ETIOLOGY AND PRECLUSION OF CHLORODONTIA (GREEN TEETH)

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ABSTRACT

Objectives: The present review explores the multifactorial etiologies of Chlorodontia (Green teeth) and aims to create awareness among dentists and dental hygienist who deal with the patient directly on use of safe medicine to prevent green discoloration of teeth.

Materials and Methods: Data has been collected from various sources which include review and research articles published in reputed journals, (pubmed, google scholar, scopus etc) web pages and books to accomplish meaningful solutions through different treatment strategies.

Results: Various factors involved in green discoloration were analyzed and the appropriate management strategies have been discussed. Tooth discoloration is usually aesthetically displeasing and psychologically traumatizing which can erode the sparkle from a smile. Green teeth is an uncommon condition that is associated with bilirubin deposits, degraded products of hemoglobin and elements like calcium, sodium, magnesium, phosphorous potassium etc in dental hard tissues and the side effects of immunosuppressive drugs in patients with a liver transplant. Discoloration is mainly observed in primary dentition. Treatment of green discoloration based on the etiology has been goal to our study. This paper will be dual beneficiary as green discoloration can be prevented in patient as well will be useful for dentist to initiate the proper therapy.

INTRODUCTION

The science of color is pivotal in dentistry as color perception is of great concern to a large number of people seeking dental treatment (1). The prominent layers in tooth are the enamel which covers the crown, the root cementum on the root surface and an inner layer of dentin in the crown and the root (2). The pulp, the inner part of the tooth is enriched with blood supply and nerve supply. Teeth are most susceptible to developmental disturbances during the mineralization phase of tooth formation (3). The permanent dentition is more prone to disturbances in mineralization by chemicals and drugs (4). Alterations in these structures will result in the modification of tooth appearance externally as well as its light transmitting and reflecting properties (5).

Etiology of Tooth Discoloration

Discoloration of the tooth is one of the most frequent reasons why patients hunt for dental care. Tooth discoloration is aesthetically displeasing and psychologically traumatizing.

An understanding of the etiology of tooth discoloration is important to a dentist in order to make the accurate diagnosis. The discolorations are mainly observed on the outer surface of the tooth structure mainly caused due to the stains taken up by the enamel or dentin during tooth development (6). The developmental defects create their own color change in the tooth caused by influences on light transmission through the dentine and enamel. Furthermore, increased enamel porosity and enamel defects (dentinogenesis imperfecta) facilitate the penetration of the stains (Chromogens) through the tubular system (7). Hence, identification of the type and extent of discoloration play a key role as intervention of dentist is a must to resolve this cosmetically unsatisfactory dentition.

Classification of Tooth discoloration

Historically, tooth discoloration has been classified as either intrinsic or extrinsic based on the location of the stain. Internalized discoloration also is of value to consider (8). Extrinsic discoloration may be due to direct or indirect staining (9). Direct staining occurs due to penetration of chromogens into the acquired pellicle and indirect staining are the consequence of chemical reaction with metals or cations used as antiseptic (5). Nevertheless, the deposition of anionic
Green Teeth (Chlorodontia)

Green teeth are an uncommon condition that is associated with bilirubin deposits in dental hard tissues, decomposed hemoglobin (15) and inorganic elements like calcium, sodium, magnesium, potassium, silicon, phosphorous and other elements in small amounts. Discoloration can also occur due to incomplete removal of obstructing material and sealer remnants in the pulp chamber, containing metallic components (16, 17) (fig 1). Green stain is found mainly on the cervical surface of the anterior teeth of children and is a remnant of Nasmyth's membrane and accumulated food debris (18).

