use of ultrasonic technology with a 6 to 7.5% hydrogen peroxide gel in a tray for two applications; each time for 5 minutes.
In 2005, Sulieman suggested that the ultrasonic power increased the production of free radicals which diffused into the tooth achieving the bleaching effect.

2.7- Bleaching Efficacy

In 2002, Ritter *et al* reported on a 10 year retrospective study, which found that night-guard vital bleaching was a safe technique with minimal clinical post treatment side effects.

In 1997 Goldstein, reported that the in-office vital bleaching was an effective, safe and quick technique for bleaching purposes.
In-office vital bleaching offers immediate bleaching results and patients do not have to wear a bleaching tray which is important in patients that suffer from the gag reflex (Sulieman, 2005). In 2009 a review of tooth bleaching efficacy conducted by Burrows, concluded that the in-office vital tooth bleaching technique could provide the required bleaching effect without the need for any further treatment modalities.
Recent reviews and clinical studies reported that the in-office vital bleaching is effective without the need to use any light sources to activate the bleaching process (Burrows, 2009, Bernardon *et al,* 2010).

In 2009, Bizhang *et al* compared the efficacy of 6% hydrogen peroxide strips with a 10% carbamide peroxide home bleaching system and a 15% hydrogen

peroxide in-office vital bleaching system and found that the in-office vital bleaching and the home bleaching techniques were superior in the whitening effect compared to the over the counter bleaching products.

The combination technique helps patients to achieve a satisfactory bleaching result by motivating the patients when they see the immediate colour change that results from in-office vital bleaching and then motivates them to continue with the home bleaching material (Sulieman, 2005). However, in 2010, Bernardon *et al* concluded that the combination technique increased the bleaching rate only in the first week when compared to the in-office vital bleaching and home bleaching techniques but after the first week the combination technique did not enhance the bleaching effect compared to the other systems.

2.8- Factors Influencing Tooth Whitening

2.8.1- Concentration of the Bleaching Material

The number, duration of applications and the concentration of the bleaching agent determine the efficacy of the bleaching procedure (Dahl and Pallesen, 2003).

The higher the concentration, the faster the whitening effect, however the change in colour for a 10% and a 16% carbamide peroxide compared to that achieved with a 5% carbamide peroxide night-guard bleaching technique was the same after two weeks (Kihn, 2007). The same findings were reported in 2007 by Braun *et al*, when they compared the whitening effect of a 10% and a 17% carbamide peroxide gel.

Sulieman *et al*, (2004) conducted an *in-vitro* study to evaluate the concentration of peroxide on tooth whitening and found that the concentration of the hydrogen peroxide affected the number of applications required to get a proper shade in the tooth. They concluded that, the higher the concentration of the peroxide, the lower the number of applications necessary to achieve a result.

2.8.2- Heat and Light

Raising the temperature of the bleaching agent by light or heat accelerates the release of hydroxyl radicals from the peroxide and this may lead to an increase in the efficacy of the bleaching material (Buchalla and Attin, 2007), Tavares *et al* concluded that the use of light enhanced the bleaching process and even noticed that the use of a placebo gel plus light had a whitening effect on the teeth when they used a short arc gas plasma lamp emitting light in the bleaching process (Tavares *et al*, 2003).

However this is in contrast to the study in 1999 by Jones *et al,* that did not detect a colour change when they used a laser activated hydrogen peroxide system over two other systems using a 10% and 20% carbamide peroxide gel. Kugel *et al*, 2006 tested the efficacy of (Brite Smile) a 15% hydrogen peroxide gel in a light activated system using a gas plasma light system and Opalescence Xtra Boost a 38% hydrogen peroxide chemically activated system. They found both systems to be effective in whitening teeth and the light source did not increase the effectiveness (Kugel *et al*, 2006). The same finding was confirmed by Marson *et al* in 2008 when they tested the effect of light on an in-office vital bleaching material without the use of a light and when using a halogen light, LED and LED/Laser light. They concluded that the light not only did not improve the bleaching activity but it also did not affect the colour stability after six months. In 2009, Burrows concluded that bleaching was effective and there was no need to use a light source while doing the bleaching procedure.

2.9- Patient Satisfaction

In a study conducted by Vallittu *et al* in 1996 to evaluate the attitude of different social and age groups towards the appearance of their teeth, it was reported that the appearance of the teeth was found to be more important in women and in younger aged patients. Patients with limited education were more concerned about having whiter teeth than those patients in the higher educational group.

The bleaching effect was not the same for each patient and bleaching results could differ from case to case with unguaranteed patient satisfaction. In 2004, Sulieman considered patients with high expectations to be contraindicated for bleaching treatment. These patients would never be satisfied following bleaching procedures and other forms of treatment for the discoloration should be considered.

In 2000, Haywood stated that no further bleaching procedures should be done to the patient whenever the patients' tooth shade reached the colour of the white of their sclera.

2.10- Shade Relapse

One of the major problems facing in-office vital bleaching is colour rebound within a few months of the procedure due to the rehydration of the etched, bleached teeth (Garber, 1997).

Bello and Jarvis, (1997) considered the bleaching effect reversible especially in patients that smoked and drank fluids that stained teeth.

In 1999, Swift *et al* examined the effects of 10% carbamide peroxide over a two year follow-up period and found that 83% had a two unit shade change using a Vita shade guide, and that the regression occurred during the first 6 months after bleaching.

The relapse in colour happens after two weeks of finishing the bleaching treatment. The oxygen that is released from the bleaching material changes the optical quality of the tooth and in two weeks time the oxygen is lost and the lightened colour disappears (Greenwall, 2001).

2.11- Adverse Effects of the Bleaching Process

2.11.1- Post-Operative Tooth Sensitivity

Jorgensen and Carroll (2002) reported mild sensitivity when using 15% carbamide peroxide in 50% of the patients, especially in patients diagnosed with gingival recession.

Fugaro *et al,* (2004) found that even night-guard bleaching in which they used a low concentration of carbamide peroxide (10%), caused a reversible minor pulp reaction.

Tooth sensitivity is a common side effect in patients treated with a vital bleaching technique (Tredwin *et al*, 2006). In one study after application of the bleaching material, the sensitivity lasted for almost four days (Schulte *et al*, 1994).

In the power bleaching technique the use of a quartz–tungsten–halogen (QTH) and plasma arc lamps increases the intra-pulpal temperature which may affect the pulp and cause tooth sensitivity (Baik *et al,* 2001). However in 2010, Bernardon *et al* concluded that the in-office vital bleaching resulted in higher sensitivity regardless of the presence of a light source when compared to home bleaching and the combination technique in a split mouth study design.

In 2000 Gökay *et al* conducted an *in-vitro* experiment to test the penetration of a bleaching material into the pulp chamber in sound and composite restored teeth and found that the composite restored teeth showed more bleaching agent penetration into the pulp chamber compared to the sound teeth.

The sensitivity mechanism is not fully understood. An *in-vitro* study conducted by Thitinanthapan *et al,* (1999) showed that peroxide can reach the pulp after penetrating the enamel and dentin and may be the cause of the sensitivity.

2.11.2- Gingival Irritation

In 2002 Pohjola *et al* tested three home bleaching systems and found that a quarter (25%) of the sample size suffered from gingival irritation.

In 2003, Zekonis *et al* compared an in-office vital bleaching system that contained 35% hydrogen peroxide to a home bleaching system that contained 10% carbamide peroxide and found that the home bleaching system caused higher gum sensitivity probably because it was used without a rubber dam or any gum protective barriers.

2.11.3- Effect of Bleaching Material on Tooth Restorations

The literature has shown that there is an effect of the bleaching material on different types of restorations. Attin *et al*, (2004) suggested avoiding contact between the bleaching agents and the restorative materials.

The release of mercury and silver from amalgam restorations was noticed, when 10% carbamide peroxide was applied to teeth with amalgam restorations (Rotstein *et al*, 2000).

In the first 24 hours after application of the bleaching material, the bond strength between the enamel and the composite is reduced (Dishmann *et al*, 1994).Tooth bleaching agents should not be used in the 24 hours prior to treatment with resin based materials (Tredwin *et al*, 2006).

In 2005, Yalcin and Gürgan tested the bleaching effect on tooth-coloured restorations and found that the bleaching material affects the gloss which is an optical phenomenon and represents the appearance and the capacity of the surface of the restoration to reflect directed light. They suggested that practitioners should not use bleaching materials when there are tooth coloured restorations especially in the anterior region of the mouth.

In 2003 Turker and Biskin, observed that the application of 10% to 16% carbamide peroxide gels decreased the surface hardness of feldspathic porcelain but the difference was not significant.

2.11.4- Effect of Bleaching on Enamel and Dentine

In 2007, Caballero *et al* examined the *in vivo* effect of 10% carbamide peroxide and 3.5% hydrogen peroxide on the enamel surface and concluded that there was no detrimental effect on the enamel surface.

In 2008, Joiner *et al* reviewed the effect of bleaching on enamel and dentine and found no significant effect. However a high number of bleaching treatments resulted in enamel microhardness reduction in another study (Attin *et al*, 2009).

2.11.5- Cervical Root Resorption

Non-vital tooth bleaching could result in external root resorption; especially if a high concentration of hydrogen peroxide is activated using heat (Friedman *et al*, 1988). However, Holmstrup *et al*, (1988) followed up 95 teeth treated using sodium perborate and after a period of three years found no cervical resorption.

In the cases where there was resorption, the speculation over the mechanism suggested on how the bleaching material reached the periodontal tissue through the dentinal tubules and caused an inflammatory reaction is possible and may explain the resorption that is evident in some cases (Cvek and Lindvall, 1985).

2.12- Shade Analysis

The efficacy of a bleaching treatment can be determined through using shade guides, a spectrophotometer, or digital image capturing device to measure the colour change over time.

2.12.1- Shade Guide

The use of a shade guide in evaluating the shade change after bleaching is considered to be the most subjective method used in shade assessment studies (Burrows, 2009).

Using a Vita Classical Shade Guide is one of the methods used to identify tooth colour in which tooth shades are arranged depending on their lightness (B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4, C4) where B1 is considered the lightest and C4 the darkest of the shade tabs (Collins *et al*, 2004).

Shade guides can result in an error in determining the exact tooth shade due to the limitations in colour selection compared to the natural tooth colour shade (O'Brien *et al*, 1991). In addition, surface texture and tooth curvature can create some difficulty in identifying the exact tooth shade using a shade guide (Preston, 1985). Visual assessments using shade guides are highly subjective and prone to observer bias (Bentley *et al*, 1999).

2.12.2- Digital photography

In 1999, Bentley *et al* investigated the use of digital photography processed and analyzed using computer software for patients treated with night-guard vital bleaching and created a brightness index which was derived from computer analysis of these photos and found that this index was reproducible and could be used to monitor the brightness effect of night-guard vital bleaching.

However sometimes there is difficulty in using the software to evaluate the shade change as digital systems with controlled lighting are subjective and expensive (Burrows, 2009).

2.12.3- Colorimeter

Colorimeters use three or four photodiode filters to control the light reaching the object and to provide standard illumination. A detector is used to measure the reflected light (Burkinshaw, 2004).

Colorimeters are easier to use and are less expensive than spectrophotometers. However the repeatability of the colorimeter is questionable (Paravina and Powers, 2004). Colorimeters have been designed for flat surfaces, which can be a challenge to get the proper shade of the human teeth which are normally curved (Burrows, 2009). Besides the curvature, reflectance colorimetry is considered as cumbersome, labor-intensive and an expensive procedure (Bentley *et al*, 1999).

2.12.4- Spectrophotometer

The spectrophotometer is a device used to measure light intensity (photometer). It has been used to measure light absorption, but is now designed to measure spectral reflectance, transmission or relative emission by utilizing a high sensor which collects the reflected light from an object and processes it using a built-in micro-computer (Joiner, 2004, Guan *et al*, 2005).

Spectrophotometers that measure spectral reflectance or transmission consist of a light source, a monochromator and a photodetector (photodiodes).

The light source in a spectrophotometer can be filtered or unfiltered. Different light sources have been used for object illumination including tungsten halogen bulbs and xenon flash tubes (Burkinshaw, 2004).

Spectrophotometrical results are displayed as Quantitative (CIE) colorimetric numerical values expressed as L*, a* and b*, being the coordinates of the colour observed (Cal *et al*, 2006).

Colour change represented by ΔE can be calculated using the following formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ (Commission Internationale de L'Eclairage1978). Where ΔL*, Δa* and Δb* represent the differences between the colour coordinates of the two samples for the variables L*, a* and b*.

