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*Research Article*

# The Effectiveness of tooth whitening products in the Maltese market: A Clinical Study

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**Abstract. Background:** Tooth whitening has gained popularity in recent years, with many products emerging on the market.
**Aim:** To assess the effectiveness of different tooth whitening products, highlight any undesirable effects of whitening on the oral soft tissues, and evaluate if tooth whitening can serve as a motivational tool for patients to improve their oral hygiene.
**Method:** 127 participants were invited to join the study and 77 were enrolled in the study according to the selection criteria. They were randomly divided into 8 groups, each group receiving a different tooth-bleaching product. Data collection was performed at 4 different time-points.
**Results:** 39% of participants were excluded due to suboptimal oral health, thus emphasizing the need for a routine check-up before treatment. Only professional tooth whitening provided by dental professionals showed significant tooth shade improvements (Kruskal–Wallis tests $p < 0.05$). Tooth whitening had no significant impact on oral soft tissues (Kruskal–Wallis test $p \geqslant 0.05$). Tooth whitening can serve as a motivating tool to improve patients' oral health.
**Conclusions:** Tooth whitening procedures should be carried out by dental professionals. Only non-over the counter (OTC) products showed significant colorimetric shade improvement. Whitening treatment had no significant impact on oral soft tissues. The achieved tooth whitening directly improved oral health.

**Keywords:** tooth whitening, tooth shade, oral health

## 1 Introduction

Society has moved into an era of high influence by media and all associated with aesthetics. The dental profession and manufacturing industry have not been immune to this shift with the dental patient as consumer directing the profession, the dental industry and dental literature. Dental cosmetic procedures have seen an increase over the past years together with the worth of the dental industry and an increasing commercial culture within dentistry (Doughty et al., 2016). Initially factors associated with the request for cosmetic procedures included female gender, young age, a lower level of education and social influence (Vallittu et al., 1996), however the ageing consumerist population is also presenting high aesthetic demands as a sign of 'successful aging' (Wulfman et al., 2010).

One such dental cosmetic procedure is that of tooth whitening. An increasing number of oral health care products now target tooth discoloration and the need for a whiter and brighter smile (Epple et al., 2019). Tooth discolorations are a result of light reflection or adsorption by tooth surfaces and may be classified as either intrinsic or extrinsic (Rodríguez-Martínez et al., 2019). Extrinsic discolorations are those due to direct or indirect staining by food products, tobacco or cetylpyridinium chloride products. Intrinsic stains are caused by metabolic disorders, medical treatments, inherited disorders, idiopatic disorders or as an effect of dental trauma. Idiopathic disorders such as molar incisor hypomineralisation are the reason for the requests for tooth whitening even by the paediatric/adolescent dental patient population. The American Academy of Pediatric Dentistry recognises this need and regulates the practice (American Academy of Pediatric Dentistry Council on Clinical, 2019). Such practice in persons under the age of 18 is however restricted in EU countries ("COUNCIL DIRECTIVE 2011/84/EU of 20 September 2011 amending Directive 76/768/EEC, concerning cosmetic products, for the purpose of adapting Annex III thereto to technical progress", 2011; Monteiro et al.,

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2019).

Tooth whitening systems are several and may be classified by various parameters including the whitening agent used, the method of application or the concentration of the oxidant agent. This study adopts the classification which defines the products as In-Office or At Home systems. The In-Office systems are those applied by dental health care professionals utilising higher concentrations of oxidant agent over a shorter period than At-Home systems. At-Home systems are further divided into those that are professionally supervised and those available as Over The Counter (OTC) products. The latter are freely available for purchase for use and potentially misuse by all ages. Due to the oxidative free radicals they contain, whitening products may have undesirable effects. These include tooth hypersentivity, root resorption, modificatons of surface morphology, gingival irritation and effects on restorative materials (Rodríguez-Martínez et al., 2019).

For countries belonging to the European Union the provision of whitening/bleaching products is regulated by directive 2011/84/EU ("COUNCIL DIRECTIVE 2011/84/EU of 20 September 2011 amending Directive 76/768/EEC, concerning cosmetic products, for the purpose of adapting Annex III thereto to technical progress", 2011). This states "that a maximum concentration of 0.1% of hydrogen peroxide present in oral products or released from other compounds or mixtures in those products is safe. It should therefore be possible to continue to use hydrogen peroxide in that concentration in oral products, including tooth whitening or bleaching products". Furthermore, "tooth whitening products containing or releasing between 0.1% and 6% hydrogen peroxide can only be sold to dental practitioners". Directive 2005/36/EC further defines a dental practitioner. Despite these regulations, studies have shown that select dental practitioners within the EU were unaware of these directives (52%), or unaware of the directives regulating their use in paediatric patients, or aware of the regulations but were still providing the treatment (Monteiro et al., 2019). A further cross-sectional survey of 179 dental practices and 76 beauty salons in the UK found that most were applying products containing a greater concentration of hydrogen peroxide permissible by current regulations (Doughty et al., 2016). This highlights that both oral health practitioners and the public may be misusing and abusing whitening products. This can be a concern especially in overzealous teenagers (Croll et al., 2014).