Chromogenic bacteria

Chromogenic stains are a type of extrinsic stains of the teeth which are seen in children and these stains can sometimes be intrinsic if the bacteria affect the tooth during the stages of development. Chromogenic stains are often observed in the incisal edges. In the fig 2 the incisal edges of the teeth are green and the middle third of the teeth is black. Green pigmentation is due to chromogenic bacteria and the black stain seen in adults is as a result of accumulation of plaque, chlorhexidine, tobacco, stannous fluoride etc (43). Chromogenic bacteria cause stains mostly when the child has received liquid amoxicillin for a prolonged period of time. These bacteria stain the teeth yellow, green or orange in newly erupted teeth of the children (44).
Green strains are attributed to fluorescent bacteria as well as fungi such as *Penicillium* and *Aspergillus* species (Fig 3). The organisms grow only in light and therefore cause staining on the maxillary surface of the anterior teeth. Fusayama et al. (45) depicted that discoloration precedes the bacterial penetration of demineralized dentine and it seems that the discoloration is caused by compounds diffusing ahead of the bacteria. However, Klette et al. (46) have suggested that it may be due to the Maillard reaction or formation of melanin or lipofuscin if there exists no relationship between the discolouration and either pigmented bacteria or metal ions. This report was validated through the evidence that bacterial irritation to the pulp may cause tissue necrosis which in turn releases disintegrated by-products that penetrate the tubule and discolor the dentine. Eg. Heme, a by-product of hemolysis discolors dentine by combining with pulp tissue to form iron sulfide (15). Fungal infections are infections caused mainly by a microorganism named fungus that occurs in both young and old with weakened immune systems. The possible factors that lead to infections are immunosuppressant, HIV/AIDS, steroids and cancer chemotherapy. Due to surplus availability of glucose in diabetics they are more prone to the fungal infections as the elevated blood sugar provides nutrition for fungal overgrowth (47).

**Green teeth due to intrinsic discoloration**

Intrinsic green discoloration of teeth is considered to be rare and the majority of reports are related to the primary dentition. Moreover, appearance of greenish tooth discoloration which may be as a result of immunosuppressive drugs in patients with a liver transplant, or antibiotics acts as a noxious stimuli to the patient and may lead to apprehension among the family members. Therapeutics and management of greenish discolored teeth remains unexplored and presumed to be more complicated. Herein, clear explanation is given in order to reduce the anxiety in the patient and to aid the dentist with appropriate dental management techniques.

**Intrinsic Green Teeth discoloration due to Drugs**

Triple antibiotic paste (TAP), a mixture of ciprofloxacin, metronidazole and minocycline first used by Sato et al. (1996) is very effective in eliminating endodontic pathogens in vitro and in vivo. TAP is commercially available as 3 MIX MP (metronidazole (500 mg), minocycline (100 mg) and ciprofloxacin (200 mg) at a ratio of 1:1:1 (50). Minocycline is a semisynthetic analogue, and a second-generation derivative of tetracycline introduced into clinical practice during 1967 for tetracycline resistant inflammatory acne in adolescents and adults (51-54). Evidences suggest that the ingestion of minocycline leads to a green-gray intrinsic staining of teeth in the erupted permanent dentition and bone (55). Minocycline 100 mg/day can cause discoloration within one month after initiation of therapy in 3-6% of patients. Pigmentation occurs in bone due to accumulation of an insoluble quinone released due to the degradation of aromatic ring of the drug. However, the exact mechanism of staining in erupted teeth remains unclear.

Contrastingly, greenish discoloration due to minocycline is localized to the middle or middle and incisal thirds of the crown in comparison with other tetracyclines (56). Additionally, Minocycline is a poor chelator of calcium ions but bind to iron ions. This interaction causes the formation of insoluble salts that are exuded from gingival crevicular fluid to either extrinsically stain the enamel or intrinsically. The affected teeth do not fluoresce under ultraviolet light, suggesting that the drug may be present as an iron-binding oxidized polymer, rather than as the calcium-bound, unchanged drug (57-59).

**Mechanism of teeth discoloration by Minocycline**

Four theories that explains the mechanism of discoloration includes

- Extrinsic theory, minocycline attaches to the glycoprotein in acquired pellicle, oxidizes on exposure to air or as a result of bacterial activity resulting in the degradation of the aromatic ring forming insoluble black complex. The pigment then gets incorporated into the dentin by a demineralization/mineralization phenomenon.
- Intrinsic theory, minocycline bound to the plasma proteins gets deposited in collagen-rich matrix, such as the teeth...
which then oxidizes slowly over time with exposure to light.
- Chelation, minocycline binds specifically with iron and forms insoluble complex.
- Deposition in dentine, minocycline deposits in dentin during secondary dentinogenesis and process gets accelerated in bruxists (60-63).