In 2007, Karamouzus *et al* found that the reflectance spectrophotometer was considered an accurate instrument in determining tooth shade clinically; however an error could be recorded on curved posterior teeth and on the labial surfaces of the lower anterior teeth during the colour measurement recording process due to the curvature of these teeth.
The spectrophotometer has been used by many researchers as an objective method in clinical shade evaluation of bleaching materials or techniques (Braun *et al*, 2007, Marson *et al*, 2008, Bernardon *et al*, 2010).

2.13- Conclusion

In-office vital bleaching is an effective, safe technique and patients can get the desired bleaching effect in a relatively short time.

The use of a spectrophotometer in determining the efficacy of the bleaching material is considered an accurate, objectively structured method.

Tooth sensitivity is one of the side effects that accompany bleaching techniques.

Patient colour perception is a subjective way to measure the colour change; however the patients' opinion is still important in determining whether he/she needs further bleaching treatment.

CHAPTER THREE

AIM AND OBJECTIVES

3.1- AIM OF THE STUDY

The aim of this study was to assess the outcome of an in-office vital bleaching technique.

3.2- OBJECTIVES OF THE STUDY

1. To evaluate the degree of colour change after vital tooth bleaching using a 35% hydrogen peroxide gel (Yotuel® Special, Biocosmetics Laboratories, Spain), using a spectrophotometer (CM-2600d Konica, Minolta) to measure the colour change if any at each intervention during the bleaching process.

2. To assess the post operative sensitivity if any during the first week after the intervention.

3. To evaluate the patients' perception of the colour change if any and to compare it to the colour change expressed as (ΔE) in numeric values.

4. To investigate whether gender differences exist in relation to the outcome of the bleaching procedure.

3.3- NULL HYPOTHESES

- There is no significant difference in tooth shade after bleaching using a high concentration (35%) hydrogen peroxide gel.

- There is no significant difference in tooth sensitivity within one week after the bleaching procedure.

CHAPTER FOUR

MATERIALS AND METHODS

4.1- Study Design

A prospective experimental clinical design was adopted, as it fulfilled the objectives of this study.

4.2- Sample Size

22 patients that requested bleaching of their maxillary anterior teeth (11 males and 11 females) constituted the sample.

4.3- Inclusion Criteria

- Healthy adults in the age range between 18 and 40 years.
- Availability of the subject in the area for six months.
- Six maxillary anterior natural teeth without any restorations.
- Patients needed to be clinically diagnosed as not having generalized gingivitis or periodontitis.
- Patients must have had at least one maxillary central incisor tooth of an A-2 shade or darker based on the Vita classic shade guide.
- No previous history of bleaching.

4.4- Exclusion Criteria

- Anterior teeth with extensive fillings or crowns.
- Teeth that showed initial hypersensitivity during the pre-treatment clinical examination.
- Young patients aged less than 18 years of age.
- Pregnant or nursing patients.

4.5- Material

Yotuel® Special, Biocosmetics Laboratories, Spain contains 35% hydrogen peroxide (the non-sensitivity whitening system) (Figure 4.1). This system consists of two bottles, the first bottle contains an activator and the second one contains the bleaching agent (Figure 4.5). Activation is done by mixing the bleaching agent with the activator.

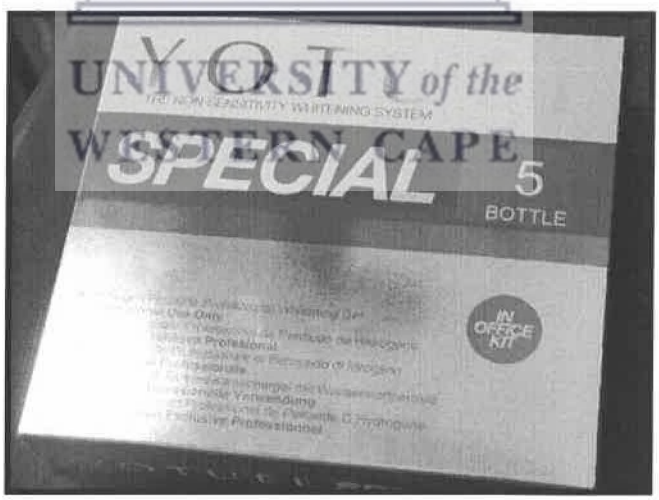


Figure 4.1: Yotuel® Special, 35% Hydrogen peroxide

4.6- Procedure

22 patients that requested bleaching of their maxillary anterior teeth formed the study sample. A full clinical and dental radiographic examination of the patient was undertaken, as well as a photographic record of the teeth prior to

treatment. Patients provided the necessary medical and dental history. Patients had at least one maxillary central incisor tooth of an A-2 shade or darker based on the Vita classic Lumin-Vacuum shade guide (Figure 4.9). Patients were blinded to the bleaching material that was used in the study.

The first reading of the shade of the teeth was taken using the spectrophotometer (CM-2600d Konica, Minolta) (Figure 4.2) prior to any intervention.

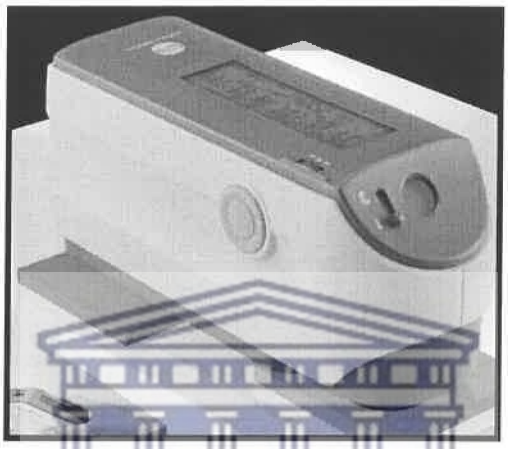


Figure 4.2: CM-2600d Konica, Minolta spectrophotometer

Three readings for tooth 11 and tooth 21 were obtained. The data were recorded on an Excel spreadsheet. A thorough scaling using an ultrasonic scaler and professional prophylaxis paste polishing material (Glitter, Premier Dental, USA) was performed of the patient's teeth. Oral hygiene instructions were given at the same visit.

The second tooth shade reading was taken immediately after scaling and polishing using the spectrophotometer. Patients were asked to use a tooth paste without any whitening agents during the period between visits. Patients were given an informed consent form (Appendix II) to take home with them after discussing its content with them in their mother language.

After one week, the informed consent form was collected and pre-bleaching readings of the shade of the maxillary central incisors was recorded.

The lips were separated from the teeth using a lip retractor. A low viscosity silicone gingival protective barrier (Figure 4.3) was applied to seal the inter-

proximal spaces and the barrier material was extended one tooth beyond the last tooth to be bleached. The material was light cured using a halogen light curing unit (Demetron LC, sdsKerr, USA) (Figure 4.4).

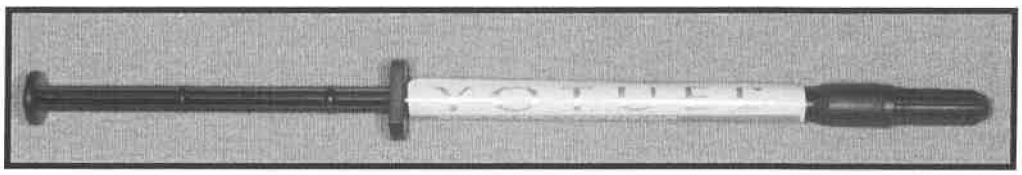


Figure 4.3: YOTUEL gingival protective barrier

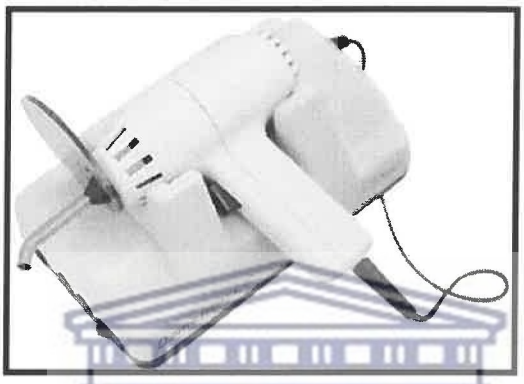


Figure 4.4: Halogen light curing unit

Material preparation

The sealed cap was removed and pressure was exerted on the red button until the white powder emerged from the bottle. The bottle (Figure 4.6) was shaken for 30 seconds until a homogeneous mixture was obtained. The bleaching material (Yotuel® Special, Biocosmetics Laboratories, Spain) was prepared by mixing 15 drops of the activator (Figure 4.7) with the bleaching agent after opening the bottle completely. The mix was stirred with a spatula until a gel like consistency was obtained (Figure 4.8).

Figure 4.5: The bleaching material with the activator

Figure 4.6: Homogenous mixture of the bleaching material

Figure 4.7: Bleaching material activation

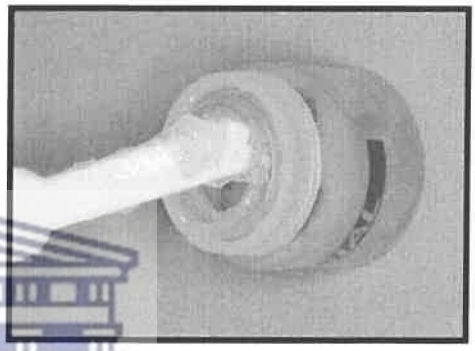


Figure 4.8: gel consistency

A layer of bleaching gel (Yotuel® Special, Biocosmetics Laboratories, Spain) approximately 1.0mm thick was applied over the labial surfaces of the teeth to be bleached (Figure 4.11) for 10 minutes. The applied gel was agitated over the teeth with a brush dipped in the activator (Figure 4.12). The gel was left undisturbed for a further 10 minutes. The gel was then removed and the teeth cleaned and rinsed, with water being directed toward the incisal edge, while using a high-volume suction. The left-over gel on the opened bottle was reactivated with another 15 drops of the activator. The gel was then stirred using a spatula and applied to the teeth.

The gel application was repeated two more times in the same session with material reactivation before each application. After completing one hour of bleaching, the bleaching gel was removed using a high-volume suction (Figure 4.13) and the teeth were rinsed with water in the presence of the high volume suction. The gingival protective barrier was removed.

Patients were asked about their perception of the colour change if any after the bleaching procedure. Whether they felt that there was no change at all, there was some change but the teeth still needed bleaching or there was a major colour change. Data were recorded in a separate sheet (Appendix IV). Readings were taken immediately after finishing the treatment using the spectrophotometer (Figure 4.14). Post-bleaching photographs were also obtained using a digital camera (EasyShare Z710, Kodak).

