

Pink Teeth Phenomenon and Asphyxia: A Reassessment and Update

Pawan Mittal^{1*}, Prateek Karagwal¹, and Deepa Gupta²

¹Department of Forensic Medicine, B.P.S. Medical College for Women, Khanpur Kalan-131305, Haryana, India

²Tooth Point Dental Clinic, Peermuchalla, Zirakpur-140603, Haryana, India

Abstract

The history of pink teeth phenomenon [PTP] dates back to 1829 when it was first described by Bell. Thereafter a number of publications were made on this topic. Initial observations on pink teeth tend to correlate it with asphyxial deaths, especially drowning and strangulation. However with the passage of time, the phenomenon was also observed in non asphyxial and unknown causes of death. On account of nonspecific nature and unclear mechanisms, the finding, however, gradually lost its medico-legal acumen. The basic process behind post-mortem pink teeth is congestion/hyperemia of pulp capillaries followed by hemolysis causing hemoglobin release where after its subsequent diffusion into dentinal tubules stains them pink. The process, as stated, requires humid and moist surroundings along with a prolonged postmortem interval, so the majorities of the cases belong to putrefied and drowned corpses that frequently depict adipocere formation too. One reason behind this is the head down position of submerged cases which predisposes them to a strong cranial congestion especially in the areas of declivous lividity. A minimum time of one week has been suggested for the first appearance of pink coloration. After a thorough review of literature, including the recent ones and from our own observations, the association of pink teeth in certain asphyxial deaths, particularly fatal neck pressures like strangulation and hangings, appears to be reemerging. Furthermore the cases depicted in the text have substantiated the truth of Clark and Law (4) that an invariable allocation of the hypostatic congestion to the pink teeth formation is not justified, although due to scarcity of enough case material and literature, a definite opinion cannot be put straightforward.

Overall this review is an attempt to bring some hope to the potential value of this phenomenon in the light of current state of knowledge and observations in forensic situations. Possible lacunas in the investigation of previous reports along with possible suggestions and future prospects are highlighted.

Keywords: Pink teeth • Asphyxia • Drowning • Congestion • Hemoglobin • Dentine • Cause of death

Introduction

The first description of pink teeth phenomenon [PTP] was made by Thomas Bell in 1829 in the victims of hanging and drowning and he suggested that the phenomenon is due to an intrinsic or extrinsic increased pressure in the tooth pulp [1]. However, the pathognomic value of pink teeth has been more than doubtful since it has been described in a variety of unnatural and violent deaths, predominated by asphyxiation and cases of blunt, sharp and gunshot trauma, as well as in deaths due to poisonings and intoxications [2-7].

Cases with unknown/unsolved cause and manner of deaths [8] and archeological situations depicting PTP are also on records [9]. The repeated discovery of the phenomenon in cases of drowning and strangulation has made the researchers to think with its potential association with asphyxia [10-15]. This is due to its dependence with the degree of congestion in the head causing increased venous pressure within dental pulp which is followed by hemolysis and release of hemoglobin that upon diffusion leads to pink staining of dentinal tubules [4,16,17]. However, the instances of pink discoloration in non-congestive modes of deaths such as hemorrhagic shock and intoxications have been reported [4,18]. Overall the specificity and medico-legal value of pink tooth has remained debatable throughout its course.

***Address for Correspondence:** Pawan M, Department of Forensic Medicine, B.P.S. Medical College for Women, Haryana, India, E-mail: drmittalpawan@gmail.com

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Literature Review

Pink teeth phenomenon

The pink tooth phenomenon [PTP] represents a cadaveric sign eventually detectable in dental autopsies [7]. The term 'pink tooth' refers to a red-pink coloration of the dentine, which becomes particularly deep towards the cemento-enamel junction, fading off towards both ends, but still visible beneath the enamel [2,4,8,10]. Its first application in forensic cases was made in 1953 in Christie murder cases among victims of strangulation and carbon monoxide poisoning, where the pink teeth from one of the victim were subjected to extensive histochemical and spectroscopic examination [10]. Thereafter several authors reported on pink teeth phenomenon [2,4-6,8,11,13]. Permanent or transient pigmentation of the teeth can occur due to extrinsic or intrinsic causes [19]. The changes can be generalized or localized [2].