Ciprofloxacin, a fluoroquinolone is a broad spectrum, bactericidal antibiotic given intravenously to infants at dosages of 10 to 40 mg/kg/day to treat infections with Klebsiella (64). The drug targets topoisomerases in bacteria. Ciprofloxacin causes greenish discoloration of the teeth (65,66). Discoloration or staining is directly related to the age of patient, dose and duration of the drug administered. Nevertheless, mechanism involved in greenish discoloration remains uncertain (67).

Green teeth as a complication of hyperbilirubinemia - Metabolic disorders

Hyperbilirubinemia

The elevated bilirubin in neonates due to certain diseases gets incorporated into developing teeth and causes yellow-green discoloration within the dental hard tissue (68-69). Bilirubin (haematoidin) is the yellow breakdown product of normal heme catabolism. Heme in hemoglobin is a prime component of red blood cells. The elevated level of bilirubin is indication of diseases. Normally, bilirubin is excreted in bile and urine, and is responsible for the background straw-yellow color of urine and the brown color of feces due to its end products urobilin and stercobilin. Hyperbilirubinemia causes accumulation of bilirubin pigment within the skin and mucous membranes that manifests as yellow pigmentation (70).

In the newborn, jaundice is visible on the face at a serum bilirubin level of about 5 mg/dL; it progresses caudally as the level increases. When bilirubin levels are elevated for numerous days, bilirubin pigments gets deposited all over the body, including the teeth. Histological evaluation of green-stained deciduous teeth from patients with hyperbilirubinemia has confirmed the deposition of bilirubin. Intrinsic staining of primary teeth may vary in color from yellow to green. The removal of stain in the soft tissues takes place gradually. Nevertheless, in the hard dental tissues, the pigment becomes entangled due to deficient metabolic activity producing permanent staining (71) (Fig. 4).

Fig 4. Green Teeth in a Child with Hyperbilirubinemia.

Neonatal hyperbilirubinemia occurs in about 60% of newborns during the first week of life. On the contrary, the prevalence of green-stained teeth associated with hyperbilirubinemia remains unidentified. So far, 50 cases of green discoloration of teeth have been reported, mostly in the dental literature. Most of these cases occurred in children with hyperbilirubinemia secondary to biliary atresia. This clearly indicates the possible role of direct hyperbilirubinemia in the pathogenesis of green-stained teeth. The conjugated bilirubin being water soluble gets incorporated into the developing dentition (72,73). Less common causes of green-stained teeth associated with hyperbilirubinemia include Rh and ABO incompatibilities. About 48 children with green-stained teeth secondary to hyperbilirubinemia were diagnosed, the mean duration of jaundice and maximum serum total bilirubin level were found to be 24.6 weeks and 20-90 mg/dL, respectively. Although discoloration was observed in permanent dentition primary teeth remained mostly affected. Often, a sharp dividing line separated the normal-colored tooth from the green discolored tooth (68,71,72). The eruption of the first tooth is a much anticipated milestone in the developing child and green discolored tooth can result in mental agony for parents. Thus, it becomes mandatory to provide proper guidance to families of children with severe hyperbilirubinemia. The evidences strongly support the fact that hyperbilirubinemia causes reversible staining of all tissues except the teeth (73). Treatment options include bleaching techniques; composite resin restorations and transillumination with UV light (74).

Chronic liver disease

Liver transplantation is becoming a widely accepted treatment for children with end-stage liver disease that have vastly improved as a consequence of advances in surgical techniques, improved postoperative care, and mostly due to the use of cyclosporine as an effective immunosuppressant drug. The primary causes for liver transplantation include chronic liver diseases like metabolic disorders, biliary hypoplasia, atresia and acute liver failure. The green-stained tooth is commonly observed in the oral cavity of these patients. Additionally, intrinsic tooth discoloration is reported in patients with blood dyscrasia such as sickle cell anemia, thalassemia, and hemolytic disease of the newborn. These diseases have the potential to cause hemolysis and the subsequent dose-dependent incorporation of biliverdin (by-product pigment of bilirubin) into developing teeth that leads to jaundice like yellow-green tint on the tooth surfaces (73-75).

