

# Bleaching Procedures

# 6

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## 6.1 Tooth Discoloration Etiology

The color of teeth is determined by a combination of intrinsic color and the presence of any extrinsic colored stain that may form on the tooth surface. The tooth discoloration can be classified according to the origin of stain in intrinsic, extrinsic, or internalized discoloration [1].

Intrinsic tooth color is associated with the light energy interaction with the dental tissues such as reflection, transmission, scattering, and absorption optical phenomena [2]. The enamel is a highly mineralized tissue (about 97%) mainly constituted of colorless hydroxyapatite crystals in needles-shape that form a complex, hierarchical, and organized microstructure. The enamel has a slight white color and higher translucency. The dentin is a protein-rich bone-like biocomposite tissue containing a mineral phase (about 70%) mainly constituted by hydroxyapatite, an organic phase mainly constituted by collagen and water. Its hue varies among yellow, orange, and brown shades with low translucency.

The intrinsic tooth discoloration occurs following a change in tooth structural composition or thickness of the hard dental tissues, altering the light-transmitting properties of tooth structure. The intrinsic tooth discoloration may be related to factors that occur prior to tooth eruption

during tooth development as metabolic disorders of *Alkaptonuria*, *congenital erythropoietic porphyria*, *congenital hyperbilirubinemia*, *amelogenesis imperfecta*, *dentinogenesis imperfecta*, molar incisor hypomineralization, other systemic syndromes, and to inherited disorders which involve only the hard tissue forming at the time as tetracycline staining, fluorosis, enamel hypoplasia [2] (Figs. 6.1, 6.2, 6.3, 6.4, 6.5 and 6.6).

However, intrinsic tooth staining can also occur after tooth eruption. First, it is related to physiological aging, which increases tooth color darkness. Due to continuous chemical and mechanical wear of enamel through age, that becomes thinner and more translucent, i.e., the dentin will become more visible. Furthermore, the darkness of tooth color intensifies due to the physiological laying down of secondary dentin,



**Fig. 6.1** Intrinsic tooth discoloration related to inherited disorders that occur prior to tooth eruption: Amelogenesis imperfecta (Photography courtesy of Dr. Dayane Oliveira et al.)

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**Fig. 6.2** Intrinsic tooth discoloration related to inherited disorders that occur prior to tooth eruption: mild tetracycline staining



**Fig. 6.3** Intrinsic tooth discoloration related to inherited disorders that occur prior to tooth eruption: severe tetracycline staining



**Fig. 6.4** Intrinsic tooth discoloration related to inherited disorders that occur prior to tooth eruption: mild fluorosis staining



**Fig. 6.5** Intrinsic tooth discoloration related to inherited disorders that occur prior to tooth eruption: moderate fluorosis staining

which lead to increased chroma and decreased value of dentin shade [3]. Some inherited disorders that occur after tooth eruption can also lead to intrinsic staining (Figs. 6.7, 6.8, 6.9 and 6.10) as pulpal hemorrhagic products following dental trauma, pulp necrosis, or root resorption [1].

Extrinsic color is associated with the absorption of darker or high-colored compounds,



**Fig. 6.6** Intrinsic tooth discoloration related to inherited disorders that occur prior to tooth eruption: severe fluorosis staining



**Fig. 6.7** Intrinsic tooth discoloration related to inherited disorders that occur prior to tooth eruption: molar incisor hypomineralization



**Fig. 6.8** Intrinsic tooth discoloration related to inherited disorders that occur after to tooth eruption: element 11 with history of dental trauma leading to pulp chamber obliteration and darkening aspect



**Fig. 6.9** Intrinsic tooth discoloration related to inherited disorders that occur after to tooth eruption: element 25 with pulp necrosis which leads to a gray staining



**Fig. 6.12** Extrinsic tooth discoloration related to deposition of chromogens onto the dental surface



**Fig. 6.10** Intrinsic tooth discoloration related to inherited disorders that occur after to tooth eruption: element 11 with history of dental trauma. Situation after 5 years of endodontic treatment and patient's report of progressively darkening intensification. Brownish staining due pulp hemorrhagic products oxidation