Reports of the clinical outcomes of the various whitening products on the market are divergent. Such conflicting reports may be due to differences in protocols, concentrations used (Rodríguez-Martínez et al., 2019) and lack of adherence to manufacturer instructions.

The aim of this study is to assess the clinical effectiveness of the various tooth-whitening products available locally, highlight any undesirable effects of whitening procedures on the oral soft tissues, and evaluate whether tooth whitening can serve as a motivational tool for patients to improve their oral hygiene. This information will serve as a guide to the general dental practitioner.

## 2 Materials and Methods

The prospective cohort study was carried out at the University of Malta, Faculty of Dental Surgery Teaching Clinic over a period of two months. Ethical approval for the research project was obtained (UREC-DP 1801010DSG).

### 2.1 Sample

Participation was voluntary following a social media posting and all eligible subjects were selected based on inclusion and exclusion criteria (table 1). Participants were randomly allocated to one of the eight 'Tooth Whitening Product' groups as outlined in table 2. This was carried out by a Senior Dental Nurse who was blinded to the type of treatment they were prescribed.

### 2.2 Study Design

All patients received a clinical examination. This included charting of the dentition according to the ICDAS (Gugnani et al., 2011; ICDAS, n.d.) a periodontal examination, and an examination of the mucosa, gingival tissue and gingival condition to assess for any lesions. The oral health profile was recorded utilising the following indices: Greene-Vermillion index for soft deposits - plaque index (Greene et al., 1964) and the Löe –Silness gingival index (H., 1967). Additionally, the patient's oral hygiene habits (brushing method, use of interdental brushes, type of toothpaste used) were recorded. Subsequently, subjects received prophylaxis to remove any staining and received oral health instructions. A pretreatment questionnaire was completed.

Impressions were taken for those patients allocated to the products requiring customised whitening trays for home use. Each whitening treatment was carried out according to the manufacturer's instructions. A one-use demonstration, following the manufacturer's directions, was given to the participants allocated the home kit. All participants received oral hygiene instructions and whitening maintenance advice based on the manufacturers' direction. The patients underwent tooth shade measurements using the VITA Easyshade® V digital spectrophotometer (VITA Zahnfabrik, Germany). The measurements were done on teeth (13) upper canine (coded 1), (11) upper first central incisor (coded 2) and (31) lower left central incisor (coded 3). The VITA Easyshade® device displays tooth shade measurement results in three different modes — The VITA

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| Adults ≤18 years of age | Medically compromised patients |
| Presence of 20 natural teeth — no prosthesis | Requiring dental treatment due to caries and poor oral hygiene |
| Willing to participate in post-whitening phase | Smoking Habits |
| Presence of all maxillary and mandibular teeth | Oral pathology requiring immediate care |
| No restorations on Anterior teeth | Previous stains due to Tetracycline |
| Absence of hypersensitivity | Pregnancy or lactating mother |

**Table 1:** Inclusion and Exclusion Criteria to participate in the study

| Group | No. of Participants | Intervention |
|---|---|---|
| Group 1 | 10 | Philips Zoom Speed In Office; 6% HP |
| Group 2 | 9 | Beyond Osmo In Office; 6% HP |
| Group 3 | 10 | Philips Zoom Home-kit (daywear); 6% HP |
| Group 4 | 9 | Beyond Corewhite Home-kit (daywear); 6% HP |
| Group 5 | 10 | Ultradent Opalescence PF Home-kit (night wear); 18% CP |
| Group 6 | 10 | Ultradent Opalescence GO Home-kit (day wear); 6% HP |
| Group 7 | 9 | PearlSmile Standard Treatment In Office; <0.1% HP |
| Group 8 | 10 | Pearl Light Home-Kit; <0.1% HP |

**Table 2:** Treatment Groups of Different Whitening agents

SYSTEM 3D-MASTER (29 shades) mode, the VITA classical A1–D4 (16 shades) tooth shade system, or as a Bleach Index. The numerical value output decreases as the tooth shade whitens.

Shade measurements were carried out 1 month before the treatment (T0), on the day of treatment after bleaching (T1), 2 weeks after the treatment (T2) and 1 month after the treatment (T3). Sequential shade readings were compared. The participants were asked to complete a post-treatment questionnaire. At the one-month visit (T3) measurements for the plaque index, gingival index and oral hygiene index were repeated. During this visit the oral mucosa and gingival tissue were examined.

### 2.3 Statistical Analyses

The results were tabulated and analysed with computer software (SPSS software IL, USA). Data derived from the history and examination of each patient were analysed per group, to assess the effectiveness of the product. The In-Office kits (Groups 1, 2, and 7) three shade readings (VITA SYSTEM 3D-MASTER, VITA classical and Bleach Index) and Home kit (Groups 3, 4, 5, 6, and 8) three shade readings were compared separately. Furthermore, all groups were then compared together. The Kruskal-Wallis H Test allowed between groups analysis of the non-parametric continuous scores derived from the various groups. In addition, analysis of before and after scores of oral hygiene indexes and oral mucosa data was carried out. Statistical significance was set at $p < 0.05$.