Figure 4.9: Vita Lumin-Vacuum classical shade guide

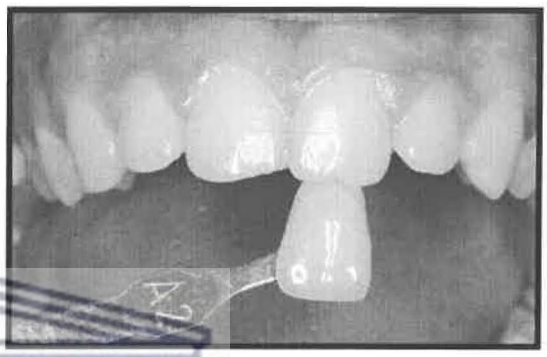


Figure 4.10: Patient tooth shade selection

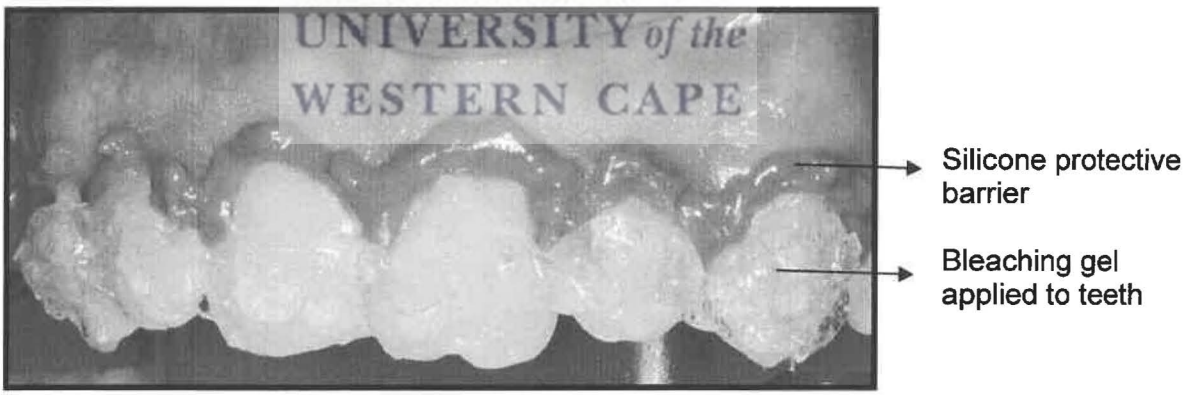


Figure 4.11: Application of bleaching gel after silicone protective barrier was applied

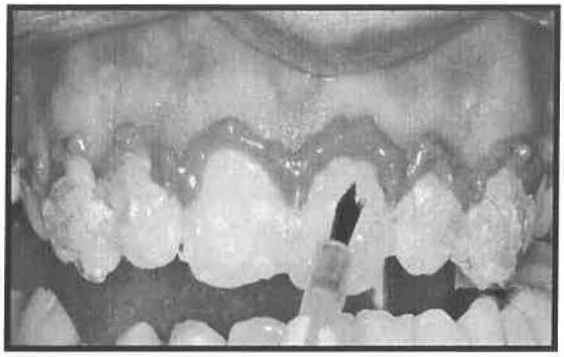


Figure 4.12: Activator applied to bleaching gel on the teeth

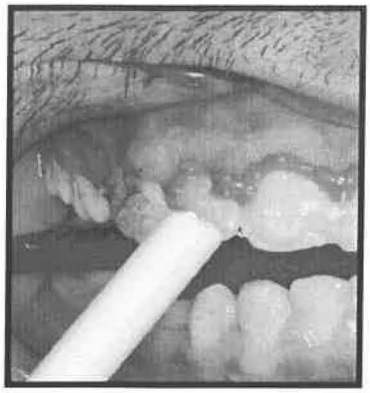


Figure 4.13: High volume suction to remove the bleaching material

Figure 4.14: Readings of the tooth colour shade using a spectrophotometer

The patients were asked to record any changes to their teeth as regards sensitivity for seven days in the sensitivity form supplied (Appendix III). The form included a table for seven days and the patients marked an (x) next to the sensitivity they might have experienced after the bleaching procedure. The responses were categorized as no sensitivity, mild, moderate or severe sensitivity, where **mild sensitivity** was regarded as slight sensitivity with no interference of normal function, i.e. it was well tolerated. **Moderate sensitivity** was regarded as some interference with normal function with the necessity of avoiding certain foods and **severe sensitivity** which resulted in major interference with normal function, i.e. the sensitivity could not be tolerated based on the work of Jorgensen and Carroll, (2002).

Tooth shade readings were obtained with the spectrophotometer one week after finishing the bleaching treatment. The sensitivity forms were collected and the patient's perception about the colour change was also recorded.

The patients were recalled after four weeks. The tooth shade readings were repeated using the spectrophotometer. The patient's perception about the colour change was recorded. Photographs were obtained after each reading. The material and method used in the study is summarized in a flowchart (Appendix XII).

4.7- Data Analysis

Three spectrophotometrical readings for 11 and 21 were obtained before scaling and polishing, after scaling and polishing, before bleaching, after bleaching, one week and one month after bleaching. Data was recorded on an Excel spreadsheet. Each reading was expressed as L*, a* and b* values representing the co-ordinates of the colour recorded. The average of the three readings for L*, a* and b* was determined. The mean of all the L*, a* and b* values for both 11, 21 for all the patients was also determined (Appendix V, VI, VII).

The difference in the L*, a* and b* values between base line (before bleaching) and immediately after bleaching was computed using the Commission Internationale de L'Eclairage (1978) formula and expressed as ΔE.

The stability of the colour change was computed after determining the differences in the L*, a* and b* values obtained immediately after bleaching and those obtained four weeks after bleaching.

The actual colour change measured was computed after determining the difference in the L*, a* and b* values before bleaching and those obtained four weeks after the bleaching procedure.

The Wilcoxon Signed Rank Sum Test a non parametrical test was used to test for statistically significant differences between the baseline values and those obtained immediately after bleaching and those obtained four weeks after bleaching.

A conformational approach was used to determine the gender difference in relation to the outcome of the bleaching procedure.

For the post-operative sensitivity analysis two ordinal variables, sensitivity and duration were used.

A Spearman correlation test was used to correlate the values of colour change obtained numerically and expressed as ΔE and the patients' perception of colour change.

4.8- Ethical Considerations

This study was submitted to the ethical committee of the University of Western Cape. The patient's participation in the project was voluntary and an informed consent highlighting the possible adverse effects of bleaching was illustrated to the patients in their mother language. All personal information disclosed was considered strictly confidential. Patients were given unique codes and only the researcher had access to these codes.

4.9- Conclusion

22 Patients of A-2 shade or darker based on a Lumin-Vacuum classic shade guide were selected for bleaching treatment using (Yotuel® Special, Biocosmetics Laboratories, Spain). The material was prepared and applied according to the manufacturer's instructions. Photographs before and after were obtained using a digital camera (EasyShare Z710, Kodak). A spectrophotometer (CM-2600d Konica, Minolta) was used to record the colour change in numerical values. Patients were asked to fill in a sensitivity form for seven days after the bleaching procedure to determine if tooth sensitivity was experienced. The patients colour perception was also recorded immediately after bleaching, one week and one month post bleaching.

CHAPTER FIVE

RESULTS

5.1- Introduction

A total of 22 patients with a mean age of 30.8 years started the study but only 20 patients completed the study. One of the patients did not return for the one week follow-up reading and the other patient did not return to complete the study; however the patients' colour perception and their responses to the sensitivity questionnaire was obtained telephonically.

This chapter highlights the findings from the spectrophotometer readings in regard to the colour shade change, sensitivity, patient's perception of colour change and the statistical analysis of the results. The data are captured in Appendix V, VI and VII but are summarized in Table 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, 5.15, 5.16, 5.17.

5.2- Colour Shade Change Assessment

5.2.1- Colour shade change before scaling and polishing and after scaling and polishing

Colour axis	Mean before scaling and polishing	Mean after scaling and polishing	Difference between before and after scaling and polishing	P values (Wilcoxon signed rank test)
L*	61.76 sd 3.29	62.82 sd 3.58	1.07 sd 1.3	0.0012■
a*	0.21 sd 0.61	0.09 sd 0.62	-0.12 sd 0.20	0.0148■
b*	6.88 sd 1.79	6.10 sd 2.12	-0.79 sd 0.97	0.0012■

■ Statistically significant $p \leq 0.05$

Table 5.1 Summarizing the L* a* b* values illustrating the scaling and polishing outcome with standard deviation (sd)

Mean ΔE=1.74 sd 1.16

There was a statistically significant difference ($p \leq 0.05$) in all three coordinates (L*, a* and b*) before and after scaling and polishing.

However calculating the ΔE before and after scaling and polishing a value of 1.74 units is obtained which according to the literature is not clinically perceptible as a change in colour.

5.2.2- Colour shade change before scaling and polishing and before bleaching

Colour axis	Mean before scaling and polishing	Mean before bleaching (Baseline)	Mean difference between before scaling and polishing and Baseline	P values (Wilcoxon signed rank test)
L*	61.76 sd 3.29	62.12 sd 3.42	0.36 sd 1.08	0.1998 •
a*	0.21 sd 0.61	0.22 sd 0.66	0.01 sd 0.26	0.721 •
b*	6.88 sd 1.79	6.62 sd 2.24	-0.27 sd 0.97	0.1998 •

• Not significant $p > 0.05$

Table 5.2 Scaling and polishing and baseline readings L* a* b* values with standard deviation (sd)

Mean ΔE=1.25 sd 0.87

There was no statistically significant difference ($p > 0.05$) in all three coordinates (L*, a* and b*) before scaling and polishing and before bleaching.

Calculating the ΔE before scaling and polishing and before bleaching, a value of 1.25 units is obtained which according to the literature is not clinically perceptible as a change in colour.

5.2.3- Colour shade change before bleaching and immediately after bleaching

Colour axis	Mean before bleaching (Baseline)	Mean immediately after Bleaching	Mean difference between Baseline and after bleaching	P values (Wilcoxon signed rank test)
L*	62.12 sd 3.42	65.11 sd 3.80	2.99 sd 1.18	0 ■
a*	0.22 sd 0.66	-0.01 sd 0.72	-0.23 sd 0.24	0.0006■
b*	6.62 sd 2.24	5.36 sd 2.72	-1.25 sd 0.99	0.0002 ■

■ Differences statistically significant at $p \leq 0.05$

Table 5.3 Baseline and immediately after bleaching readings L* a* b* values with standard deviation (sd) and statistical significance

Mean ΔE=3.40 sd 1.17

There was a statistically significant difference ($p \leq 0.05$) in all three coordinates (L*, a* and b*) before and after bleaching.

However calculating the ΔE before and after bleaching, a value of 3.4 units is obtained which according to the literature is not clinically perceptible as a change in colour as the threshold to perceive a change in colour is a ΔE value of 3.7 units. However some authors feel that depending on the circumstances this difference may be perceptible clinically to some individuals (Douglas and Brewer, 1998, Douglas *et al*, 2007).

5.2.4- Colour shade change before bleaching and one week after bleaching

Colour axis	Mean before bleaching (Baseline)	Mean one week after Bleaching	Mean difference between Baseline and one week after bleaching	P values (Wilcoxon signed rank test)
L*	62.12 sd 3.42	63.98 sd 3.82	1.95 sd 1.25	0 ■
a*	0.22 sd 0.66	-0.02 sd 0.66	-0.22 sd 0.24	0.002■
b*	6.62 sd 2.24	5.57 sd 2.32	-.80 sd 0.84	0 ■

■ Differences statistically significant at $p \leq 0.05$

Table 5.4 Baseline and one week after bleaching readings L* a* b* values with standard deviation (sd) and statistical significance

Mean ΔE=2.24 sd 1.32

There was a statistically significant difference ($p \leq 0.05$) in all three co-ordinates (L*, a* and b*) before bleaching and one week after bleaching.
However calculating the ΔE before bleaching and one week after bleaching, a mean value of 2.24 units is obtained which according to the literature is not clinically perceptible as a change in colour.

5.2.5- Colour shade change before bleaching and one month after bleaching

Colour axis	Mean before bleaching (Baseline)	Mean one month after Bleaching	Mean difference between Baseline and one month after bleaching	P values (Wilcoxon signed rank test)
L*	62.12 sd 3.42	63.31sd 4.05	1.19 sd 1.91	0.0071 ■
a*	0.22 sd 0.66	0.02 sd 0.70	-0.20 sd 0.26	0.0032 ■
b*	6.62 sd 2.24	6.00 sd 2.19	-0.47 sd 1.01	0.0854 ●

■ Differences statistically significant at $p \leq 0.05$

● Statistically significant at $p \leq 0.1$

Table 5.5 Baseline and one month after bleaching readings L* a* b* values with standard deviation (sd) and statistical significance

Mean ΔE=2.18 sd 1.24

There was a statistically significant difference ($p \leq 0.05$) in (L*, a*) co-ordinates, however (b*) co-ordinate was statistically significantly at ($p \leq 0.1$) before bleaching and one month after bleaching.

Calculating the ΔE before bleaching and one month after bleaching, a mean value of 2.18 units is obtained which according to the literature is not clinically perceptible as a change in colour.

5.2.6- Colour shade change before scaling and polishing and immediately after bleaching

Colour axis	Mean before scaling and polishing	Mean immediately after Bleaching	Mean difference between before scaling and polishing and immediately after bleaching	P values (Wilcoxon signed rank test)
L*	61.76 sd 3.29	65.11 sd 3.80	3.35 sd 1.45	0■
a*	0.21 sd 0.61	-0.01 sd 0.72	-0.22 sd 0.33	0.006■
b*	6.88 sd 1.79	5.36 sd 2.72	-1.52 sd 1.47	0.0006 ■

■ Differences statistically significant at $p \leq 0.05$

Table 5.6 Before scaling and polishing and immediately after bleaching readings L* a* b* values with standard deviation (sd) and statistical significance

Mean ΔE=5.14 sd 2.15

There was a statistically significant difference ($p \leq 0.05$) in all three co-ordinates (L*, a* and b*) before scaling and polishing and immediately after bleaching.