**Fig. 6.13** Internalized discoloration related to extrinsic stain incorporation within the tooth structure due enamel porous surface by dental caries



**Fig. 6.11** Extrinsic tooth discoloration related to deposition of chromogens onto the dental surface

named chromogens by the pellicle coating (a salivary protein film) and to their deposition onto the enamel surface (Figs. 6.11 and 6.12). There are two different chromogen types: (1) large organic molecules that have conjugated double bonds in their chemical structure and (2)

metal-containing molecules. The dental extrinsic staining is influenced by inadequate tooth brushing, dietary intake of colored food and solutions (e.g., coffee, tea, cola soda, and red wine), exposure to nicotine and other tobacco products, and use of cationic agents such chlorhexidine and metal salts (e.g. tin and iron) [1]. Inorganic chromophores are colored transition metal ions of iron, copper, manganese, or tin. In the form of metal complexes, organic and inorganic chromophores may also be present in combination, e.g., in hemoglobin, where a colored porphyrin ligand is combined with a colored iron [4].

The internalized discoloration is the extrinsic stain incorporation within the tooth structure, mainly those associated with dietary and tobacco products chromogens. It becomes more evident in enamel defects (i.e., fluorosis, dental caries, and enamel cracks, hypoplasia, and hypocalcification) and in the porous surface of exposed dentin [5–7] (Fig. 6.13).



**Fig. 6.14** Intrinsic tooth discoloration related to inherited disorders that occur after tooth eruption: element 11 with history of dental trauma. Situation after 3 years of endodontic treatment and patient's report of progressively darkening intensification. Yellowish/orangewish staining due endodontic products oxidation

Some restorative materials may have an effect on tooth color, as some used for root canal treatment as eugenol, phenolic compounds, and poly-antibiotic pastes, which contain pigments that lead to dentin discoloration (Fig. 6.14). Some amalgam alloys may lead to dark grey discoloration of dentin due to tin and mercury penetration in dentinal tubules [8].

## 6.2 Tooth Whitening Techniques

Tooth whitening can be described as any process that increases teeth lightness. It can be achieved by mechanical or chemical removal of darker or high-colored compounds which are accumulated on the surface or inside the dental tissues.

The extrinsic stain related to the acquired pellicle on the tooth surface can be removed by tooth brushing and flossing while those adhered to the enamel, i.e., dental calculus, by abrasive and polishing action of professional dental prophylaxis. The control of extrinsic stains formation can be made using daily dentifrice containing abrasive agents, which increases the stain cleaning, or/and chemical agents as phosphate salts and enzymes, which prevent their aggregation into the surface [9].

### 6.2.1 Bleaching Agents

Bleaching is defined as a discoloration process that can occur in a solution or surface. The dental

bleaching process may be defined as the chemical degradation of the enamel and dentin chromogens by reactive molecules as peroxides or sodium hypochlorite. Currently available peroxide-containing materials for tooth whitening include professionally dispensed products for supervised at-home use by patients, in-office products use by professionals, and over-the-counter products for sale directly to patients [10].

#### 6.2.1.1 Hydrogen Peroxide

In general, the bleaching mechanism with peroxides is considered to be oxidation, although the process is not well understood. *Hydrogen peroxide* is a highly reactive molecule with low molecular weight. It diffuses into and through the enamel to reach the enamel dentine junction and dentin regions, reacting with the organic molecules, oxidizing the double bonds in conjugated chains and cleaving them. The reaction process forms a number of different active oxygen species depending on conditions, including temperature, pH, light activation, and presence of transition metals [10, 11].

#### 6.2.1.2 Carbamide Peroxide

The *carbamide peroxide* is a chemical adduct of urea and hydrogen peroxide, which, when in contact with water or saliva, disassociates back into hydrogen peroxide and urea. A carbamide peroxide at 10% yields close to 3–3.6% of hydrogen peroxide and 6.4–7% of urea [10]. While hydrogen peroxide can be considered its active ingredient, urea may provide some beneficial side effects because it tends to raise the pH of the solution.