## 3 Results

One hundred twenty-seven subjects agreed to participate in the study. Following dental examination, 77 subjects (61%) were eligible for this study, based on the inclusion and exclusion criteria. Participants were excluded due to dental decay, suboptimal oral hygiene and the need for dental treatment necessary before tooth whitening procedures. The eligible participants in the study (44 females and 33 males) varied in age from 18 to 60+, however, 65% were between the ages of 18 and 25 years (table 3). 50% of participants had a graduate or higher level of education.

### 3.1 In-Office Kits

Table 4 shows the average change in tooth shade for the three teeth, each measured by the three shade readings off the VITA Easyshade® device for the three In-Office whitening products over four measurement episodes. Kruskall Wallis tests revealed statistically significant differences in shade changes across the three whiten-

| Age and Gender of Participants | | | | |
|---|---|---|---|---|
| | | Female | Male | Total |
| Age | 18 – 25 | 30 | 20 | 50 |
| | 26 – 35 | 10 | 10 | 20 |
| | 36 – 45 | 2 | 2 | 4 |
| | 46 – 60 | 1 | 1 | 2 |
| | 61 and over | 1 | 0 | 1 |
| | Total | 44 | 33 | 77 |

**Table 3:** Demographics of Participants

ing products, for the three teeth over time. The results showed that the Philips Zoom Speed system exhibited the best results over the period T0 to T3 on all the 3 teeth examined.

#### 3.1.1 Tooth 1

The best overall result for this system was a 5.1 shade advancement when measured by Vita 3D Master and Bleaching Score output on tooth 1 (T0–T3). A statistically significant difference was observed between Philips Zoom Speed System shade changes as compared to those achieved by the Pearl Smile Standard treatment at T2 (KW $p = 0.012$). Similar significant results were also recorded between Philips Zoom Speed system and Pearl Smile Standard treatment on tooth 1 at time T2 (KW, $p = 0.009$) and time T3 (KW, $p = 0.05$) when measured by the Classic Vita Shade.

#### 3.1.2 Tooth 2

Shade changes observed for tooth 2 by the three In-Office whitening systems at T1, T2 and T3 were not significantly different to each other when measured by the three shade guide systems.

#### 3.1.3 Tooth 3

Significantly different shade changes were however observed for Tooth 3 again between Philips Zoom Speed System and Pearl Smile Standard at T2 (KW, $p = 0.023$) and T3 (KW, $p = 0.050$) when measured using the Classic Vita shade system and also when using the Vita 3D Master Shade system at T2 (KW, $p = 0.009$) and T3 (KW, $p = 0.010$).

### 3.2 Home Kits

Table 5 shows the average change in tooth shade for the three teeth, each measured by the three shade readings off the VITA Easyshade® device for the three home-use whitening products over four measurement episodes. For the period T0 to T3, results varied from a 9.37 shade improvement score for Philips Zoom Home kit on tooth 1 when measured by the Vita 3D Master shade guide to the reading of −1.89 shade deterioration recorded for Pearl Light Home kit on tooth 1 when measured by Classic Vita shade guide. The greatest shade improvements occurred mostly in period T0 to T1, whereas the shades then deteriorated or remained the same in periods T1 to T2 and T2 to T3.

#### 3.2.1 Tooth 1

When measured using the Classic Vita shade, both Philips Zoom Home kit and the UltraDent Opalescence PF Home kit showed statistically significant differences in shade changes as compared to the Pearl Light Home kit both at T1 (KW, $p = 0.005$, $p = 0.003$, respectively) and at T2 (KW $p = 0.001$, $p = 0.001$, respectively) and at T3 (KW $p < 0.001$, KW $p < 0.001$, respectively). Beyond Corewhite Home Kit also reported significant shade differences to the Pearl Light Home kit at T3 (KW, $p = 0.034$).

Statistically significant differences in shade change were also reported between Philips Zoom Home kit and Pearl Light Home kit when measured using the 3D Master shade guide at T1 (KW, $p < 0.001$), T2 (KW, $p < 0.001$) and T3 (KW, $p < 0.001$). Similar results were observed between the Beyond Corewhite Home Kit and the Pearl Light Home kit at T1 (KW, $p < 0.001$), T2 (KW, $p < 0.001$) and T3 (KW, $p < 0.001$) and between the UltraDent Opalescence PF Home kit and the Pearl Light Home kit at T1 (KW, $p < 0.001$), T2 (KW, $p < 0.001$) and T3 (KW, $p < 0.001$).

Similar results were reported (KW, $p < 0.001$) for the products Philips Zoom Home kit, Beyond Corewhite Home Kit and UltraDent Opalescence PF Home kit when compared independently to the Pearl Light Home kit at T1 (KW, $p < 0.001$), T2 (KW, $p < 0.001$) and T3 (KW, $p < 0.001$) using the Bleaching Score output.