Calculating the mean ΔE before scaling and polishing and immediately after bleaching, a mean value of 5.14 units is obtained which according to the literature is clinically perceptible as a change in colour

5.2.7- Colour shade change before scaling and polishing and one month after bleaching

Colour axis	Mean before scaling and polishing	Mean one month after Bleaching	Mean difference between before scaling and polishing and one month after bleaching	P values (Wilcoxon signed rank test)
L*	61.76 sd 3.29	63.31sd 4.05	1.55 sd 2.15	0.0068■
a*	0.21 sd 0.61	0.02 sd 0.70	-0.21 sd 0.36	0.0228■
b*	6.88 sd 1.79	6.00 sd 2.19	-0.80 sd 1.17	0.0038■

■ Differences statistically significant at $p \leq 0.05$

Table 5.7 Before scaling and polishing and one month after bleaching readings L* a* b* values with standard deviation (sd) and statistical significance

Mean ΔE=3.24 sd 2.27

There was a statistically significant difference ($p \leq 0.05$) in all three co-ordinates (L*, a* and b*) before and after bleaching.

However calculating the ΔE before scaling and polishing and one month after bleaching, a mean value of 3.24 units is obtained which according to the literature is not clinically perceptible as a change in colour.

5.2.8- Colour shade change after bleaching and one month after bleaching

Colour axis	Mean immediately after bleaching	Mean one month after Bleaching	Mean difference between immediately and one month after bleaching	P values (Wilcoxon signed rank test)
L*	65.11 sd 3.80	63.31sd 4.05	-1.80 sd 1.48	0.0002■
a*	-0.01 sd 0.72	0.02 sd 0.70	0.04 sd 0.30	0.5316♦
b*	5.36 sd 2.72	6.00 sd 2.19	0.81 sd 0.92	0.0018 ■

■ Differences statistically significant at $p \leq 0.05$

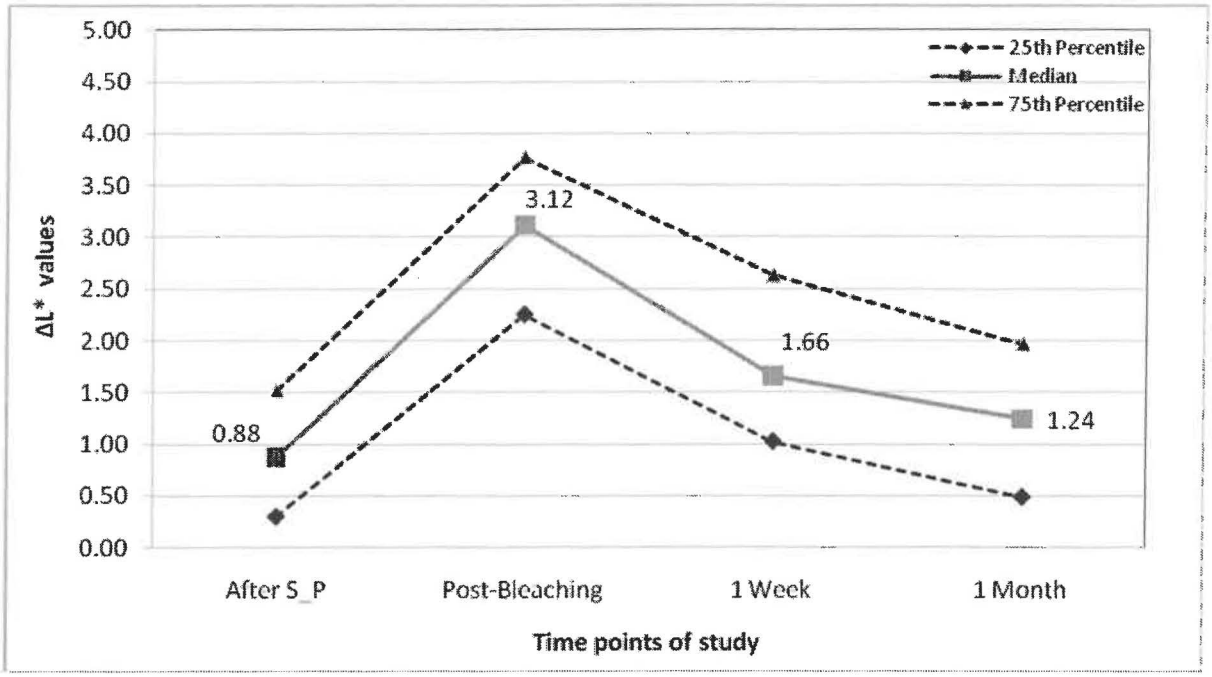
♦ Statistically not significant $p > 0.05$

Table 5.8 Immediately and one month after bleaching readings L* a* b* values with standard deviation (sd) and statistical significance

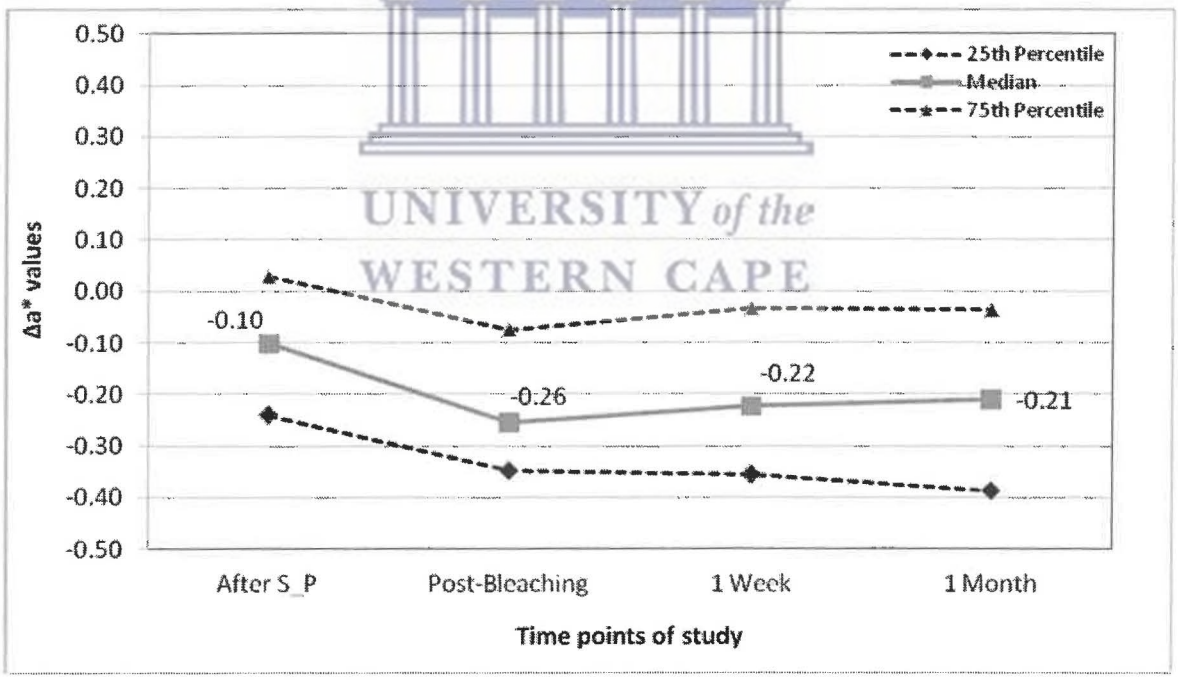
Mean ΔE=2.37 sd 1.14

There was a statistically significant difference ($p \leq 0.05$) in (L*, b*) co-ordinates, however (a*) co-ordinate was not statistically significant ($p > 0.05$) immediately after bleaching and one month after bleaching.

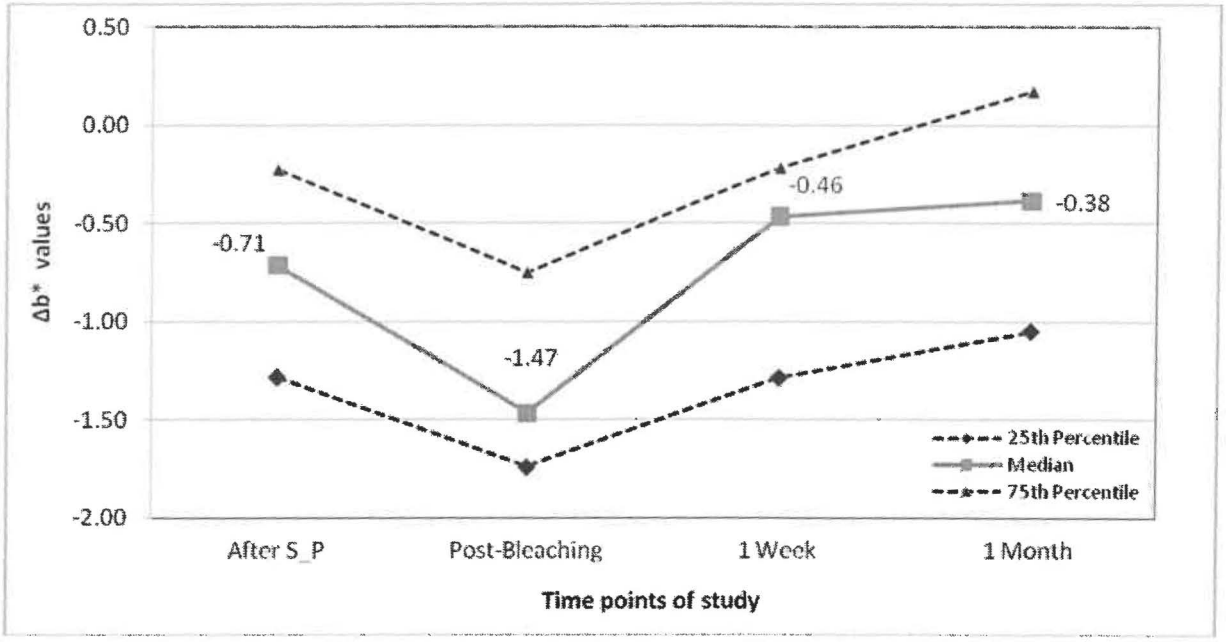
Calculating the ΔE before bleaching and one month after bleaching, a mean value of 2.37 units is obtained which according to the literature is not clinically perceptible as a change in colour.



Graph 5.1: The 25 percentile, median and 75 percentile differences in the L* values between the base-line (before bleaching) and after treatment.

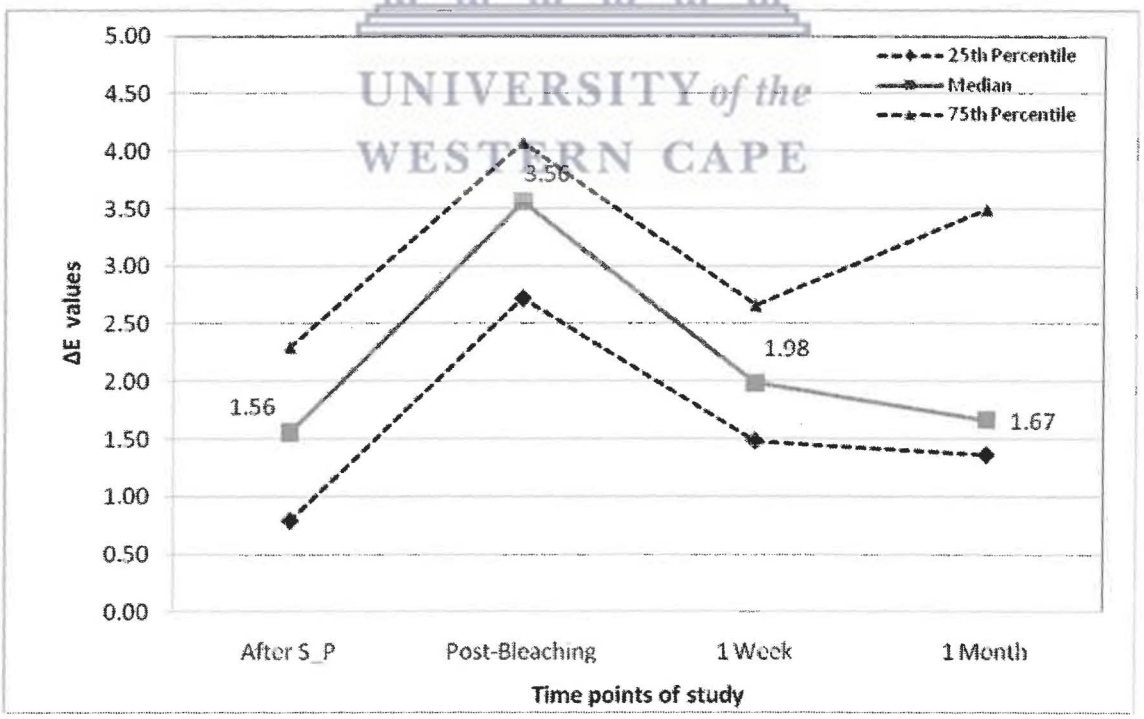


Graph 5.2: The 25 percentile, median and 75 percentile differences in the a* values between the base-line (before bleaching) and after treatment.