The finding has been recorded in the living as well as in the dead, although due to its frequent occurrence in medico-legal as well as dental autopsies the finding has been exclusively explored by the forensic odontologists and pathologists.

Pink teeth in the living

During life, pink teeth may be associated with a number of pathological conditions such as typhoid disease [20], congenital erythropoietic porphyria [21], pulpitis, pulp necrosis or root resorption due to pathologic granulation tissue accumulation within the dental pulp [22]. They may also be the result of traumatic or iatrogenic injuries to the pulp during endodontic procedures [23,24]. In these cases, the tooth eventually becomes permanently grey, black or brown because of necrosis of the pulp [16]. Transient pink discoloration of isolated teeth can occur during dental treatment in connection with preparations

involving dentine, which may cause disturbances in the microcirculatory system of the pulp [24]. This may in turn result in vascular stasis and/or hemorrhages causing a further increase of vascular stasis in the pulp [24]. Stanley et al. reported on the rarity of a permanent pink or red discoloration of isolated teeth during life and stated that most of the time single tooth is involved [25]. The authors reported red discoloration in only 2 teeth out of their study material comprising of 79 teeth [25] (Figures 1 (a-c).

Such a phenomenon has been also observed in a pilot after combat, who survived by executing an inverted loop or "bunt", as well as in an anaesthetized cat after centrifugation; both were subjected to severe negative gravitational force resulting in blood forced into the head thereby causing remarkable cranial congestion [26].

However, the differential diagnosis of antemortem and postmortem pink discoloration of teeth should not be a problem, because there are other factors that the forensic odontologist must consider, when pink to red stained teeth are evaluated and later described in a legal report; i.e., the clinical case history [dental and medical], teeth involved [single or multiple], localization, extent and intensity of discoloration [16].

Pink teeth in the medico-legal and forensic context

In the forensic context, pink teeth have been described in a variety of unnatural and violent deaths predominated by asphyxia such as drowning, strangulation, hanging, plastic bag suffocation and in cases of gunshot injuries, stabbing, blunt head trauma, poisonings, intoxications and hypothermia [2-8,27]. The finding has been also observed in cases where cause and manner of death remained unexplained [8] and in archeological remains too [9]. Although some authors have denied its presence in historical situations and skeletal remains [10].

The triggering process in the pink teeth formation is increased venous pressure in the dental pulp [4,12]. The accumulation of blood in the pulp is followed by hemolysis of the red cells and seepage of the hemoglobin into the pulp whereafter diffusion into the dentine takes place [17]. Some authors have described the presence of pigments such as protoporphyrin responsible for the pink staining [4]. Subsequent studies however ruled out the involvement of other pigments like hemosiderin, bile or bile-related pigments, and porphyrins and confirmed that the hemoglobin is most likely pigment responsible for pink coloration [2,5,8,12,13,28].

Campobasso et al. in their 18 drowning cases involved in a shipwreck accident and displaying pink teeth did not find any evidence of ferric ion or hemosiderin on microscopic examination of decalcified tooth sections [13]. The dentinal tubules of the most representative pink teeth demonstrated a negative hemosiderin staining with Perl's Prussian blue method and positive hemoglobin staining with Pickworth's benzidine method. The positive reaction for hemoglobin was further magnified by autofluorescence from argon-ion laser excitation of tissues. The "LUT" [8-bit look-up table] images depicted a spotty positive autofluorescence reaction for hemoglobin and its derivatives within and around the dentinal tubules previously treated with Pickworth's and Perl's methods [13]. From these results, the authors confirmed that the hemoglobin is most likely pigment responsible for pink teeth discoloration. No fluorescence was observed in negative controls [13].

However, the exact etiology behind pink coloration taken on by the hemoglobin [seemingly under pressure] within the pulp cavity is less clear [8].

The staining pattern in pink teeth involves dentine and pulp while the enamel is totally devoid of discoloration [2]. This is due to the hard and dense nature of enamel while the dentine is less compact and containing many tubules is easily stained [1,2,29]. Furthermore, the moist and humid surrounding is an enhancing factor for the diffusion and seepage of hemoglobin into the dentine tubules [2,13]. This is further supported by the fact that most of the cases depicting PTP were related to drowning while many of them depicted adipocere formation at the same time [12,13]. That the humidity plays a role in the development of pink teeth is further evident from the fact that red coloration was found in 10 cases with unknown causes of death recovered from the water in the study of Brondum and Simonsen [12].