#### 3.2.2 Tooth 2

The upper central incisor (Tooth 2) showed statistically significant differences in shade changes when whitened

| In-Office Kits | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tooth Type | 1 | | | 2 | | | 3 | | |
| **Shade measurement system** | **Classic Vita shade guide** | **Vita 3D Master shade guide** | **Bleaching score** | **Classic Vita shade guide** | **Vita 3D Master shade guide** | **Bleaching score** | **Classic Vita shade guide** | **Vita 3D Master shade guide** | **Bleaching score** |
| Whitening Product | Philips Zoom Speed | Philips Zoom Speed | Philips Zoom Speed | Philips Zoom Speed | Philips Zoom Speed | Philips Zoom Speed | Philips Zoom Speed | Philips Zoom Speed | Philips Zoom Speed |
| T0 – T3 average shade improvement | 4.29 | 5.1 | 5.1 | 2.8 | 3.84 | 3.84 | 3.9 | 4.3 | 4.3 |
| Whitening Product | Beyond Osmo | Beyond Osmo | Beyond Osmo | Beyond Osmo | Beyond Osmo | Beyond Osmo | Beyond Osmo | Beyond Osmo | Beyond Osmo |
| T0 – T3 average shade improvement | 3.78 | 3.9 | 3.9 | 1.22 | 0.67 | 0.67 | 0.78 | 1.78 | 1.78 |
| Whitening Product | Pearl Smile | Pearl Smile | Pearl Smile | Pearl Smile | Pearl Smile | Pearl Smile | Pearl Smile | Pearl Smile | Pearl Smile |
| T0 – T3 average shade improvement | −0.7 | −0.45 | −0.45 | −0.11 | −0.22 | −0.22 | −0.22 | −0.89 | −0.89 |

**Table 4:** Difference in shade measurements obtained by the VITA Easyshade® device for the In-Office Kits

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| Home Kits | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tooth Type | 1 | | | 2 | | | 3 | | |
| **Shade measurement system** | **Classic Vita shade guide** | **Vita 3D Master shade guide** | **Bleaching score** | **Classic Vita shade guide** | **Vita 3D Master shade guide** | **Bleaching score** | **Classic Vita shade guide** | **Vita 3D Master shade guide** | **Bleaching score** |
| Whitening Product | Philips Zoom | Philips Zoom | Philips Zoom | Philips Zoom | Philips Zoom | Philips Zoom | Philips Zoom | Philips Zoom | Philips Zoom |
| T0 – T3 average shade improvement | 7.63 | 9.37 | 9.37 | 4.62 | 3.63 | 3.63 | 2.25 | 2.51 | 2.51 |
| Whitening Product | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF | Ultra Dent Opalescence PF |
| T0 – T3 average shade improvement | 7.57 | 8 | 8 | 7.57 | 2.87 | 2.87 | 4.29 | 3.5 | 3.5 |
| Whitening Product | Ultra Opalescence GO | Ultra Opalescence GO | Ultra Opalescence GO | Ultra Opalescence GO | Ultra Opalescence GO | Ultra Opalescence GO | Ultra Opalescence GO | Ultra Opalescence GO | Ultra Opalescence GO |
| T0 – T3 average shade improvement | 6 | 6.8 | 6.8 | 4.57 | 2.2 | 2.2 | 1.01 | 1.4 | 1.4 |
| Whitening Product | Beyond Corewhite Home kit | Beyond Corewhite Home kit | Beyond Corewhite Home kit | Beyond Corewhite Home kit | Beyond Corewhite Home kit | Beyond Corewhite Home kit | Beyond Corewhite Home kit | Beyond Corewhite Home kit | Beyond Corewhite Home kit |
| T0 – T3 average shade improvement | 5.78 | 7.44 | 7.44 | 4.11 | 5.44 | 5.44 | 2.78 | 5.11 | 5.11 |
| Whitening Product | Pearl Light | Pearl Light | Pearl Light | Pearl Light | Pearl Light | Pearl Light | Pearl Light | Pearl Light | Pearl Light |
| T0 – T3 average shade improvement | −1.89 | −0.55 | −0.55 | 0.67 | −0.55 | −0.55 | 0.67 | 0.22 | 0.22 |

**Table 5:** Difference in shade measurements obtained by the VITA Easyshade® device for the At-Home Kits

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using the Philips Zoom Home kit versus the Pearl Light Home kit at T1 (classic vita shade guide KW, $p = 0.011$, Vita 3D Master KW, $p = 0.001$; Bleaching score KW, $p = 0.001$) at T2 (classic vita shade guide KW, $p = 0.015$, Vita 3D Master KW, $p = 0.002$; Bleaching score KW, $p = 0.002$) and at T3 (classic vita shade guide KW, $p = 0.011$, Vita 3D Master KW, $p < 0.001$; Bleaching score KW, $p < 0.001$).

Similar results were observed between the products UltraDent Opalescence PF Home kit and the Pearl Light Home kit at T1 (classic vita shade guide KW, $p = 0.038$, Vita 3D Master KW, $p = 0.006$; Bleaching score KW, $p = 0.006$), T2 (classic vita shade guide KW, $p = 0.024$, Vita 3D Master KW, $p = 0.016$; Bleaching score KW, $p = 0.016$) and also at T3 (classic vita shade guide KW, $p = 0.018$, Vita 3D Master KW, $p = 0.004$; Bleaching score KW, $p = 0.004$).