#### 6.2.1.3 Sodium Perborate

The *sodium perborate* is an oxidizing agent available as a powder. It is stable when dry, but it breaks down, which when in contact with water to form sodium metaborate, hydrogen peroxide, and nascent oxygen. Sodium perborate is easier to control, and it considers safer than concentrated hydrogen peroxide solutions [12].

#### 6.2.1.4 Alternative Molecules

The *sodium percarbonate* is an alternative hydrogen peroxide source. It is used in a silicone polymer containing paint-on gel that is applied onto

the tooth surface, forming a durable pellicle for overnight bleaching [13]. Alternative tooth bleaching molecules were proposed as *sodium chlorite*, *peroxymonosulphate*, *metal catalysts associated with peroxides* and *oxidoreductase enzymes*, but their efficacy and long-term acceptability require further investigations [10].

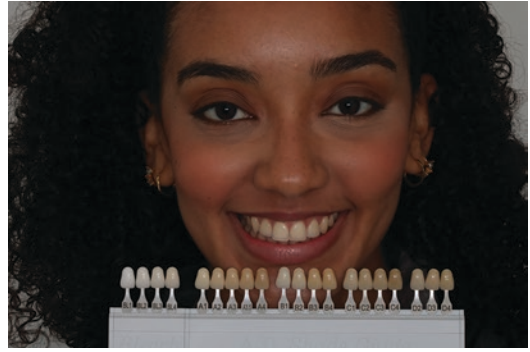
## 6.2.2 Vital Tooth Whitening

There are a number of methods and approaches that have been described in the literature for bleaching of vital teeth with variation in different agents, concentrations, times of applications, product formats, application modes, and light activation [11]. Vital teeth can be bleached at home using dentist-dispensed or over-the-counter products, and/or in the dental office by professional application products.

### 6.2.2.1 Dentist-Monitored At-Home Bleaching

The original concept of *at-home bleaching* was introduced in 1989 by Haywood and Heymann, also called *nightguard bleaching* [14]. It consists of 10% carbamide peroxide gel use in a customized tray for at least 2 weeks with the supervision and guidance of a dentist [14, 15]. Depending on the tooth darkness and staining type, results are generally seen 2–3 weeks, and the final outcome may be complete in 5–6 weeks. Later products have offered gel concentrations of 1–10% of hydrogen peroxide and 10–22% of carbamide peroxide.

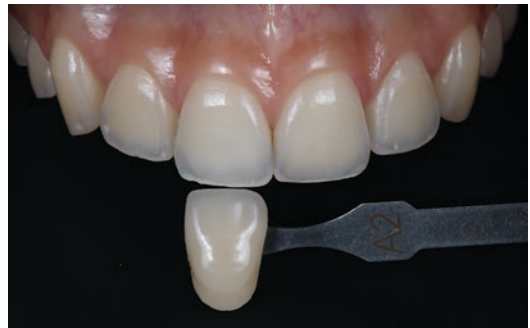
Individual custom-fitted bleaching trays can be made with 0.5–1.0 mm silicon sheets in a heat and vacuum tray-forming machine over plaster models. After cooling, the trays should be cut 2 mm above the gingival margins. Then, it should be tested in the mouth to check their adaption and if any sharp edges bother the tongue and cheeks. The dentist must demonstrate to the patient the application of the whitening gel on the internal facial surface of the tray. Patients should be advised to perform oral hygiene before the bleaching tray application (Figs. 6.15, 6.16, 6.17, 6.18, 6.19, 6.20, 6.21 and 6.22).