The cephalic congestion has been found to have a direct relation with the pink discoloration of teeth [16]. The blood accumulation in the head can be caused either by a vital congestion or by a postmortem head-down position that permits blood to leak into the hypostatic regions [2,12]. The phenomenon has been repeatedly discovered in drowned corpses depicting putrefaction [12,13]. The drowned victims often float with their head in a downward position [30,31]. So the cranial congestion in drowned cases may be either an intravital process [vena caval superior congestion due to preterminal heart failure against hypoxia] or a postmortem hypostatic phenomenon [16].

Sainio et al. have mentioned three primary factors responsible for PTP in immersed corpses: hypotonic haemolysis, outside pressure of the water and head down position of the drowned person [32]. Although from experimentation studies no differences have been found between the outside and inside pressure in drowned corpses [16]. Furthermore a prefinal heart failure causing venous backflow stasis with possible changes in intrathoracic pressure, such as occurs in drowning and smotherings, causes a lesser degree of cranial congestion in comparison to asphyxial deaths involving direct compression of neck and thoracic vasculature [33]. However the occurrence of PTP in deaths of non-congestive nature, such as hemorrhage and shock, gunshot injuries, stabbing and cases of unexplained deaths raises doubt over the invariable involvement of congestion in its genesis [6,8,12,18]. In this regard a leading role of degree of putrefaction along with atmospheric moisture and humidity and body position have been proposed as leading factors for the occurrence of pink teeth [2,16].

Furthermore, it is worth noting that only in a few case reports and studies, the position of the body, especially the head, or the comprehensive details of crime scene and circumstances are available [6,12,18]. Most of the studies have felt it enough to state the cause of death, general condition of the body, a note of site of body discovery and thereafter analyzing and/or speculating the most likely cause[s] for the pink teeth. This fact can have a significant bearing while postulating the possible reasons, especially the role of hypostatic congestion and hemorrhages, in causing haemorrhage within dental pulp and hence pink discoloration of tooth [16,34,35]. The forensic value of recording body position at the site of body discovery and its effects on the postmortem findings needs no further emphasis [34-37].

Borrmann et al. in their detailed review denied the occurrence of this phenomenon under the circumstances of a dried milieu, e.g. incipient mummification [16]. However few authors have substantiated the presence of pink teeth in partially to significantly mummified corpses [4,27] and also in historical situations [9].

Dye et al described pink teeth in archeological conditions [9]. The authors sectioned six of eight externally well preserved teeth taken from four skeletons and made observations using light microscopy, crossed polarized light and uv microcopy. The teeth were found to be displaying a superficial similarity to those described in the forensic literature as 'pink teeth'. It was suggested that the pink coloration of ancient teeth could be a postmortem process, resulting from the decay process caused by tunneling hyphae [mycelia] of various species of saprophytic fungi. However, the exact cause of pink teeth in those specimens could not be explained [9].

Ortmann and Du Chesne have described similar pink discolorations in teeth as well as nails of bilateral thumbs and left little finger in a putrefied and partially mummified female corpse which was found in a forest [27]. The cause of death was combined effect of trimipramin intoxication, hypothermia and pneumonia. The authors commented that the pink phenomenon depends on special anatomical features such as the existence of porous structures protected by a dense material, and results from hemoglobin staining of these structures after hemolysis, which explains the occurrence of a pink discoloration in teeth and fingernails [27]. Although COHb of 3 mg% was detected in teeth through immunohistochemical analysis which was related to smoking, spectroscopic examination failed to reveal any amount of CO-Hb in the subungual tissues [27]. The authors further added that due to adjacent hard and dense tissues, the congested blood vessels of the nail beds and the surrounding tissue can be protected from drying and possibly from [oxidative] degradation similar to the blood substances in the dentinal tubules of pink teeth, thereby helping in the

occurrence of pink teeth [27]. Clark and Law have described about the suicide of a young mummified and decomposed male displaying pink teeth, with cause of death remaining unanswered [4].