There were no significant differences in shade changes between all the other home kit products for Tooth 2 when measured using the Classic Vita Shade guide at T1, T2 and T3.

The Vita 3D Master Shade Guide detected significant differences in shade changes for Tooth 2 between results observed for the Beyond Corewhite Home Kit and the Pearl Light Home kit at T1 (KW 0.018), T2 (KW $p = 0.017$) and T3 (KW $p = 0.006$) and between the Ultradent Opalescence GO Home-kit the Pearl Light Home kit only at point T3 (KW $p = 0.05$).

The Bleaching Score Guide results gave significant differences in shade changes for tooth 2 when whitened either using the Beyond Core white home kit or the Pearl Light Home kit at T1 (KW $p = 0.018$), T2 (KW $p = 0.017$) and T3 (KW $p = 0.006$) and between the Ultradent Opalescence GO Home-kit the Pearl Light Home kit only at point T3 (KW $p = 0.05$).

#### 3.2.3 Tooth 3

Tooth 3 showed significant changes in shade when measured using the Classic Vita shade for both the Philips Zoom Home kit and the UltraDent Opalescence PF Home kit as compared to the Pearl Light Home kit both at T1 (KW, $p = 0.036$, $p = 0.020$, respectively), at T2 (KW, $p = 0.025$, $p = 0.009$, respectively) and at T3 (KW, $p = 0.015$, $p = 0.05$, respectively). The Beyond Core white home kit and the Pearl Light Home kit only gave statistically significant different results at T2 (KW, $p = 0.034$) and T3 (KW, $p = 0.033$).

The Vita 3D Master Shade guide and the Bleaching Score guide results produced more statistically significant differences between product results for Tooth 3.

The Vita 3D Master Shade Guide Readings detected significant shade change readings between Philips Zoom Home kit and Pearl Light Home kit at T1 (KW, $p < 0.001$), T2 (KW, $p = 0.001$) and T3 (KW, $p < 0.002$). Significant changes were reported for differences between the Beyond Core white home kit or the Pearl Light Home kit at T1 (KW, $p = 0.001$), T2 (KW, $p < 0.001$) and T3 (KW, $p = 0.004$) and between the Ultradent Opalescence GO Home-kit the Pearl Light Home kit at T1 (KW, $p < 0.001$), T2 (KW, $p < 0.002$) and T3 (KW, $p = 0.002$). The Opalescence GO home kit only showed significant shade differences with those achieved by the Pearl Light Home kit at T1 (KW, $p = 0.032$) and at T2 (KW, $p < 0.0026$).

The Bleaching score guide detected the greatest number of significant colour changes between the products. The Philips Zoom Home kit, the Beyond Core white home kit, UltraDent Opalescence PF Home kit and the Ultradent Opalescence GO Home-kit all showed statistically better shade improvements than the Pearl Light Home kit at T1 (KW, $p < 0.001$, KW, $p < 0.001$, KW, KW $p < 0.001$, KW, $p = 0.032$ respectively) and at T2 (KW, $p = 0.001$, KW, $p < 0.001$, KW, $p = 0.002$, KW, $p = 0.026$ respectively). Only The Philips Zoom Home kit, the Beyond Core white home kit and the UltraDent Opalescence PF Home kit recorded significant improvements in shade over the Pearl Light Home kit at T3 (KW, $p = 0.002$, KW, $p = 0.004$, KW, KW, $p = 0.002$, respectively).

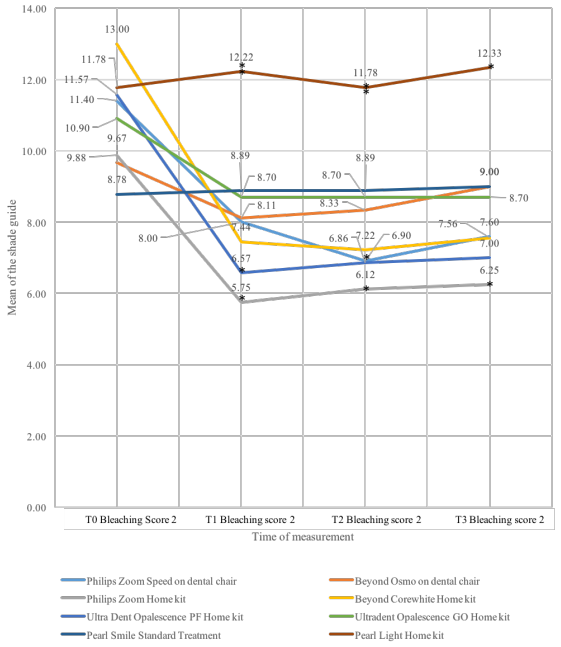
### 3.3 In-Office Kits versus Home Kits

Figure 1 depicts the results similarly obtained for Tooth 2 as recorded by the Bleaching Score Guide Output. Shade changes for this tooth were not as large as for Tooth 1. As illustrated the greatest colour change was that produced by Ultra Dent Opalescence PF Home kit and the Philips Zoom Home kit. These were however not found to be significantly different to that produced by the rest of the kits except for that produced by the Pearl Light Home Kit at T1 (KW, $p = 0.0021$, KW, $p = 0.002$, respectively). The Philips Zoom Home Kit persisted to be significantly better than the Pearl light Home kit both at T2 (KW, $p = 0.011$) and at T3 (KW, $p = 0.013$). It was however not found to be significantly better than the rest of the products.