Graph 5.3: The 25 percentile, median and 75 percentile differences in the b* values between the base-line (before bleaching) and after treatment.

5.3- ΔE Values



Graph 5.4: The 25 percentile, median and 75 percentile differences in the ΔE values during one month of the bleaching process.

Id#	Gender	ΔE Before and After Scaling and polish	ΔE Before bleaching and Immediately after bleaching	ΔE Before bleaching and One week after bleaching	ΔE Before bleach and One month after bleaching
1	M	3.21	3.53	1.03	0.71
2	F	1.50	5.37	4.76	4.09
3	F	2.04	2.87	1.87	0.88
4	F	4.41	1.96	0.31	1.71
5	F	0.15	3.03		
6	M	1.15	3.79		2.30
7	M	0.47	1.85	1.57	1.31
8	M	2.39	3.59	2.10	2.26
9	M	1.88	4.12	2.43	1.37
10	F	1.45	4.07	1.75	1.66
11	M	0.31	5.72	4.18	4.04
12	M	3.84	4.47	5.33	4.00
13	M	2.44	4.40	3.02	1.51
14	M	1.96	1.62	0.88	2.33
15	F	3.18	4.03	1.74	1.57
16	F	0.50	2.13	2.18	3.49
17	F	0.99	3.60	0.84	1.46
18	F	0.72	3.28	1.62	1.13
19	M	1.62	1.10	1.23	1.67
20	F	1.48	2.67	3.35	3.95
21	F	1.98	4.07	2.11	3.96
22	M	0.57	3.49	2.54	0.27
MEAN		1.74	3.40	2.24	2.18
SD		1.16	1.17	1.32	1.24

Denote a ΔE equal or greater than 3.7 which can be clinically perceptible according to the literature.

Table 5.9: ΔE values using (before bleaching) as a baseline reading

Id#	Gender	ΔE Before and After scaling and polish	ΔE Before scaling and polish and Before bleaching	ΔE Before scaling and polish and Immediately after bleaching	ΔE Before scaling and polish and One week	ΔE Before scaling and polish and One month
1	M	3.21	1.79	8.87	4.58	4.78
2	F	1.50	1.22	9.77	6.72	8.08
3	F	2.04	1.43	2.82	1.08	0.68
4	F	4.41	2.10	5.57	3.20	1.57
5	F	0.15	0.39	3.88		
6	M	1.15	1.07	3.58		0.72
7	M	0.47	0.69	3.07	1.91	2.40
8	M	2.39	1.54	7.66	4.07	5.70
9	M	1.88	1.37	5.16	2.06	1.08
10	F	1.45	1.20	6.36	2.33	3.29
11	M	0.31	0.55	7.00	3.72	4.01
12	M	3.84	1.96	7.10	6.36	6.72
13	M	2.44	1.56	7.39	4.05	2.97
14	M	1.96	1.40	2.82	1.82	2.63
15	F	3.18	1.78	5.45	1.90	1.92
16	F	0.50	0.71	4.25	3.10	6.53
17	F	0.99	1.00	5.87	1.60	3.03
18	F	0.72	0.85	3.65	0.97	0.76
19	M	1.62	1.27	1.68	1.38	1.82
20	F	1.48	1.21	3.05	2.92	5.92
21	F	1.98	1.41	4.01	0.68	3.35
22	M	0.57	0.75	4.01	2.13	0.19
MEAN		1.74	1.24	5.14	2.83	3.24
SD		1.16	0.46	2.15	1.68	2.27

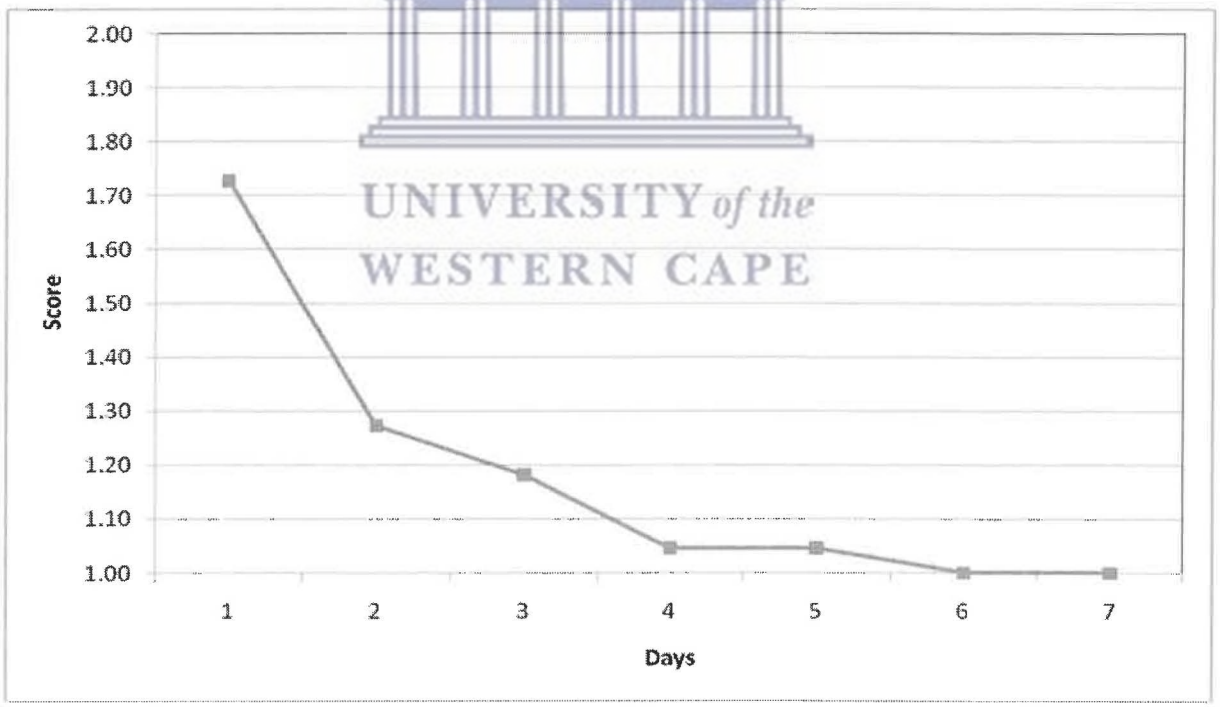
Denote a ΔE ≥ 3.7 which can be clinically perceptible according to the literature.

Table 5.10: ΔE values using before scaling and polishing value as a baseline

5.4- Sensitivity

Sensitivity	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
No sensitivity	12	17	18	21	21	22	22
Mild	6	4	4	1	1	0	0
Moderate	2	1	0	0	0	0	0
Severe	2	0	0	0	0	0	0
Total	22	22	22	22	22	22	22

Table 5.11: Sensitivity data



Graph 5.5: Mean values of tooth sensitivity during one week after the bleaching process

5.5- Patients' Colour Perception

Colour perception	Immediately after bleaching	One week after bleaching	One month after bleaching
No change	1	2	4
Slight change but more bleaching is still needed	17	16	15
Major change	4	4	3
Total	22	22	22

Table 5.12 Patients' colour perception data

Graph 5.6 Mean values of patients' colour perception after the bleaching process

Change measured in ΔE

Change measured in ΔE	ΔE Before-After Scaling and polishing	ΔE After-Before Bleach	ΔE 1 week-Before Bleach	ΔE 1 month - Before Bleach
ΔE Before-After Scaling and polishing	◘ 1	0.121	-0.141	0.006
	■ 0	0.59046	0.55221	0.97771
	• 22	22	20	21
ΔE After-Before Bleaching	0.121	1	0.639	0.310
	0.59046	0	■0.00242	0.17088
	22	22	20	21
ΔE 1 week-Before Bleaching	-0.141	0.639	1	0.450
	0.55221	■0.00242	0	■0.04670
	20	20	20	20
ΔE 1 month -Before Bleaching	0.006	0.310	0.450	1
	0.97771	0.17088	■0.04670	0
	21	21	20	21

◘	Spearman Correlation
■	p-value
•	Number of Valid Pairs

Positive Correlation p<0.01

Positive Correlation p<0.05

Table 5.13: Spearman correlation test between ΔE values

Patients' colour perception

Patients' colour perception	After bleaching	One week	One month
After bleaching	◘ 1	0.719	0.031
	■ 0	**■0.00017**	0.89098
	• 22	22	22
One week	0.719	1	0.328
	■0.00017	0	0.13609
	22	22	22
One month	0.031	0.328	1
	0.89098	0.13609	0
	22	22	22

◘	Spearman Correlation
■	p-value
•	Number of Valid Pairs

Consistent relation

Table 5.14: Spearman correlation test between patients' colour perception values

Patients' colour perception

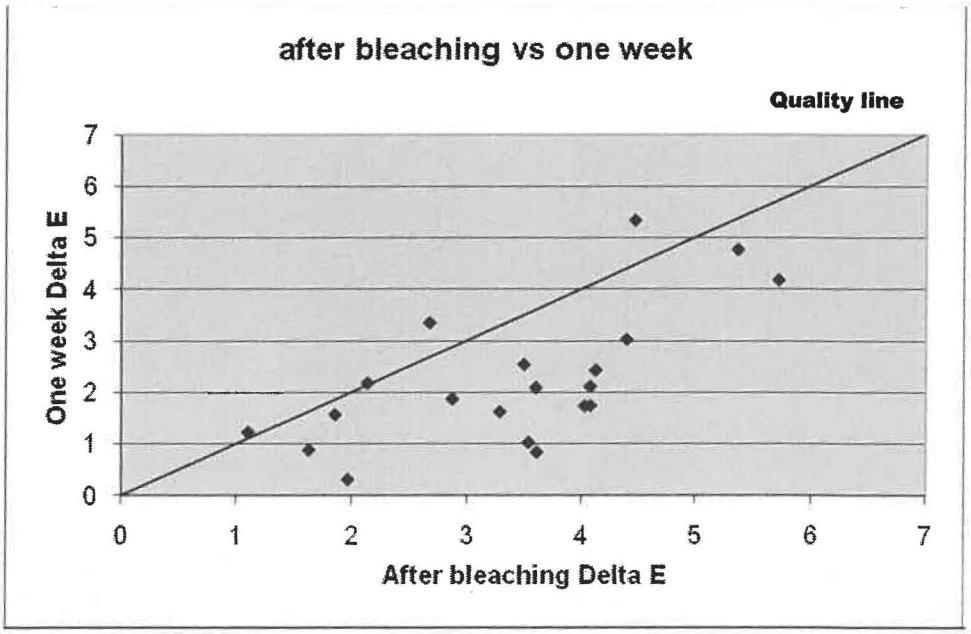
Change measured in ΔE

	After bleaching	One week	One month
ΔE After-Before Bleaching	◘-0.114 ■0.61462 • 22	0.152 0.49995 22	0.124 0.58360 22
ΔE After-Before Bleaching	-0.067 0.76620 22	0.068 0.76377 22	-0.009 0.96854 22
ΔE 1 week-Before Bleaching	-0.085 0.72164 20	-0.160 0.50005 20	-0.170 0.47433 20
ΔE 1 month -Before Bleaching	-0.298 0.18920 21	-0.296 0.19211 21	0.412 ■0.06354 21

◘	Spearman Correlation
■	p-value
•	Number of Valid Pairs

Week relation

Table 5.15: Spearman correlation test between ΔE values and patients' colour perception



Graph 5.7: Relation between after bleaching and one week Δ E values

1	2	3
No change	Slight change but still more bleaching is needed	Major change

Table 5.16: Patients' colour perception scoring code

Count of Id#	Immediately post Bleaching			
1 week	1	2	3	Grand Total
1	1	1	0	2
2	0	15	1	16
3	0	1	3	4
Grand Total	1	17	4	22

Table 5.17: Patients' colour perception immediately and one week after bleaching based on the scores in (Table 5.16)