Still the presence of a local humid environment surrounding the head region, for a certain postmortem interval seems to be essential [5,38]. Furthermore it is possible that different parts of the body may be placed in separate environmental milieu, thereby leading to the phenomenon of differential decomposition [39].

Other factors such as heat and cold were found to promote the phenomenon [5]. Franco et al. have described multiple pink teeth in a charred and decomposed body that died due to cranioencephalic trauma [6]. On the contrary, in the study of Clarke et al. heat from fire did not cause pink teeth in their series of 50 cases [4]. The involvement of carbon monoxide and carbon dioxide has been suggested in the development of pink coloration [8,10,29] but could not be substantiated in other studies [5,27].

Pink staining of the teeth most commonly occurs in cases of sudden death [17] where the blood remains liquid after death, either due to increased fibrinolytic activity or inhibition of coagulation process [15,40]. Berg found an increase in fibrinolytic activity and high catecholamine levels in human cadavers of sudden deaths [41]. The same results were obtained in a further study involving animal experimentation using different methods of sacrifice with varying results depending upon the method of sacrifice [29]. The authors concluded that the fibrinolytic activity and the catecholamine levels were higher after death from O_2 deficiency than from other causes [29,41].

In the literature, there is not a strict connection between pink teeth and the cause of death [4,8,12]. Therefore, the possibility of pink teeth in natural deaths requires consideration, especially if circumstances are favorable [16]. However, people who die a natural death are not usually placed with their head in a prone position to allow the blood to drain into the teeth [17,42]. In this context, it requires consideration that natural death was not reported in any of the pink teeth cases described by Brondum and Simonsen [12]. According to Beeley and Harvey, all of their cases had met a violent death [8].

In most of the cases reported till date, the cause of death has been said to be drowning [1,8,12,43-45]. In fact, Van Wyk reported that he observed pink teeth in all victims of drowning [17]. But, it has to be emphasized that bodies recovered from water have not been necessarily drowned [31,39]. However, if humidity is a contributing factor in the development of pink teeth, it is not surprising that pink teeth have been reported in all cases of drowning [2,13].

Whittaker et al. have stated regarding the common occurrence of pink teeth phenomenon, especially in cases of drowning and carbon monoxide toxicity, but under-estimation or reporting of the finding in autopsy reports [38].

The pink tooth phenomenon has been explained through *in vitro* studies by using cadaver blood and sectioned tooth [42] and also by instilling blood and hemolysed erythrocytes into the pulp chambers [46]. Van Wyk in an *in vitro* study has also shown an increased permeability of the capillaries soon after death which allows seepage of the pigment into the pulp and dentine [42].

Time dependency of pink teeth

Pink teeth have been found in the dead bodies that were recovered after prolonged post mortem interval, such as putrefied corpses or cases depicting various modifications of decomposition and their formation is a time dependent phenomenon [16].

Almost all researches have noted a time delay between the death and formation of pink teeth. Van Wyk has explained this on the grounds of narrower diameter of dentine tubules [$3\ \mu\text{m}$] as compare to erythrocytes [average $7.5\ \mu\text{m}$] so that pink dentine can occur only after breakdown of erythrocytes walls due to autolysis with subsequent diffusion of hemoglobin and/or its products into the dentine [28]. In the same study the author tried to correlate the time sequence of pink coloration with the pattern of hemolysis of blood. All the teeth were divided longitudinally and one half received blood which contained a piece of skin [to imitate pulpal autolysis] and the other half cadaver blood only [28]. No difference was noticed between the blood with and without skin. The

author concluded that the pink staining of teeth can occur only after hemolysis and that discoloration becomes macroscopically obvious after about 6 days and peaks at 18 days [28].

Similarly, pink teeth and a postmortem interval of greater than five days was observed in 21 cases which included deaths due to drowning, stabbing and necklacing [2]. Some authors have suggested a post mortem interval of 1 to 2 weeks for PTP [16]. Pink teeth were absent after a postmortem interval of 96 hours involving 17 drowned bodies, recovered at a sea depth of 200 metres in a civilian helicopter crash [47]. On the basis of this fact, Borman et al. suggested that pink teeth phenomenon does not occur immediately [16].