**Fig. 6.15** At-home bleaching: initial situation. Face photography



**Fig. 6.16** At-home bleaching: initial situation. Smile photography



**Fig. 6.17** At-home bleaching: initial situation. Intraoral photography

The vital teeth tooth whitening efficacy is determined mainly by the bleaching agent concentration and application period, among several other factors. Basically, the higher the concentration, the faster the whitening effect. However, low concentrations of hydrogen or carbamide



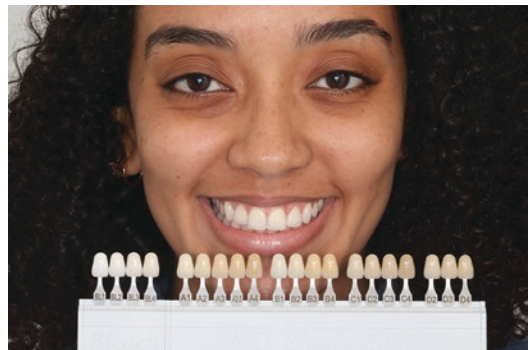
**Fig. 6.18** At-home bleaching: individual custom-fitted bleaching trays over plaster models



**Fig. 6.21** At-home bleaching: final situation. Smile photography



**Fig. 6.19** At-home bleaching: bleaching trays test to check their adaption and if any sharp edges bother the tongue and cheeks



**Fig. 6.22** At-home bleaching: final situation. Face photography



**Fig. 6.20** At-home bleaching: final situation. Intraoral photography

peroxides can lead to the same efficacy with an extension of the treatment period [16, 17]. Also, the type of intrinsic stain and initial tooth color plays a significant part in the tooth whitening outcome. The efficacy of the at-home bleaching technique has been demonstrated successful for approximately 91% of non-tetracycline staining teeth but less successful with tetracycline discol-

ored teeth. Tetracycline-stained teeth are the least responsive to bleaching; depending on the severity of the stain, mild to moderate stains tend to respond to extended bleaching regimes of 2–6 months, while severe stains are difficult to bleach. The darker the initial color, the longer the treatment time [18].

Adhering to a white diet during the process (e.g., avoid colorful food and beverages) of tooth whitening does not impair the esthetic outcome [19]. However, patients should be notified to avoid the consumption of citrus food or acidic drinks (due to their low pH) to decrease the risk of teeth hypersensitivity.

In some countries like in the USA, there are mass-market products directly available to the general public. These products contain low concentrations of peroxide agents (e.g., 3–6% hydrogen peroxide) that are self-applied to teeth in

different forms as gum shields, strips, and paint-on gels. Usually, it requires two daily applications by 2 weeks approximately [10, 13, 20].

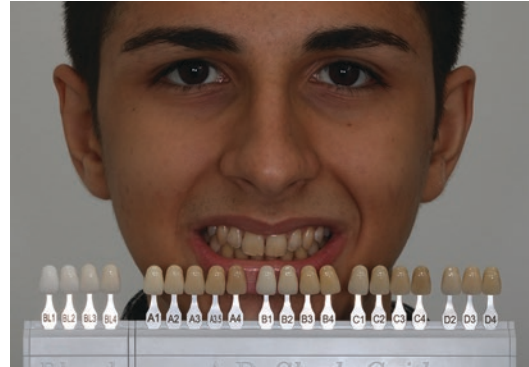
### 6.2.2.2 In-Office Bleaching of Vital Teeth

High concentrations of peroxide agents are used for professional in-office bleaching of vital teeth, also known as *power bleaching*. It can result in significant whitening after just one professional application, but it requires multiple appointments for optimum whitening results. For vital teeth, hydrogen peroxide at 25–35%, or carbamide peroxide at 35%, are used in short periods of time, between 20 and 40 min of application (Figs. 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29 and 6.30).

Before application of bleaching gel, the soft tissues should be protected. First, it should be selected an effective lip retractor that also protects the tongue and cheeks from contact with the bleaching gel. A sliced sucker or bite block can be used to restrain dental occlusion and retract the tongue if the lip retractor cannot promote this

(Figs. 6.31 and 6.32). Then, a gingival barrier must be applied on the gingival margins of the dental crowns and then photoactivated. Therefore, the bleaching agent should be applied to the teeth labial surface, according to the manufacturer's instructions.