Pathogenesis

The acquired pellicle is a microscopically thin layer of salivary glycoproteins that forms the surface coating of erupted tooth and offers acid resistance, lubrication and remineralization, which intum facilitates the adherence of chromogenic (or colour-producing) materials to the tooth’s surface (76). During odontogenesis, teeth may become discolored from the changes in the quality or quantity of enamel or dentin, or from the incorporation of discoloring agent into the hard tissues. Post-eruption discoloration occurs when the discoloring agent enters the hard tissues and originates from the pulp or the tooth surface (77).

The diseases that have the potential to cause neonatal hyperbilirubinemia or sepsis due to severe infections may cause green discoloration due to the incorporation of bilirubin/
pathogenic microorganisms into developing teeth (fig 5) within the dental hard tissue known as chlorodontia (75,76).

**Fig 5. Chlorodontia due to sepsis. Green Teeth due to severe infection (Neonatal Sepsis).**

The calcification of primary teeth starts during second trimester of intrauterine life and continues until the calcification of second molars. If there are too much bilirubin and biliverdin pigments in the blood, a change in tooth color might occur due to its invasion in the dentin and/or enamel formation. Many specific reciprocal interactions govern dentin and enamel formation which differs in mechanism. The odontoblast usually synthesizes and secretes the organic collagen-rich dentin matrix that subsequently mineralizes while the ameloblasts secretes a poorly mineralized matrix until the end of the secretory phase of amelogenesis. Subsequently, ameloblasts degrades its entire organic matrix to allow the increasing of the enamel mineral content during the maturation phase of amelogenesis. Thus, it is conceivable that the green pigment was deposited into dentin as it was secreted by odontoblasts (77-78,112).

**Treatment of Green Teeth discoloration**

Treatment of green pigmented teeth is mainly cosmetic. Recently, esthetics is considered as essential as function. The appearance of discoloration in dentition is of major concern to mankind and craves for dental treatments. Hence, deterrence of preventable causes of tooth discoloration must be a priority issue for the dentist. Appropriate therapy of discolored primary dentition will eventually lead to the normal permanent teeth. As children’s age advances dental management improves self-esteem and confidence. Treatment options include vital and non-vital bleaching, micro abrasion, composite and porcelain veneers, and porcelain crowns. These treatments are combined at times for a more successful effect. Bleaching and composites/crowns are the techniques used for stained primary or permanent dentition (79-81).

**Bleaching**

Dental bleaching or tooth whitening is a most commonly used method in dentistry (82-83). Whitening restores natural tooth color and bleaching whitens and improves the natural color (FDA). Tooth bleaching has been an age old remedy. In ancient days Romans utilized milk and urine of goat to brighten and whiten the teeth. Bleaching is followed with bleaching gel, pen, strips or laser bleaching (84-85). Bleaching methods contain carbamides which react with water to form hydrogen peroxide. The peroxides remove the stain by perforating the pores of the enamel. Power bleaching uses light to accelerate the process of bleaching in a dental office. Nowadays, 6-phthalimido peroxy hexanoic acid (PAP) is being used as bleaching agent (86). The mechanism of bleaching by hydrogen peroxide is unclear. The possible mechanism includes hemolytic cleavage of O-H or O-O bond in hydrogen peroxides to release hydroxyl radical (HO), perhydroxyl radicals (HOO-), perhydroxyl anions (HOO-), and superoxide anions (OO-). The photochemical reactions due to light or lasers, augments the release of these radicals from hydrogen peroxide (87-89). Hydrogen peroxide being an oxidizing agent releases oxygen in the form of unstable free radicals and causes disintegration of the conjugated double bonds in the chromophore to form a single bond that is flushed out by water which thereby facilitates the removal of pigments that cause tooth discoloration (90-91). The entire process will in turn lead to a shift in the absorption spectrum of pigment and results in tooth whitening (92 -93). Bleaching can be either carried out externally (night guard bleaching or vital tooth bleaching), or intracoronally in root-filled teeth (non-vital tooth bleaching) (94).