Sainio et al. found an increasing amount of "hemosiderin" in the dental pulp of rats 24 hours after death [32]. Whittaker, et al. explained pink teeth in two groups of hamsters, one of which was buried in soil and the other was drowned in sea water, after strangulation and overdosing with barbiturates, respectively [38]. The authors made their analysis on occurrence of pink teeth from 1 week to 3 months after death. The intensity of pink teeth was maximum after 2 to 3 months, was faster in strangled hamsters as compared to the poisoned group and more intense in animals allowed to putrefy in saline in comparison to those buried in earth [38].

Experimental research on animals has shown that specimens stored in presence of moisture will stain faster and more intensely than if kept in a dry atmosphere [5,38]. The occurrence and the long time stability of the pink color seems to depend on the special anatomical conditions of [otherwise] hard and dense dentin such as the existence of porous structures in the form of dentinal tubules [27].

To conclude, the time of occurrence of pink teeth phenomenon has been very variable [5,32,38,48]. Furthermore, it has to be kept in mind that the time of occurrence and discovery of pink teeth may not be equal, so whatever time intervals have been suggested through multiple studies have to be considered as time of analysis [16]. This fact may carry an important evaluative and medico-legal bearing.

Ortmann and Du Chesne stated that the non-specificity and the long time stability of the pink discoloration suggests that pink teeth are not completely uncommon in putrefied corpses [27].

Distribution and morphological facts

The distribution and number of pink teeth can vary in a mouth from a single to every tooth involved in the phenomenon [38,42]. The pigmentation is more prominent in the anterior teeth with single roots than the posterior teeth with multiple roots [20].

Franco et al. calculated the number and location of pink teeth in their case-specific characteristic study and found a total of 331 postmortem colored teeth, out of which 163 were anterior [incisors and canines] teeth, while 87 were premolars and 81 were molars; the posterior teeth outnumbered the anterior teeth with a small difference [49]. However it is worth noticing that the premolars show a considerable variation in the number of roots [50] while no specific mentioning regarding this fact is available.

Furthermore, the preferential staining of a few teeth over the other has been suggested on the basis of dependent position of the head [17]. Van Wyk stated that the handling of the body after death might be a factor if one assumes accumulation of blood due a prone position of the body as the cause for staining of the teeth [17]. The author discovered unstained vital teeth at different locations and mentioned that if the bodies had remained in one position after death the staining patterns might have been more uniform. He furthermore added that if pink teeth are part of the "livid stain" manifestation, several adjacent teeth should have similar pulpal features [17].

The role of a hypostatic phenomenon has been doubted by finding similar intensity of pink discoloration in the dependent as well as non-dependent/ contra-lateral teeth, thereby suggesting a congestion intravital rather than a hypostatic phenomenon [4]. Although not many studies have verified this statement [2,13]. In one study, the body was found to be lying on the left side but the degree of pinkness of the molars on both sides was identical [4]. The

authors stated "It appears unlikely therefore that this finding is related to post-mortem lividity due to gravitation of blood to the dependent parts. Whether or not all teeth undergo this change possibly depends on the ante-mortem vitality and vascularity of the pulp and is not related to the position of the head post-mortem. It would appear, therefore, that where pink teeth are noted to be present in a decomposed or skeletonized body, it is possible that death was due to unnatural causes possibly of an asphyxial nature and that a damp environment is involved" [4]. The variation in coloration of adjacent teeth is difficult to explain [38]. The variation as well as similarity in the color intensity of different pink teeth, on the basis of congestion and body position, mandates further observations.

Borrman et al. in their review on pink teeth stated "The change of a normal feature, in this case the change of color of a tooth from white to pink, could be dependent on the method of analysis. Therefore, in the future one should have some kind of quantification of the phenomenon which is being studied..... Other important factors to consider are the types of teeth that are examined and whether these teeth have restorations or not..."[16]. Although the authors stated this in context of antemortem pink teeth in the living [16], the same also applies to the observation of post mortem pink teeth. Van Wyk has suggested that histological evaluation of well controlled decalcified sections should be done due to the fact that the dentine could be involved to a higher or lesser degree [17].