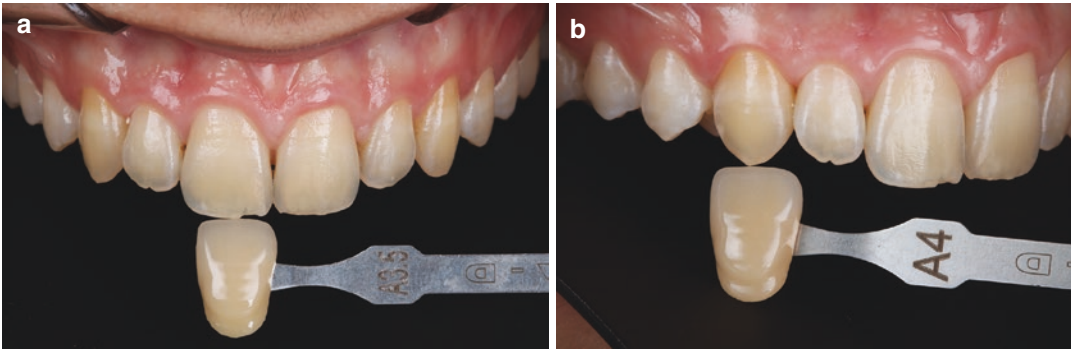
The bleaching gels may be further activated by light, despite the irrelevance of light activation in



**Fig. 6.23** In-office bleaching: initial situation. Face photography



**Fig. 6.24** In-office bleaching: initial situation. Smile photography—front (a), right (b), and left (c)



**Fig. 6.25** In-office bleaching: initial situation. Intraoral photography and color measurement for incisors (a) and canines (b)



**Fig. 6.26** In-office bleaching: soft tissues protection with tongue, cheeks, and lips retractor and gingival barrier application



**Fig. 6.28** In-office bleaching: bubble formation into the bleaching gel during bleaching reaction



**Fig. 6.27** In-office bleaching: application of in-office peroxide gel over teeth surface

the efficacy of tooth whitening. Also, the combination of in-office and at-home bleaching techniques can increase the rate of bleaching in shorter

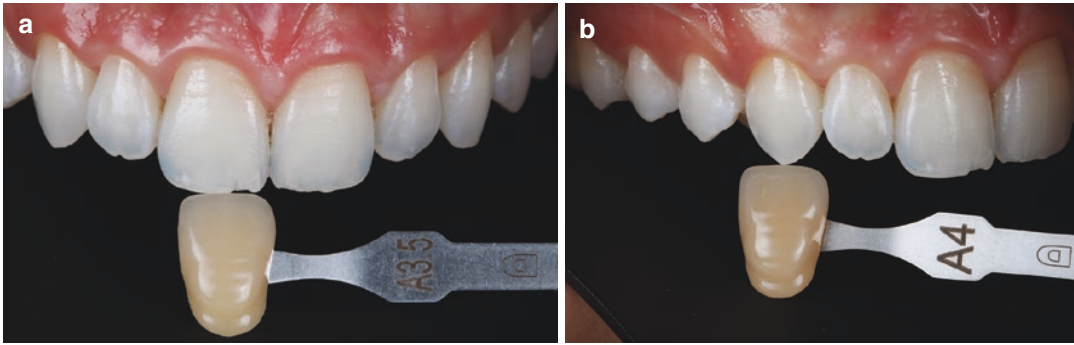
periods of time. However, the bleaching efficacy is not dependent on the technique used [21].

## 6.2.3 Non-Vital Tooth Whitening

### 6.2.3.1 Walking Bleaching

The intracoronal or internal bleaching, also known as the *walking bleaching technique*, was introduced in 1967 by Nutting and Poe [22] and is probably the most popular option for bleaching non-vital teeth. Originally, this technique involves filling the pulp chamber with a mixture of 20–30% hydrogen peroxide and sodium perborate, which needs to be reapplied every 2–7 days [15]. However, other peroxide agents can be used as hydrogen peroxide (up to 35%), carbamide peroxide (16–37%), or sodium perborate alone (i.e., mixed with water) [12].