The best result for the upper central incisor (T0 – T3 = 7.57) was that achieved by the Ultra Dent Opalescence PF Home kit as measured by both the Classic Vita Shade guide. A deterioration in shade of the upper central incisor was observed when using the Pearl Light Home Kit (T0 – T3 = −0.55), as measured by the Vita 3D Master shade guide and the Bleaching Score readings.

### 3.4 Debris and Gingival Indices

A significant improvement in patients' oral hygiene status was observed relative to outcome of the tooth whitening procedures. Patients who experienced improvement with tooth whitening also exhibited better oral hygiene as evidenced by a decrease in the debris




T1 Bleaching score 2: * Kruskal–Wallis Test: $p = 0.002$.
(Philips Zoom Home kit/Pearl light home kit)
T1 Bleaching score 2: * Kruskal–Wallis Test: $p = 0.021$.
(Ultra Dent Opalescence PF Home kit/ Pearl light home kit)
T2 Bleaching score 2: * Kruskal–Wallis Test: $p = 0.011$.
(Philips Zoom Home kit/Pearl light home kit)
T2 Bleaching score 2: * Kruskal–Wallis Test: $p = 0.031$.
(Philips Zoom speed on dental chair/Pearl light home kit)
T3 Bleaching score 2: * Kruskal–Wallis Test: $p = 0.013$.
(Philips Zoom Home kit/Pearl light home kit)

**Figure 1:** Plots of shade changes for all tooth-whitening systems on tooth 2 as measured by the Bleaching Score

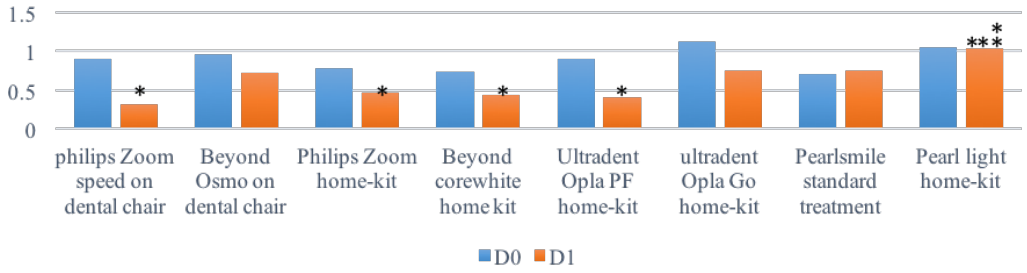
and gingival indices. Figures 2 and 3 illustrate the change in debris and gingival indices before and after treatment. None of the patients reported any major adverse soft tissue changes following whitening procedures. However, three patients, using Non-OTC home-kit products, reported minimal soft tissue changes. Clinical examination of these cases revealed minor gingival burns that healed uneventfully within 3 days.

## 4 Discussion

In this prospective clinical study, the effectiveness of different tooth whitening products, and their impact on soft oral tissues was investigated. The products included 3 In-Office treatments and 5 Home-Kits, one of which was an over the counter product (OTC). Moreover, the authors assessed objectively whether achieving tooth whitening can serve as a motivation for patients to improve their oral hygiene.

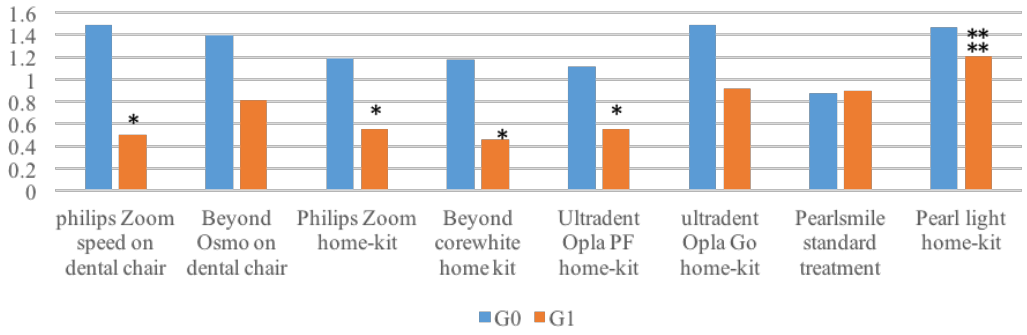
Sixty-five percent of the participants who approached this study for tooth whitening treatment were between the ages of 18–25 years. A further 26% fell within the 26-35 year old bracket. This was a slightly younger age cohort to a systematic review involving 649 patients with mean age of 36 years (Pontes et al., 2020). This could be due to this study being notified and held on a university campus and therefore attracted a younger cohort of people. Such treatment is however also becoming increasingly appealing to older age groups. Half of online respondents aged 55-65 interested in having their teeth bleached seek not only a functional but also a pleasing dentition (Wulfman et al., 2010). These could be potentially heavily restored dentitions in patients with multiple co-morbidities (Lewis, 2011) that need to be handled carefully by the trained dental professional.