Anatomical considerations

The pink coloration of the tooth has been found to be more deep and intense at the cementum enamel junction and cervical part of the root, fading at both ends and rarely found in apical portion of root [2,38]. In the case report of Ortman and Du Chesne, the pink discoloration was most pronounced at the neck of the teeth, however not all of the teeth were affected and the extent of the pink discoloration varied from tooth to tooth [27]. Stavrianos et al. have described the pink phenomenon to be an intra tooth variation with some teeth affected in the coronal dentine while the root dentine may be primarily affected in others [51].

In the study of Clarke and Law, two of the cases had teeth that were completely free of discoloration with pink teeth on either side [4]. Strangely, non-pigmented anterior teeth [lateral incisors] were present [4]. Borrman et al. have explained it on account of peculiar anatomy of the incisors [lateral] in comparison to other teeth [16]. Kirkham et al. also discovered completely unstained teeth in the pink teeth cases [5].

Gustafson has suggested for recording anatomical variations, pathology, dental procedure or trauma in non-pigmented tooth that may likely cause an interference with pigmentation [52]. It is further pertinent to mention that only a few experimental and other forensic studies are available to explain the time dependency, head position with inclination and other factors required to produce hypostatic hemorrhages [34,35,53]. But none of them have explained the effects of such conditions on dental tissue [34,35].

It may be possible that the time length required for congestive changes to appear in dental tissue may be considerably longer than that usually present in such situations. One important fact to notice is that the blood vessels of the dental pulp are closed in the tooth [16]. A raised congestive vascular pressure within the dental pulp, along with an enclosed vasculature, easily leads to hemorrhage and extravasations, particularly under conditions of prolonged head down, suffocation and strangulations [2,3,4,8,12,16]. It is further added that the persistence of soft tissue congestion after death is highly variable, as the same is usually drained away by the gravity hypostasis. In the same way, the congestion in pulp capillaries is likely to be drain away along with the soft tissue congestion of the face [16]. This is further obvious from the fact that an early separation/removal of constricting force/ligature from the neck in the immediate postmortem interval frequently leads to disappearance of facial congestion while the petechiae and larger congestive bleeds remain unaffected. A situation causing congestion with hemorrhage and extravasation of RBC's within dental pulp will enhance the possibility of PTP in comparison to other congestive modes of death [27].

It is not necessary for all the cadavers with prolonged post mortem interval

to depict this phenomenon, as even in cases of mass disasters, where the cause of death, surrounding environment and postmortem interval is the same for each dead body, each corpse does not necessarily reflect the pink tooth staining [13]. Thus, the presence and intensity of the pink characteristics vary between different cases, in cases with similar cause of death and also between different teeth of the same individual [2,16] This was also evident from the famous Christie [murders] Case file, in which only one of the eight strangled victims showed pink teeth at the time of analysis [10]. Overall, a definite evaluation of all the parameters that will come into play in a particular case is difficult to assess.

Age and sex predilection

The PTP has a biological predilection for manifesting in young victims because the dentinal tubules of young teeth have a larger diameter in comparison to older teeth [5,54]. Franco et al. have confirmed this fact in their case-specific characteristic study after considering highly specific parameters from previous studies [49]. Another responsible factor for the pink color preference in the young is a constant reduction in the volume of the pulp and pulp chamber space due to the deposition of secondary dentin as one ages [55]. Although the occurrence of pink teeth in the middle and advanced aged population cannot be completely denied [4,8,12,13]. The pink teeth have been described in deciduous dentition involving cases of unnatural child death [6,49].

Sakuma et al. investigated whether racemization can be applied for age estimation in the cases of pink teeth when whole tooth is used [56]. The pink teeth belonged to three cases while the normal teeth for control were five mandibular canines of known age [56]. Age of the pink teeth was calculated on the basis of regression formula obtained from the five control teeth. Based on the results of testing pink teeth of known age, authors suggested that racemization techniques allow for the age estimation of pink teeth using the same methods for normally colored teeth [56].

On the contrary, PTP has not shown any predilection for sex [49]. From the demographic point of view, however, the studies may depict a male directed biasing as the men are generally largely more involved and affected by violent deaths worldwide in comparison to women [57].