**Fig. 6.29** In-office bleaching: final situation after three appointments: intraoral photography and color measurement for incisors (a) and canines (b)



**Fig. 6.30** In-office bleaching: final situation: Smile photography—front (a), right (b), and left (c)

After the access to the pulp chamber of endodontic treated teeth, the sealing material should be removed close to 3 mm in an apical direction beyond the clinical crown height to create a space for cervical sealing and exposes the dentinal tubules directed towards the cervical region of the tooth (Figs. 6.9, 6.32, 6.33, 6.34, 6.35, 6.36, 6.37 and 6.38). Then, a 2 mm base of glass-ionomer cement should be applied to protect the

endodontic sealing material. Therefore, the bleaching agent is placed into the pulp chamber, cover with a cotton pellet, and then with a provisory restorative material.

The lower the bleaching agent pH, the higher the risk of external cervical root resorption. Although the isolated use of sodium perborate may be a slower process, it is potentially less destructive to the tooth due to its alkaline pH and hence safer.



**Fig. 6.31** Use of sliced sucker as tongue retractor and to restrain dental occlusion



**Fig. 6.34** Non-vital bleaching: protection of endodontic sealing material with a 2 mm base of glass-ionomer cement



**Fig. 6.32** Use of bite block as tongue retractor and to restrain dental occlusion



**Fig. 6.35** Non-vital bleaching: application of bleaching gel



**Fig. 6.33** Non-vital bleaching: after endodontic treatment, removal of endodontic sealing material close to 3 mm in an apical direction beyond the clinical crown height to create a space for cervical sealing and exposes the dentinal tubules directed towards the cervical region of the tooth



**Fig. 6.36** Non-vital bleaching: covering the bleaching gel with a cotton pellet



**Fig. 6.37** Non-vital bleaching: provisional restoration with provisional direct composite



**Fig. 6.38** Non-vital bleaching: final situation after 2 weeks of walking bleaching

After the internal bleaching end, the bleaching agent should be removed from the pulp chamber with an extended water flush. Then, the pulp chamber must be provisionally filled with a paste of calcium hydroxide and water in order to render the pH alkaline in the tooth cervical region [23].

### 6.2.3.2 In-office Internal Bleaching

The *in-office internal bleaching* is considered an alternative treatment for non-vital teeth bleaching. It involves the application of 30–40% hydrogen peroxide inside the pulp chamber and over the external surface of the crown for 20–40 min. In the past, a heating instrument was used to accelerate the process, but this is strongly inadvisable due to the external root cervical resorption increased risk [24].

## 6.3 Color Measurement for Bleaching Procedures

### 6.3.1 Patients' Whiteness Perception

The dental color is a frequent concern for patients and is associated with an increased desire for esthetical dental treatments. Psychophysical studies indicate that whitened teeth lead to positive judgements of personality traits such as social competence and appeal, intellectual ability, and relationship satisfaction [25]. The color and overall visual aspect of teeth is a complex phenomenon influenced by several factors as lighting conditions, translucency, opacity, fluorescence, opalescence, iridescence, tooth surface, light scattering, gloss, and human visual system [26]. The teeth whiteness perception by the patients is greatly influenced by the color of their gums, lips, and skin [27, 28]. The darker the color of the tissues around the teeth, the higher the effect of lighter teeth perception. Due to the lower contrast effect, whiter-skinned patients may report less satisfaction with the tooth whitening outcome.

Data from literature indicate that the perception that very white teeth are beautiful significantly decreased with the increase of age group, as well as younger patients expressed a greater preference for white teeth than older patients [29]. Despite the fact that similar expectations with tooth whitening could exist among the different age groups, the standard esthetic preferences are personal. Some patients may seek to have the whitest teeth color possible regardless of their age.