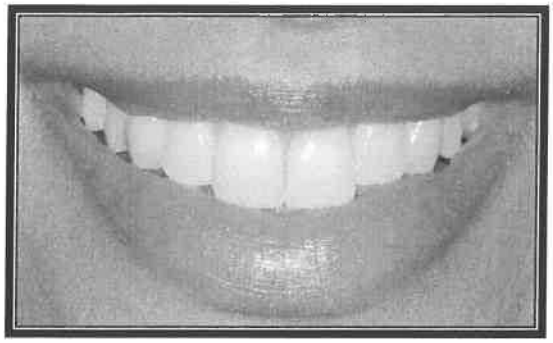


Figure 5.1: Before bleaching

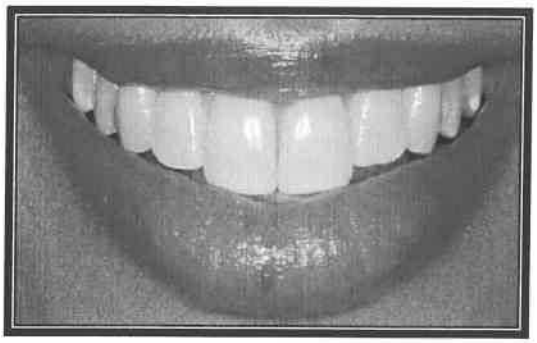


Figure 5.2: After bleaching

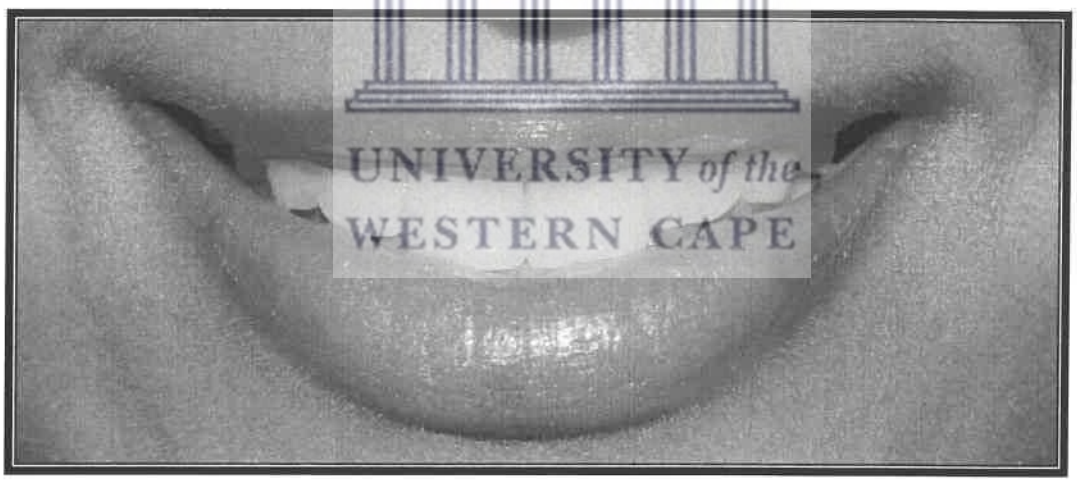


Figure 5.3: One month after bleaching

CHAPTER SIX

DISCUSSION

6.1- Introduction

The use of the spectrophotometer made it possible to quantify the colour and the change in the tooth shade after bleaching using a three-dimensional colour space (Bernardon *et al,* 2010), represented by the three coordinates L*, a* and b*, where L* refers to the lightness coordinate (with 0 being perfect black and 100 being perfect white), a* represents the red–green axis (+a red and -a green) and b* represents the yellow–blue axis (+b yellow and -b indicates blue) (Seghi *et al,* 1986, Uchida *et al,* 1998).

6.2- Quantitative Bleaching Effect on Tooth Colour Shade

6.2.1 Before scaling and polishing outcome and Baseline determination

18 out of the 22 L* values were larger after scaling and polishing with a mean value of 62.82 sd 3.58 which means it moved in the white direction, 15 out of the 22 a* values were less with a mean value of 0.09 sd 0.62 which indicates the colour movement into the green direction and 19 out of the 22 b* values were also less with a mean value of 6.10 sd 2.12 which indicate that the colour shade moved in the blue direction and all the changes were statistically significant as the p values were ≤ 0.05 (Table 5.1). However after one week from the scaling and polishing, there was no statistically significant difference ($P > 0.05$) between the L*, a*, b* co-ordinates before scaling and polishing and before bleaching which is regarded as baseline values (Table 5.2). This indicates that there was no significant change in colour shade after one week of the scaling and polishing effect implying that the change seen immediately after the scaling and polishing was only a temporary change and the colour reverted to its original state.

Calculating the ΔE between before scaling and polishing values and those obtained before bleaching shows that there is no difference in the colour as a difference in colour can only be clinically perceptible with a ΔE equal to or greater than 3.7 (Table 5.10).

6.2.2- L* a* b* Values

6.2.2.1- "L*" Values

When comparing the "L*" values immediately after bleaching to baseline, all 22 patients had an L* value which was larger immediately after bleaching with a mean value of 65.11 and a sd 3.80. "L*" values obtained one week after bleaching compared to baseline showed 20 patients out of 20 to have larger L* values with a mean of 63.98 and a sd 3.82 and the "L*" values obtained one month after bleaching were larger for 18 patients out of a maximum 21 with a mean of 63.31 and a sd 4.05. This means that the L* values moved in the white direction and the changes were statistically significant for all L* values ($p \leq 0.05$) (Table 5.3, 5.4, 5.5).

Comparing the "L*" values immediately after bleaching to before scaling and polishing, all 22 patients had an L* value which was larger immediately after bleaching. This means that the L* values moved in the white direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.6). However, when comparing the "L*" values one month after bleaching to before scaling and polishing, 16 out of a maximum 21 patients have larger L* values. This means that the L* values moved in the white direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.7).

Comparing the "L*" values one month after bleaching to immediately after bleaching, 18 out of a maximum 21 patients had an L* value which was less in value one month after bleaching. This means that the L* values moved in the black direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.8), implying colour rebound between immediately after bleaching and one month after bleaching.

6.2.2.2- "a*" Values

When comparing the "a*" values immediately after bleaching to baseline, 17 patients out of a maximum 22 were less in value with a mean value of -0.01 and a sd 0.72. "a*" values obtained one week after bleaching compared to baseline showed 15 patients out of a maximum 20 were less in value with a mean value of -0.02 and a sd 0.66 and the "a*" values obtained one month after bleaching were also less in value for 18 patients out of a maximum 21 with a mean value of 0.02 and a sd 0.7 when compared to baseline values which indicates that the movement of the "a*" value is into the green direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.3, 5.4, 5.5).

comparing the "a*" values immediately after bleaching to before scaling and polishing, 17 out of a maximum 22 patients had an a* value which was less in value which indicates that the movement of the "a*" value is into the green direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.6). However, when comparing the "a*" values one month after bleaching to before scaling and polishing, 15 out of a maximum 21 patients had an a* value which was less which indicates that the movement of the "a*" value was also into the green direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.7).

Comparing the "a*" values one month after bleaching to immediately after bleaching, only 9 out of 21 patients had an a* value which was less one month after bleaching. This means that the majority of a* values moved in the red direction and the changes were not statistically significant ($p > 0.05$) (Table 5.8).

6.2.2.3- "b*" Values

When comparing the "b*" values immediately after bleaching to baseline, 20 patients out of a maximum 22 b* values were less with a mean value of 5.36 and a sd 2.72. "b*" values obtained one week after bleaching compared to baseline showed 20 patients out of a maximum 20 were less with a mean value of 5.57 and a sd 2.32 and the "b*" values obtained one month after bleaching

were also less for 12 patients out of a maximum 21 with a mean value of 6.0 and a sd 2.19 when compared to baseline values which indicates that the movement of the "b*" value is into the blue direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.3, 5.4) except for the mean value of b* one month after bleaching which was not significant ($p > 0.05$) (Table 5.5).

Comparing the "b*" values immediately after bleaching to before scaling and polishing, 18 out of a maximum 22 patients had a b* value which was less. That indicates the movement of the "b*" value is into the blue direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.6). However, when comparing the "b*" values one month after bleaching to before scaling and polishing, 16 out of a maximum 21 patients had a b* value which was less. This indicates the movement of the "b*" value into the blue direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.7).

Comparing the "b*" values one month after bleaching to immediately after bleaching, 19 out of a maximum 21 patients had a b* value which was larger one month after bleaching This means that the majority of b* values moved in the yellow direction and the changes were statistically significant ($p \leq 0.05$) (Table 5.8). Implying a colour rebound between immediately after bleaching and one month after bleaching.

6.2.2.4- Median difference in "L*" Values

The difference in median L* values between immediately after bleaching and baseline values increased to 3.12 units, but after one week this change decreased to become 1.66 units and after one month it reached 1.24 units which suggests a regression in colour after bleaching and is represented by the area between the 75th percentile and 25th percentile which represents 50% of the values (Graph 5.1).

6.2.2.5- Median difference in "a*" Values

The difference in median a* values between immediately after bleaching and baseline values decreased to "-0.26" units, however after one week this change increased to become "-0.22" units and after one month it reached "-0.21" units. Although there is this slight increase in a* values, the difference in a* values after one month of the bleaching process is considered relatively stable and reflected as a flat graph (Graph 5.2).

6.2.2.6- Median difference in "b*" Values

The difference in median b* values between immediately after bleaching and baseline values decreased to "-1.41" units but after one week this change increased to become "-0.46" units and after one month it reached "-0.38" which suggests that there is a regression in colour after bleaching (Graph 5.3).

6.2.3- Bleaching efficacy

The bleaching efficacy of (Yotuel® Special, Biocosmetics Laboratories, Spain) has not been investigated by independent scientific research. The quantitative effect of the bleaching material on tooth colour showed an increase in L* values and a decrease in a* and b* values, when comparing the results to other in-office bleaching materials that contain high concentrations of hydrogen peroxide gel, similar findings are noted (Zekonis *et al,* 2003, Gurgan *et al*, 2009).

In this study the difference in the L* value was more than that in the b* value (Graph 5.1, 5.3), However Ishikawa-Nagal *et al* 2004 and Goodson *et al* 2005 stated that the b* value is more important in determining the bleaching effect.

6.2.4- ΔE values

Colour change represented by ΔE was calculated using the following formula:

$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ (Commission Internationale de L'Eclairage1978).

Where ΔL*, Δa* and Δb* represent the differences between the coordinates for the variables L*, a* and b* at different times during the study.

Researchers have attempted to use ΔE values in dentistry to find an accurate perceptibility and acceptability threshold in which the perceptibility threshold refers to the minimal colour difference that can be visually detected between two samples and the acceptability threshold refers to unacceptable colour differences between two samples that can affect aesthetics (Douglas *et al*, 2007, Ishikawa-Nagai *et al*, 2009), where the sample can be the natural tooth colour (Yuan *et al*, 2007), the bleaching effect on natural teeth, composite restorations (Jarad *et al*, 2008) and dental porcelain (Wee *et al*, 2002). There is no exact clinically perceptible threshold; however ΔE values for perceptibility can range from 0.4 units (Douglas and Brewer, 1998) to 3.7 units (Yuan *et al*, 2007), while for acceptability thresholds the magnitude ranges from 1.7 units (Douglas and Brewer, 1998) to 6.8 units (Johnston and Kao, 1989).
The acceptability thresholds are higher in magnitude than the perceptibility thresholds (Douglas *et al*, 2007)

Tooth colour change can be detected when ΔE values are less than 1 unit but this change is considered difficult to detect by most of the observers, only 50% of the observers could detect the colour difference (Kuehni and Marcus, 1979). When ΔE values are less than 2 units, tooth colour change is a noticeable change; however not all the observers can detect this change. Values greater than 2 units can be detected by all observers as a colour difference (Seghi *et al*, 1989, O'Brien *et al*, 1990).

A ΔE value equal to or greater than 3.7 units is considered as clinically visible colour change (Johnston and Kao, 1989).

In 2007, Douglas *et al* reported a 2.6 ΔE unit difference as a colour perceptibility threshold for 50% of observers. However the spectrophotometer that was used in this study was not designed for intraoral use (Ishikawa-Nagai *et al*, 2009).
In 2009, Ishikawa-Nagai *et al* concluded that at a value of 1.6 ΔE units all-ceramic crowns cannot be distinguished from natural teeth while colour differences between contralateral natural teeth was possible at 0.9 ΔE units.

For the mean values of colour change a ΔE between baseline and after bleaching was found to be 3.4 units which did not exceed the visible clinical colour change of 3.7 units, however nine patients out of a maximum 22 exceeded the visible clinical colour change immediately after bleaching (Table 5.9).