One of the most important findings of this study was that roughly only half of the participants who volunteered were eligible for testing. Forty-nine percent (49%) of interested participants required dental treatment to optimise their oral health before undergoing whitening procedures. These participants were excluded from the study. This underscores a very important issue that tooth-whitening procedures should be carried out by properly qualified professionals who can diagnose oral health issues. Regrettably, OTC products are readily available online, in supermarkets, shopping mall kiosks and pharmacies away from professional supervision, beyond registered dental clinics. Such products come in the form of mouth rinses, toothpastes, strips, paint on gels, floss and tray-based tooth whiteners with many such products having no scientific studies to support them, are very often ineffective and fall into a grey zone within no regulation. Patients might not be aware of ongoing oral health issues and failure to interact with a dental professional may allow oral patho-




* Kruskal-Wallis Test: $p = 0.000$. (Philips Zoom speed on dental chair/Pearl light home kit)
* Kruskal-Wallis Test: $p = 0.014$. (Philips Zoom home kit/Pearl light home kit)
* Kruskal-Wallis Test: $p = 0.006$. (Ultra Dent Opalescence PF Home kit/ Pearl light home kit)
* Kruskal-Wallis Test: $p = 0.006$. (Beyond core white home kit/Pearl light home kit)

**Figure 2:** Debris Index Changes before and after treatment per product




* Kruskal-Wallis Test: $p = 0.000$. (Philips Zoom speed on dental chair/Pearl light home kit)
* Kruskal-Wallis Test: $p = 0.002$. (Philips Zoom home kit/Pearl light home kit)
* Kruskal-Wallis Test: $p = 0.004$. (Ultra Dent Opalescence PF Home kit/ Pearl light home kit)
* Kruskal-Wallis Test: $p = 0.000$. (Beyond core white home kit/Pearl light home kit)

**Figure 3:** Gingival Index Changes before and after treatment per product

logy to go unnoticed and preclude timely dental treatment. Furthermore what has been termed as 'bleachorexia' has been documented where in conditions similar to body dismorphic disorder, patients misuse and abuse such products away from professional care, causing tooth erosion, extreme sensitivity and gingival irritations (Demarco et al., 2009).

In this study, the bleaching effects of three In-Office kits (Philips Zoom Speed In Office, Beyond Osmo In Office, PearlSmile Standard Treatment In Office) and five Home kits (Philips Zoom Home-kit (daywear), Beyond Corewhite Home-kit (daywear); Ultradent Opalescence PF Home-kit (night wear), Ultradent Opalescence GO Home-kit (day wear), Pearl Light Home-Kit) were compared using three shade readings (VITA SYSTEM 3D-MASTER, VITA classical and Bleach Index) on three teeth using the The VITA Easyshade® device in vivo.

A number of methods are available for measuring the colour of teeth and the colour changes undergone during tooth whitening procedures. One of the most common methods is the simultaneous comparison of the tooth with a standard shade guide. This is however, a subjective method and a number of factors can influence this process. These may include lighting conditions, experience, age, fatigue of the human eye, make-up, room decor and colour blindness (Joiner, 2006b). Alternative methods include the use of instrumental measurements using spectrophotometry, chromameters and digital image analysis. This study utilised instrumental measurements by using a digital imaging device - VITA Easyshade® V digital spectrophotometer (VITA Zahnfabrik, Germany). This allowed standardised measurements to be repeatedly taken over time and changes in shade to be recorded numerically allowing for statistical analysis.

The Pearl Smile Standard Treatment (< 0.1% HP) and Pearl Light Home kit (< 0.1% HP) produced very little change in tooth shade throughout the study period. Some data displayed minimal improvement while most read a final darker shade to that present initially. These findings are in accordance with previous published literature which states that there is a tendency to reversion to a darker shade with time (Al-Tarakemah et al., 2016); the lighter the initial presenting shade, the greater the risk for a worse outcome. Al-Tarakemah et al. (2016), suggest that reversion to darker tooth shade is caused by the substantial enamel matrix breakdown by the bleaching agent allowing for an increased permeability and therefore diffusion of dietary derived colorants into the enamel. This study observed that (Figure 1) for kits such as In Office Philips Zoom Speed, Beyond Core White Home Kit and Ultradent Opalescence GO Home kit and Beyond Osmo, Ultra Dent Opalescence PF Home kit and Philips Zoom Home kit, there was some regression of tooth colour from time T1 to T3 but however still showed an improvement over the shade recorded initially at T0. Azer et al. (2011) explain how an increased surface roughness caused by the bleaching agent allows subsurface penetration of dietary derived colourants producing extrinsic stain. Such highly pigmented foodstuffs include black tea and red wine (Azer et al., 2011). However a double blind randomized clinical trial of at home tooth bleaching systems with a 6 month recall reported that high consumption of staining beverages and foods did not affect longevity of whitening effect (Meireles et al., 2008). Outcome is not affected by gender, but seems to be influenced by the nature of the intrinsic stain, initial tooth colour and age (Joiner, 2006a).