### 6.3.2 Color Measurement Techniques

As previously mentioned in Chap. 3, there are two different ways to evaluate the color of the teeth, objectively or subjectively. The objective method is based on instrumental color measure-

ments; while the subjective method consists of the visual comparison between teeth and shade guides [30]. The tooth whitening effect can be evaluated both visually and instrumentally. However, the visual method is the most used due its simplicity and reduced cost.

The color of teeth is mainly subjectively measured by the visual comparison method using a tab from paper, colored porcelain, or acrylic resin shade guides [26]. These guides are made of a set of shade tabs intended to cover the range of colors present in human teeth. For tooth whitening monitoring, dental shade guides should be used to follow the color change. Visual evaluation is performed by registering the tab that most closely matches the tooth shade throughout the whitening treatment period.

### 6.3.2.1 Shade Guides for Tooth Whitening Monitoring

In worldwide clinical practice, the most commonly used dental shade guide is the Vitapan Classical (Vita Zahnfabrik). As mentioned in Chap. 3, the color range of this shade guide is divided into four different hue groups designated by A, B, C, and D letters, representing reddish-brown for A hue, reddish-yellow for B hue, grayish for C hue, and reddish-gray for D hue. For each hue group, there are different tabs differentiated by an Arabic number ranging from 1 to 4, with different chromas and values. The higher the number, the higher chroma and the lower the value. For tooth whitening monitoring, it is recommended to rearrange the tabs according to the value, from the highest (B1) to the lowest (C4) (Fig. 6.39) [31]. Recently, a modification for this

shade guide was proposed, adding three new tabs for bleached teeth 0M1, 0M2, and 0M3 [32].

The Bleachedguide 3D-MASTER (Vita Zahnfabrik) is a cross-section of Toothguide 3D-MASTER (Vita Zahnfabrik) with 15 tabs and a linear arrangement from the highest (0M1) to the lowest (5M3) value (Fig. 6.40). It contains 8 original Toothguide 3D-MASTER tabs and 7 interpolated tabs, included to bridge large color differences among middle tab (M2) in different groups. The lightest part of the Bleachedguide 3D-MASTER exhibits subtle color gradation with several tabs lighter than the lightest tab of Vitapan Classical (B1) [33].

There are other value-arranged shade guides exclusively designed for tooth whitening monitoring as the R-20 and R-27 (Vakker Dental) with 20 and 27 tabs, respectively (Fig. 6.41). However, no research data is available in the literature about their use for shade matching in Dentistry.

There are several shade guides made from paper, available to purchase by regular consumers (non-dentists) with different color and whiteness gradations. Its use for tooth whitening monitoring should not be encouraged by clinicians due to the paper perishability, color differences among shade guides due to printing errors, inadequate flat surface of the tabs, or even due to the absence of detachable tabs.

### 6.3.2.2 Visual Color Measurement

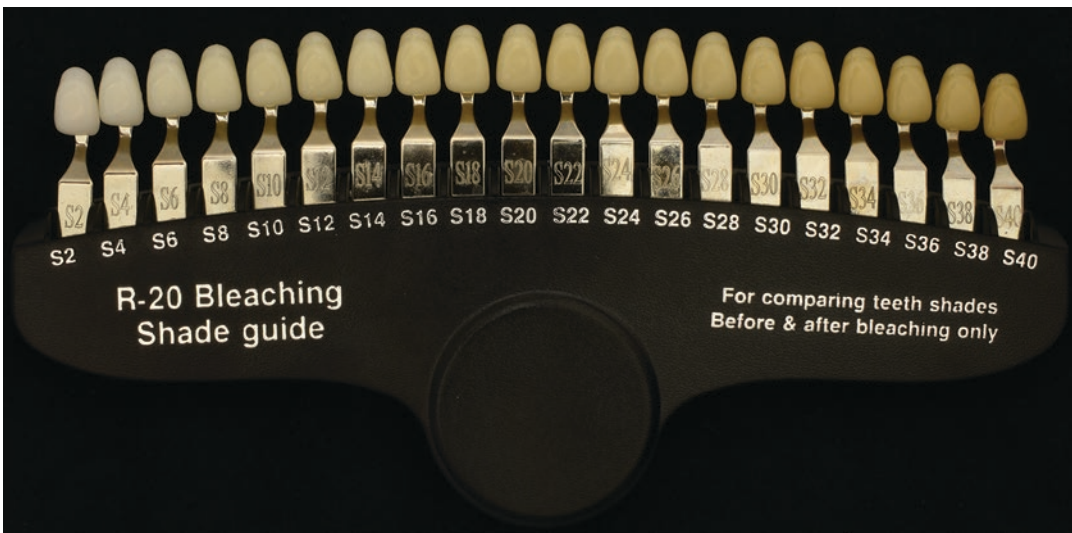
During the tooth whitening monitoring, color measurement should be performed in order to follow the color change. As mentioned in Chap. 3, color from any object, as the tooth and shade guide tab, is directly influenced by illumination.