When comparing the mean colour change expressed as ΔE between before scaling and polishing and after bleaching, it is noticeable that it was 5.14 units which is more than the clinical visible colour change value of 3.7 units. 15 patients out of a maximum 22 exceeded the visible clinical colour change (Table 5.10).

In 2009, Gurgan *et al* examined four different in-office bleaching materials with different light sources One of the groups was (Opalescence Xtra Boost, Ultradent) which is chemically activated that contains 38% hydrogen peroxide, after two applications where each application lasted 15 minutes and found that the mean ΔE after bleaching for this group which consisted of ten patients was 5.54 units change.

In this study the median ΔE value was 3.56 units immediately after bleaching, 1.98 units after one week of the bleaching procedure and 1.67 units after one month of the bleaching procedure (Graph 5.4). This indicates that there was a rapid rebound after the bleaching procedure. Similar findings were reported in 2007 by Matis *et al* when they evaluated eight in-office bleaching systems and concluded that the ΔE value was reduced by 51% which indicated a rapid colour rebound after one week and a 65% reduction after six weeks of the bleaching procedure. In 2003, Al Shethri *et al* reported that colour regression started after finishing the bleaching procedure until the fifth week after the bleaching procedure.

6.3- Gender Difference

The Conformation approach in sorting ΔE values during the bleaching process was used to determine the gender difference. Data were sorted according to ΔE values before and after scaling and polishing (Appendix VIII), ΔE values

before and after bleaching (Appendix IX), ΔE values before bleaching and one week after bleaching (Appendix X) and ΔE values before bleaching and one month after bleaching (Appendix XI). This sorting resulted in a good mixture and fair distribution of the data as regards the ΔE values, implying that none of the values were consistently larger for the one gender compared to the other.

6.4- Tooth Sensitivity

Tooth sensitivity is considered a side effect of bleaching and in this study sensitivity was reported until the fifth day after bleaching. The mean value of the patients' tooth sensitivity was found to be 1.73 in the first day on a 4 point visual analog scale where 1 represented no sensitivity, 2 mild sensitivity, 3 moderate sensitivity and 4 represented severe sensitivity (Graph 5.5).

Ten out of the twenty two patients (45.5%) experienced tooth sensitivity on the first day after bleaching. On the second day after bleaching only five patients (22.7%) reported some sensitivity and only four patients (18.2%) experienced sensitivity on the third day. Only one patient (4.5%) experienced mild sensitivity on the fourth and the fifth day after bleaching.
Six out of the ten patients experienced mild sensitivity on the first day after bleaching, two patients had moderate sensitivity and another two patients had severe sensitivity.

In 2005, Auschill *et al* reported slight tooth sensitivity with a mean value of 2.85 when evaluated on a visual analog scale from 0 – 10 where 0 represented no discomfort and 10 represented severe discomfort, Gurgan *et al*, 2009 also reported tooth sensitivity with a mean value of 3.37 on the same scale. Similar findings were reported by Marson *et al* (2008), when they stated that 92% of the patients that suffered from sensitivity in their study reported that only mild and moderate sensitivity was experienced that lasted for only 24 hours despite the use of a light source in three groups out of the four.

In 2010, Bernardon *et al* examined the in-office vital bleaching in a split design study compared to home bleaching and found that tooth sensitivity could be

related to the higher hydrogen peroxide concentration in the in-office vital bleaching system.

Charakorn *et al*, 2009 compared the effect of using analgesics (Ibuprofen 600 mg) in a single dose 30 minutes before the in- office bleaching treatment to a placebo group and found that the use of the analgesics prior to the bleaching treatment significantly lowered the sensitivity scores immediately after bleaching but not after one hour or twenty four hours after the bleaching treatment.

6.5- Patients' colour perception

The mean value of the patients' colour perception was found to be 2.14 immediately after bleaching on a 3 point visual analog scale (Graph 5.6), where 1 represented no change, 2 a slight change but more bleaching was still needed and 3 represented a major change.

Immediately after bleaching; 77.3% of the patients felt a slight change but they still thought that more bleaching was needed, 18.2% of the patients were satisfied and they noticed a major change in their teeth due to the bleaching effect. However 4.5% reported no change in their tooth colour due to the bleaching process.

After one week of the bleaching process 72.7% of the patients felt a slight change but they still thought that more bleaching was needed, 18.2% of the patients were satisfied and reported a major change in the colour of their teeth due to the bleaching effect. However 9.1% reported no change in the colour of their teeth.

After one month of the in-office vital bleaching 68.2% of the patients felt a slight change but they still thought that more bleaching was needed, 13.6% of the patients were satisfied and they reported a major change in the colour of their teeth due to the bleaching effect. However 18.2% of the patients reported no change in the colour of their teeth.

A Spearman correlation test was conducted to correlate the values of colour change ΔE (Table 5.13), the patients' own colour perception (Table 5.14) and

between ΔE colour change values and the patients' colour perception (Table 5.15).

The test showed a positive relationship between ΔE values immediately and one week after bleaching. Values were more after bleaching than that after one week and most of the values lie below the quality line (Graph 5.7). Moreover, there was a weak relation one week and one month after bleaching (Table 5.13).

There was significant consistency in the patients' colour perception data immediately and one week after the bleaching (Table 5.14). There were 15 patients that reported a slight change but more bleaching was still needed (score 2) (Table 5.16) immediately after bleaching; however the same patients reported the same colour perception one week after bleaching (Table 5.17).

When ΔE values are compared to the patients' colour perception data, a weak relationship between ΔE values and the patients' colour perception one month after the bleaching is evident (Table 5.15).

In 2005, Auschill *et al* reported patients' acceptance with a mean value of 3.31 when evaluated by a visual analog scale from 0 – 10 where 0 represented best acceptance and 10 represented no acceptance.

In 2003, Al Shethri *et* al suggested a second in-office treatment for a more whitening effect, while a single treatment did not give the required bleaching effect. Similar findings were reported by Marson *et al* (2008) when they conducted two sessions of in-office vital bleaching in a one-week period and used a four point analog scale (None- Slight- Moderate- A lot) and found that 92.5% of patients reported "moderate" and "a lot" one week after the bleaching procedure using a 35% hydrogen peroxide concentration and 94% of the patients recommended in-office vital bleaching to others

CHAPTER SEVEN

LIMITATIONS OF THE STUDY

This clinical study attempted to control most of the variables that could interfere with the study results, however there were certain limitations which include:

- The small sample size.
- The sample was not randomly selected, patients asked for their teeth to be bleached.
- The follow up period was four weeks after bleaching which was relatively short.
- The negative behavior by the patients in the pool which could affect the colour stability after the bleaching procedure such as smoking, tannin rich food (red wine) could not be monitored.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1- Conclusions

This clinical study evaluated Yotuel® Special, Biocosmetics Laboratories, (Spain) an in-office bleaching material containing 35% hydrogen peroxide. This material was able to bleach patients' teeth with perceptive colour change noticeable by the patients. However the chalky white teeth were not obtained for all the patients in the study.

The first null hypothesis was rejected because the results showed statistically significant differences in the L*, a* b* values before and after bleaching.
The change in colour shade was significant for the whole study period, however colour regression was evident quantitatively from the first week.

The second null hypothesis was also rejected since tooth sensitivity although in only a limited number of patients and of a temporary nature was present as a side effect and could be traced until the fifth day after bleaching.

8.2- Recommendation

A second in-office treatment after one week might give the patients the chalky whitening effect they desire. However it will be important to monitor the rebound effect after repeated bleaching procedures.

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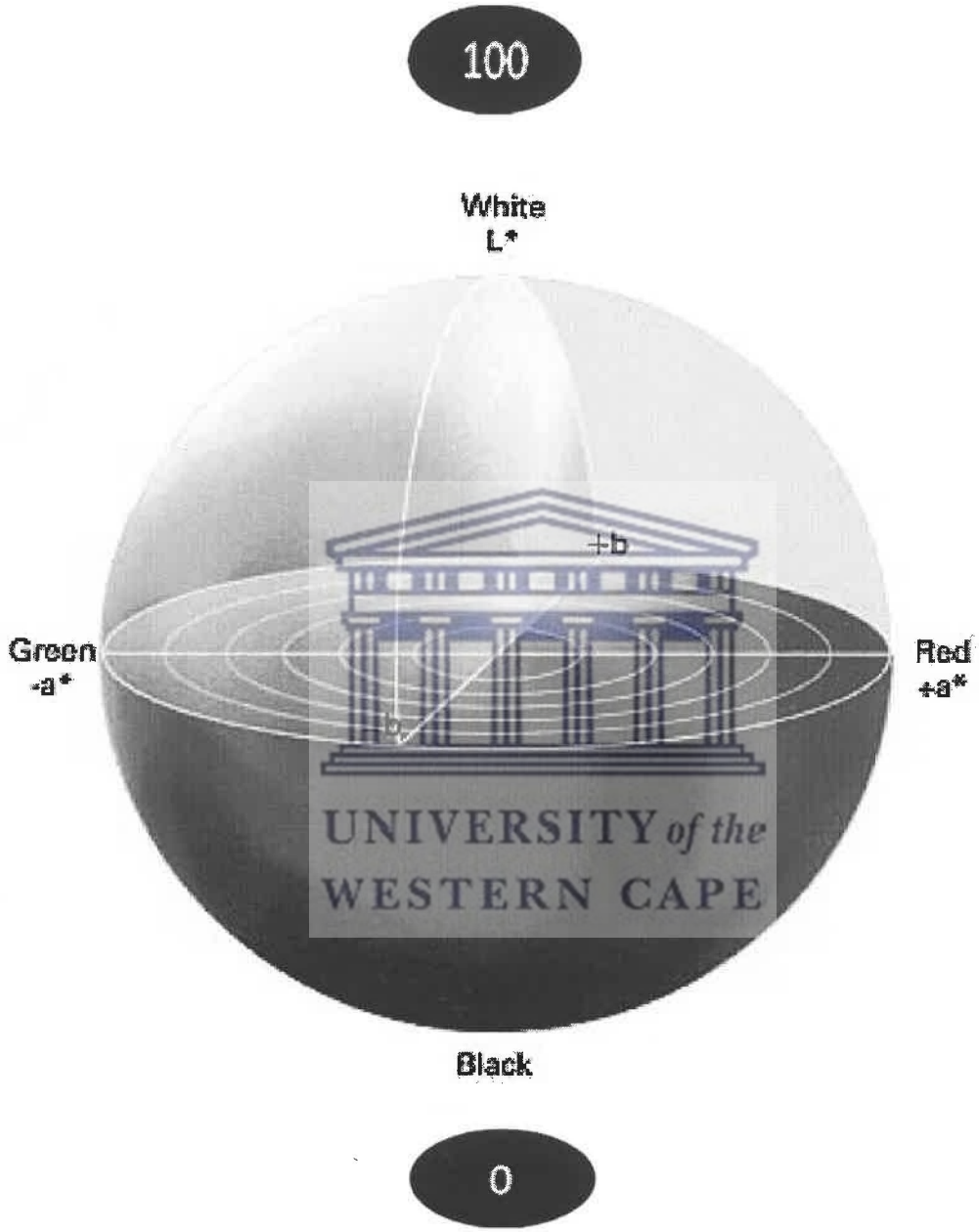
APPENDIX-I



Three dimensional colour space (L*a*b*)

APPENDIX-II

TEETH WHITENING CONSENT FORM

Oral & Dental Research Institute

Faculty of Dentistry & WHO Oral Health Collaborating Centre

University of the Western Cape

Teeth whitening techniques are designed to lighten stained, darkened or discoloured teeth.

Scientific literature has shown that the materials used in the whitening process are safe and effective. However, there are some presently known side effects. Tooth sensitivity is the most common side effect. Soft tissue (gums, lips, cheek, and tongue) irritation can also occur. If you experience these or another adverse effect, call Dr Salem for instructions.

I understand that the amount of whitening achieved and the duration of its effect will vary. Significant whitening can be achieved in most cases but there is no absolute way to predict how light your teeth will become. Teeth with multiple colourations, spots, bands due to tetracycline staining or fluorosis do not whiten as well and may appear more spotted after treatment. However, these effects are generally shorter in duration.

I also understand that whitening treatments are not intended to lighten artificial teeth, crowns, veneers or porcelain, composite or other restorative materials.

All personal information I disclose to Dr Salem will be considered strictly confidential. Only information relevant to the results of the study will be published.