This study reported that apart from The Pearl Smile Standard treatment and the Pearl Light home kits, there were no significant differences in bleaching results achieved when comparing all In-Office and all Home kits to each other. The best overall result achieved was that for tooth 1 using the Philips Zoom Home kit.

In-Office tooth bleaching is done under direct supervision of a dentist ensuring protection of gingival tissues and requiring minimal dependence on patient compliance, allows for proper treatment planning prior to treatment, is carried out in a short period of time and gives immediate results, albeit using higher concentration of product. On the other hand, this treatment option is costlier to the patient and requires more chair time. Additionally, some products require further at – home applications and tend to produce more hypersensitivity (Rodríguez-Martínez et al., 2019). In this study, the Philips Zoom Speed system exhibited the best results over the period T0 to T3 on all the 3 teeth examined.

Home Kits are divided into those that are professionally supervised and the OTC products. The professionally supervised products require the fabrication of custom bleaching trays however require much reduced office chair time. These products require greater patient commitment to follow instructions carefully and longer treatment time to achieve results. Research shows that a whitening endpoint is usually reached at 6 weeks independent of concentration and type of peroxide used (Matis et al., 2000). This study followed up participants for 4 weeks. This study noted the greatest improvement in shade at initial application (T1), with very little change observed from periods T1 to T2 and T2 to T3. Purely OTC systems are widely used, are entirely patient controlled may be used indiscriminately or inappropriately without prior diagnosis of tooth discolouration. The dental professional may not be aware of the use of such products by the patient who does not disclose such information. This is critical as research shows

that bleaching agents affect shear bond strength of resin composite to acid-etched enamel when composite resin restorations are placed soon after bleaching (Khamverdi et al., 2016). OTC products do require a longer time to achieve results due to their lower hydrogen peroxide concentration however; this may be a factor patients accept, as the systems are inexpensive. This study reports the greatest shade improvement observed by Philips Zoom Home kit on tooth 1 when measured by the Vita 3D Master shade guide.

Upon comparing all In-Office to all At Home kits this study reports that apart from the Pearl Smile Standard treatment and the Pearl light Home Kit, there was no statistically significant difference reported between the results obtained by all the rest of the products. Additionally, the greatest shade improvement (T0 – T3 = 9.37) for tooth 1 was that obtained by the Philips Zoom Home Kit. This study therefore concludes that professional tooth whitening Home-Kits were more effective than In-Office systems. These findings correlate with published literature that states that ultimately the two key factors that determine whitening efficacy are the concentration of the oxidizing agent and the duration of application (Joiner, 2006b). Bleaching efficacy is found to be greater for higher concentration products however, upon extending treatment time, the differences in tooth lightness were no longer of statistical significance (Leonard et al., 1998; Matis et al., 2000). This may be of clinical relevance if one is to consider that higher concentrations of product increase the possibility of alterations in enamel surface morphology and hardness values together with soft tissue burns (Rodríguez-Martínez et al., 2019).

The debris and gingival indices results showed significant improvements in patients' oral hygiene, associated with a positive tooth whitening experience. Participants exhibiting positive tooth whitening improved their oral hygiene from fair-to-poor to good-to-fair oral hygiene levels as evident by a decrease in debris and gingival indices. However, this improvement could also be attributed to the peroxide itself which is antimicrobial and thus may have a cleansing effect on the mouth (Nuss, 2004). Furthermore, it was noted that many participants requested oral hygiene advice during the final visit. The same oral hygiene advice was given before the treatment and after the treatment. Study participants who did not achieve the desired whitening results had a minimal increase in the debris index while their gingival index decreased slightly. This can be a result of participants being made more aware of their aesthetic look upon visualising the change in shade thereby increasing their motivation towards their oral hygiene habits and maintaining the results obtained. Additionally, when all non-OTC products were compared to OTC products, statistical significance was observed in terms of debris and gingival indices reduction.

Gingival irritation is one of the most common side effects of tooth bleaching (Majeed et al., 2015). This was observed in three participants using non-OTC home kits. This can be due to excessive application of whitening gel, an ill-fitting tray or improper use of the home kit in breach of the manufacturer's guidelines. Home kits caused minimal gingival burns in five patients, one of which dropped out of the study due to the pain. This is one of the most common side effects. However, these adverse effects did not last longer than 3 days, and they did not reappear within the period of one month. Long-lasting adverse effects could be avoided or reduced by using low concentrations of hydrogen peroxide, which is the causative agent for these events. OTC products showed no undesirable side effects on soft oral tissues. HP is a caustic substance and can cause burns of the gingival or mucosal tissue. Rubber dam or light-cured resin, provided by the manufacturer, should always be used to protect the soft tissues during In-Office bleaching procedures (Majeed et al., 2015).

## 5 Conclusion

The mechanism of tooth whitening and the processes involved in the tooth sensitivity that may ensue are not yet fully understood (Rodríguez-Martínez et al., 2019). Additionally, new products are constantly emerging on the market and the provision of tooth whitening services by non-dental professionals if of concern. This study highlights that the use of bleaching agents may be effective and of value in carefully selected cases and that all products are not to be used indiscriminately. Dental practitioners are to help patients make informed decisions after considering all factors involved and providing professional advice and realistic expectations.

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