**Non-Vital bleaching**

Non-Vital bleaching dates back to 19th century using chloride of lime. The non-vital bleaching procedures commonly practiced are i) ‘walking bleach and modified walking bleach’; ii) non-vital power bleaching, also known as ‘thermo/photo bleaching’; and iii) Inside/outside bleaching (79,80,95). This technique is indicated for non-vital, endodontically treated teeth that are discoloured due to the deposition of blood degradation products in the dentinal tubules and is based on usage of either hydrogen peroxide or both hydrogen peroxide and sodium perborate (Bocasan) (96).

**Vital Bleaching**

Vital Bleaching involves the external application of hydrogen peroxide to the surface of the tooth followed by thermal stimulation (93,97). It is primarily used for mild tetracycline staining without obvious banding and single teeth with sclerosed pulp chambers and root canals (98-99). Tetracycline stained teeth can be bleached with 10% Carbamide peroxide that ensures stability even after 3 months of treatment (100). In vitro studies imply that accumulation of blood forming pigments hemoglobin and/or hematin molecules precipitates discoloration of teeth. Bleaching agents have demonstrable benefits in the removal of teeth stain specifically caused by blood pigment (101).

**Veneers**

Dental veneers (sometimes called porcelain veneers or dental porcelain laminates) are wafer-thin, customized shells of tooth-color materials designed to cover the front surface of teeth to improve the appearance. These shells are bonded to the front of the teeth changing their color, shape, size, or length (102). The advantages of veneers includes: a natural tooth appearance, Gum tissue tolerance and resistant to the stains. The color of a veneer can be chosen such that it makes dark teeth appear whiter and offer a conservative approach to changing a tooth's color and shape; veneers generally don't
require the extensive shaping prior to the procedure that
crowns do and is most preferred aesthetic alternative (103).
However, there are demerits as the process is irreversible, and
irreparable. Veneers are expensive than composite resin
bonding. Due to the removal of enamel, tooth may become
more sensitive to hot and cold foods and beverages.
Sometimes, veneers may not exactly match the color of the
other teeth and cannot be altered once it is placed. Veneers will
have to be replaced every 5 years as it does not last longer (104).
Veneers are used in tetracycline staining (105).

Porcelain Veneers

Porcelain veneers are indicated for hypoplastic and discoloured
teeth in patients aged 16 years and above, when techniques
such as microabrasion, non-vital bleaching and composite
cements have failed to produce a satisfactory clinical results
(105).

Microabrasion

Microabrasion is based on the elimination of a considerable
amount of surface enamel and incorporating ‘abrasion’ and
‘erosion’ together with dental instrument and an acid mixture.
The two main techniques available for microabrading
discolored or hypoplastic teeth are hydrochloric acid/pumice
technique, which requires very careful isolation of the affected
teeth, and the phosphoric acid/pumice technique. Microabrasion is mostly indicated for fluorosis, post-
orthodontic demineralization, localized hypoplasia due to
infection or trauma, and idiopathic hypoplasia wherein the
discoloration is limited to the outer enamel layer (106-107).
Tetracycline discoloration is removed by combined treatment
modality in which the teeth are bleached after the preparation
for porcelain laminate veneers (108). However, for
minocycline staining a wide variety of treatment options is
available. The different modalities of esthetic treatment
available for managing such discolored teeth include vital
bleaching, microabrasion, composite/ceramic veneers or
ceramic crown (109-112).

Conclusion

Identification of the possible etiologies of green discoloration of
teeth is prime need to achieve the satisfactory cosmetic
outcome. A detailed investigation was carried out to enumerate
the pathological processes involved in green discoloration of
teeth. The evidences from previous literatures suggest that
possible factors involved in green staining are hyperbilirubinemia, drugs, metals and heme products. Hence, it is vital to consider these aforementioned factors for a complete evaluation of the impact of the chromogens on the teeth. Based on the causes appropriate dental management techniques are referred in this review which may render useful to dentist and patient.

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