My participation in the project is voluntary and I have been informed that I can withdraw from the study at any moment, without any explanation. My withdrawal from this project will have no negative impact on any current or future treatment at this or any other institution.

I have read and understand the above description of possible consequences of whitening techniques. I read and understand English. I have asked Dr Salem any questions I have concerning this procedure and the consent form and they have been answered to my satisfaction.

Consent is also hereby given for photographs to be taken. I understand that they may be used for documentation, illustration or for educational purposes.

Date: _____ Participant's Name: _____

Signature of Participant: _____

Witness: _____ Dr Y Salem: _____

APPENDIX-III

Tooth sensitivity form:

Sensitivity / Day	No sensitivity	Mild	Moderate	Severe
Day 1				
Day 2				
Day 3				
Day 4				
Day 5				
Day 6				
Day 7				

Please put (x) mark next to what you experience after bleaching

Mild sensitivity: slight no interference with function, well-tolerated.
Moderate sensitivity: some interference with function, necessity of avoiding certain foods.
Severe sensitivity: major interference with function, cannot be tolerated.

APPENDIX-IV

Patients' perception to colour change

change	No change	Slight change but still more bleaching is needed	major colour change
Immediately after bleaching			
One week			
One month			

APPENDIX-V

L*, a*, b* average data before and after scaling and polishing

Id#	Gender	Average b4 S-P L*	Average b4 S-P a*	Average b4 S-P b*	Average After S-P L*	Average After S-P a*	Average After S-P b*
1	M	60.68	0.13	4.23	61.47	-0.39	1.16
2	F	65.63	0.01	4.92	66.68	-0.24	3.88
3	F	61.39	0.52	5.92	63.34	0.68	5.33
4	F	60.37	-0.11	8.04	64.36	-0.23	6.15
5	F	62.37	-0.11	8.59	62.44	0.00	8.49
6	M	64.61	0.60	8.51	64.84	0.09	7.50
7	M	58.78	-0.24	7.33	58.77	-0.40	6.89
8	M	58.54	0.41	6.95	60.89	0.61	6.61
9	M	64.45	-0.52	7.57	65.82	-0.59	6.29
10	F	65.13	-0.02	6.47	65.69	-0.43	5.20
11	M	63.54	-0.20	6.04	63.47	-0.17	5.75
12	M	59.59	0.15	7.24	63.17	0.19	5.83
13	M	63.75	-0.08	6.30	64.50	-0.32	3.99
14	M	65.74	0.26	7.77	66.81	-0.03	6.15
15	F	67.69	-0.79	3.02	70.75	-0.85	2.19
16	F	58.07	0.22	8.08	58.54	0.21	8.24
17	F	60.46	1.22	8.91	61.42	1.08	8.69
18	F	65.00	-0.43	5.81	65.67	-0.40	5.54
19	M	57.43	0.86	6.80	56.02	0.89	7.60
20	F	58.96	0.73	6.76	59.94	0.60	7.85
21	F	54.91	1.95	11.36	56.47	1.72	10.15
22	M	61.59	0.04	4.85	61.05	-0.05	4.72

APPENDIX-VI

L*, a*, b* average data before bleaching and immediately after bleaching

Id#	Gender	Average B4 BLCH L*	Average B4 BLCH a*	Average B4 BLCH b*	Average POST BLC L*	Average POST BLC a*	Average POST BLC b*
1	M	63.08	-0.35	1.64	66.22	-0.70	0.07
2	F	67.00	-0.28	3.14	72.11	-0.68	1.56
3	F	60.68	1.09	6.20	63.30	0.64	5.11
4	F	63.24	0.06	7.34	63.90	-0.41	5.55
5	F	62.16	0.18	9.64	65.11	0.17	8.91
6	M	63.81	0.70	8.49	65.97	-0.18	5.50
7	M	59.10	-0.34	7.26	60.93	-0.29	7.00
8	M	60.54	0.70	6.86	63.86	0.46	5.49
9	M	63.92	-0.34	6.90	67.78	-0.52	5.48
10	F	65.87	-0.19	6.35	69.34	-0.39	4.24
11	M	63.02	-0.06	6.09	68.19	-0.34	3.66
12	M	60.24	0.37	6.37	64.13	0.03	4.18
13	M	64.22	-0.26	4.32	68.34	-0.31	2.78
14	M	65.90	-0.16	6.82	67.15	-0.08	5.78
15	F	68.44	-0.73	4.35	71.42	-0.87	1.64
16	F	58.99	0.27	7.88	61.06	-0.24	7.85
17	F	61.18	0.85	8.71	64.43	0.57	7.20
18	F	64.36	-0.36	5.94	67.53	-0.63	5.12
19	M	57.56	0.77	6.77	58.60	0.79	7.13
20	F	58.53	0.69	6.62	61.05	0.52	7.49
21	F	53.56	2.17	12.58	57.62	2.42	12.54
22	M	61.22	0.09	5.30	64.31	-0.19	3.70

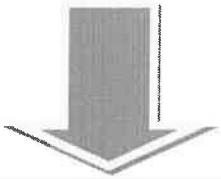
APPENDIX-VII

L*, a*, b* average data one week and one month after bleaching

Id#	Gender	Average 1 WEEK L*	Average 1 WEEK a*	Average 1 WEEK b*	Average 1 MONTH L*	Average 1 MONTH a*	Average 1MONTH b*
1	M	63.76	-0.69	0.95	63.56	-0.71	1.25
2	F	71.57	-0.74	1.86	71.08	-0.49	3.35
3	F	62.40	0.70	5.57	61.25	0.91	5.55
4	F	63.41	0.09	7.08	61.58	0.14	7.77
5	F						
6	M				64.24	0.02	6.34
7	M	60.66	-0.39	7.06	60.40	-0.39	7.43
8	M	62.57	0.46	6.38	62.51	0.29	5.81
9	M	66.31	-0.69	6.71	65.27	-0.38	7.03
10	F	66.77	-0.49	4.88	67.12	-0.58	5.32
11	M	66.50	-0.38	3.80	66.33	-0.29	3.77
12	M	64.45	-0.32	3.16	64.19	-0.14	5.94
13	M	67.24	-0.40	4.27	65.64	-0.44	4.81
14	M	66.45	-0.06	6.13	67.15	-0.44	4.87
15	F	69.59	-0.78	3.04	69.07	-0.75	2.91
16	F	61.08	-0.30	7.60	62.45	-0.21	8.06
17	F	61.93	0.94	8.35	62.42	0.89	7.95
18	F	65.97	-0.41	5.71	65.48	-0.53	5.90
19	M	58.77	0.56	6.68	55.97	0.38	7.06
20	F	61.87	0.71	6.57	55.06	1.26	8.41
21	F	54.62	1.61	10.85	57.26	1.91	11.20
22	M	63.72	0.15	4.85	61.47	0.06	5.40

APPENDIX-VIII

Conformation approach, data were sorted according to ΔE (before scaling and polishing and after scaling and polishing)



Id#	Gender	ΔE Before -After Scaling and polishing	ΔE Before bleaching - After Bleaching	ΔE Before bleaching-one week after Bleaching	ΔE Before bleaching-One month after bleaching
5	F	0.15	3.03		
11	M	0.31	5.72	4.18	4.04
7	M	0.47	1.85	1.57	1.31
16	F	0.50	2.13	2.18	3.49
22	M	0.57	3.49	2.54	0.27
18	F	0.72	3.28	1.62	1.13
17	F	0.99	3.60	0.84	1.46
6	M	1.15	3.79		2.30
10	F	1.45	4.07	1.75	1.66
20	F	1.48	2.67	3.35	3.95
2	F	1.50	5.37	4.76	4.09
19	M	1.62	1.10	1.23	1.67
9	M	1.88	4.12	2.43	1.37
14	M	1.96	1.62	0.88	2.33
21	F	1.98	4.07	2.11	3.96
3	F	2.04	2.87	1.87	0.88
8	M	2.39	3.59	2.10	2.26
13	M	2.44	4.40	3.02	1.51
15	F	3.18	4.03	1.74	1.57
1	M	3.21	3.53	1.03	0.71
12	M	3.84	4.47	5.33	4.00
4	F	4.41	1.96	0.31	1.71

Female

Male

APPENDIX-IX

Conformation approach, data were sorted according to ΔE (before bleaching and immediately after bleaching)

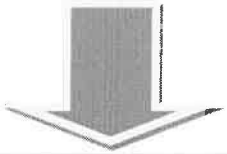
Id#	Gender	ΔE Before -After Scaling and polishing	ΔE Before bleaching -After Bleaching	ΔE Before bleaching-one week after Bleaching	ΔE Before bleaching-One month after bleaching
19	M	1.62	1.10	1.23	1.67
14	M	1.96	1.62	0.88	2.33
7	M	0.47	1.85	1.57	1.31
4	F	4.41	1.96	0.31	1.71
16	F	0.50	2.13	2.18	3.49
20	F	1.48	2.67	3.35	3.95
3	F	2.04	2.87	1.87	0.88
5	F	0.15	3.03		
18	F	0.72	3.28	1.62	1.13
22	M	0.57	3.49	2.54	0.27
1	M	3.21	3.53	1.03	0.71
8	M	2.39	3.59	2.10	2.26
17	F	0.99	3.60	0.84	1.46
6	M	1.15	3.79		2.30
15	F	3.18	4.03	1.74	1.57
21	F	1.98	4.07	2.11	3.96
10	F	1.45	4.07	1.75	1.66
9	M	1.88	4.12	2.43	1.37
13	M	2.44	4.40	3.02	1.51
12	M	3.84	4.47	5.33	4.00
2	F	1.50	5.37	4.76	4.09
11	M	0.31	5.72	4.18	4.04

Female

Male

APPENDIX-X

Conformation approach, data were sorted according to ΔE (before bleaching and one week after bleaching)



Id#	Gender	ΔE Before -After Scaling and polishing	ΔE Before bleaching -After Bleaching	ΔE Before bleaching- one week after Bleaching	ΔE Before bleaching-One month after bleaching
4	F	4.41	1.96	0.31	1.71
17	F	0.99	3.60	0.84	1.46
14	M	1.96	1.62	0.88	2.33
1	M	3.21	3.53	1.03	0.71
19	M	1.62	1.10	1.23	1.67
7	M	0.47	1.85	1.57	1.31
18	F	0.72	3.28	1.62	1.13
15	F	3.18	4.03	1.74	1.57
10	F	1.45	4.07	1.75	1.66
3	F	2.04	2.87	1.87	0.88
8	M	2.39	3.59	2.10	2.26
21	F	1.98	4.07	2.11	3.96
16	F	0.50	2.13	2.18	3.49
9	M	1.88	4.12	2.43	1.37
22	M	0.57	3.49	2.54	0.27
13	M	2.44	4.40	3.02	1.51
20	F	1.48	2.67	3.35	3.95
11	M	0.31	5.72	4.18	4.04
2	F	1.50	5.37	4.76	4.09
12	M	3.84	4.47	5.33	4.00
5	F	0.15	3.03		
6	M	1.15	3.79		2.30

Female

Male

APPENDIX-XI

Conformation approach, data were sorted according to ΔE (before bleaching and one month after bleaching)

Id#	Gender	ΔE Before -After Scaling and polishing	ΔE Before bleaching -After Bleaching	ΔE Before bleaching-one week after Bleaching	ΔE Before bleaching-One month after bleaching
22	M	0.57	3.49	2.54	0.27
1	M	3.21	3.53	1.03	0.71
3	F	2.04	2.87	1.87	0.88
18	F	0.72	3.28	1.62	1.13
7	M	0.47	1.85	1.57	1.31
9	M	1.88	4.12	2.43	1.37
17	F	0.99	3.60	0.84	1.46
13	M	2.44	4.40	3.02	1.51
15	F	3.18	4.03	1.74	1.57
10	F	1.45	4.07	1.75	1.66
19	M	1.62	1.10	1.23	1.67
4	F	4.41	1.96	0.31	1.71
8	M	2.39	3.59	2.10	2.26
6	M	1.15	3.79		2.30
14	M	1.96	1.62	0.88	2.33
16	F	0.50	2.13	2.18	3.49
20	F	1.48	2.67	3.35	3.95
21	F	1.98	4.07	2.11	3.96
12	M	3.84	4.47	5.33	4.00
11	M	0.31	5.72	4.18	4.04
2	F	1.50	5.37	4.76	4.09
5	F	0.15	3.03		

Female

Male

APPENDIX-XII

FLOWCHART