**Fig. 6.39** Tooth whitening monitoring: rearrange the Vitapan Classical tabs according to the value, from the highest (B1) to the lowest (C4)





**Fig. 6.40** Tooth whitening monitoring: bleachedguide 3D-MASTER shade guide



**Fig. 6.41** Tooth whitening monitoring: value-arranged R-20 bleaching shade guide

Therefore, it is important to place the tab at an equal level with teeth to get the same amount of illumination.

### 6.3.2.3 Photographic Register

Taking photographs in the beginning and during the course of tooth whitening treatment is strongly recommended due to different reasons. Sometimes, patients may be demotivated with the treatment due to self-perception of no efficacy. So, beyond registering the color change throughout the whitening period, taking stan-

dardized photographs is necessary to show the patient the treatment evolution.

A photographic protocol is suggested for the beginning and for the end of tooth whitening: (1) full-face smiling photo; (2) face smiling photo with dental shade guide placement just below the smile; smile photos in (3) front, (4) right and left (5) sides; (6) and (7) intraoral photos of upper anterior teeth over a black background with the tab placement that most closely matches the actual color of the upper central incisors (6) and upper canines (7).

During the whitening progress monitoring, the same intraoral photos can also be taken i.e., before-after an in-office power bleaching appointment and at each at-home whitening control appointments.

#### 6.4 Considerations to Bleaching Related to Direct Restorative Approaches

The bleaching procedures may negatively affect the marginal seal of restorations in both pre- and post-operative periods. Meticulously clinical examination must be performed before application of peroxide agents. Unsatisfactory restorations need to be repaired or replaced prior to bleaching in order to achieve an optimal seal of the pulp chamber, reducing the risk of adverse effects [34].

Considering the bleaching of restored teeth, the peroxide agents react to the resin-based composite' components and produce color and surface alterations. They increase the elution of unpolymerized monomers, additives, and other organic components oxidation [35, 36]. At the same time, they are increasing the lightness and decreasing the chroma for the natural tooth; they act in the opposite way on the resin-based composite materials, accentuating the color mismatch between the two structures. Therefore, composite restorations in anterior teeth often need to be replaced after the tooth whitening treatment [35].

During the whitening treatment, teeth get an increase in lightness through the process and reach a maximum lightness regardless of the concentration of the agent or contact time used. With the peroxide agent removal, dental rehydration occurs, and the teeth will get a decrease in lightness due to light absorption by water into the dental tissues. So, for restorative approaches after tooth whitening, it is necessary to wait for at least 10 days before measuring the real tooth color [37].

The peroxide agents oxidizing effect alters the organic matrix of enamel and dentin, impairing a strong and stable bond between the composite applied and the superficial etched enamel layer.

Moreover, the residual oxygen present in dental tissues after the bleaching process decreases the bond strength to enamel and dentin, because the oxygen inhibits the monomer polymerization that cures via a free-radical mechanism [38, 39]. For this reason, it is recommended to delay at least 1 week after the tooth whitening before placement/replacement of direct restorations in order to the residual oxygen may have sufficient time to leach from the dental hard tissues. Optimal bonding to pre-bleached dental hard tissue could be achieved after a period of about 3 weeks [35].

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