Stability of pink teeth

Various authors have reported a change in pink color to brown, grey or dark blue under special circumstances such as dry and light conditions [4,5,10]. The color can disappear by addition of oxygen [5]. The red color has been found persisting without change for 6 months in an atmosphere of carbon dioxide [4,5]. It has been also found that after prolonged storage for as long as a year at low temperature, the post mortem pink color gradually fades away [58]. In one study, the pink discoloration of the teeth persisted for one week under refrigeration while the discoloration faded in 1 day upon exposure of teeth to room temperature [59]. This has been our personal experience too where we made sequential observations on the loss of pink color in a living 9 years old child that presented with a single deciduous and immobile molar pink tooth (Figure 1(c), Figure 2 and Figure 3).

In the case described by Ortmann and Du Chesne, the pink color did not show any considerable fading after storage for 2 days at room temperature, for 6 months at -18°C and protection from air contact [27]. Ikeda et al. on the basis of their experimentation study involving scanning electron microscopy and electron probe x-ray microanalysis, found that tooth with less compact and more dentine tubules could be stained pink easily [30]. The authors further pointed out on the remarkable stability of the pink teeth phenomenon [30]. Overall, the stability of pink color tends to be dependent upon the surrounding conditions, yet capable of persisting for a longer time under selected situations.

Pink teeth and strangulation

In the study of Franco et al. who evaluated the significance of pink teeth in a retrospective case characteristic specific study, a few cases depicted numerous teeth with PTP [11,49,60]. This involvement was particularly noticeable in cases of homicidal strangulation where in two cases, 26 [81%] and 32 [100%] teeth depicted this finding [11,49,60].

Furthermore, our personal case as shown in Figure 4 [homicidal ligature



(1a) Immobile deciduous first molar showing pink discoloration of the crown. (Difficult extraction caused bleeding from gum above; rest of the teeth were healthy and unstained).



(1b) X-Ray image showing complete dentinal resorption and necrosis, likely responsible for pink discoloration.



(1c) Tooth immediately after extraction, showing fading of pink colour.

Figure 1. (Case 1) Single pink tooth in a 9 year old (living) child.



Figure 2. (From Case 1) Crown lost pink colour upon exposure to air (30 minutes post-extraction). Pink staining of neck and root is still visible.



Figure 3. (From Case 1) Appearance of tooth one week after refrigeration (temperature: 4 degree celsius). Almost complete loss of pink colour can be noticed.

strangulation] depicted PTP of an unprecedented intensity in all [i.e., 32] the permanent teeth [Author's [PM] personal case file]. Interestingly, the head and rest of the body were placed in a right lateral position due to tying and concealed disposal of the corpse in a deep dried up ditch. The effect of hypostasis induced bleeding and thereby pink staining was in doubt due to involvement of all the left sided [contralateral] teeth that showed coloration of an equivalent intensity. The postmortem interval was approx. 30 days [perpetrator's confession present. Our case supports further the fact of hypostatic non dependence of pink tooth phenomenon, as observed by Clark and Law [4].

Inoue et al. reported on pink teeth discoloration in two cases. In the first case, one tooth presented red discoloration and the cause of death was unknown, while in the second case the cause of death was suffocation by hanging, and all teeth presented discoloration [61]. We have similar experience in a case of suicidal atypical hanging (Figure 5). Here too we were unable to provide a definite exclusion of hypostatic congestion in a few left sided pink teeth, as the neck was slightly tilted to the right on account of an atypical position of the knot.

A case of homicidal strangulation has been reported by Soriano et al. where all the permanent teeth on the putrefied body of a man, who was kidnapped and murdered, depicted remarkable pink staining [11]. The presence of a wire around the neck and hemorrhage in the soft tissues were the diagnostic autopsy findings. Furthermore the identification was achieved on the basis of dental comparison. The postmortem interval was approximately 30 days [11].

Mittal et al. reported on the putrefied body of 23 years old male who was killed by ligature strangulation [60]. Presence of the mark of ligature along with fractures of thyroid and cricoid cartilages were found at autopsy. All [i.e. 32] the permanent teeth revealed PTP with the pink color primarily focused at the crown neck junction and fading at both ends [60]. In this regard it is important to add here that one of the authors [PM] had personally conducted the autopsy of the strangulation case mentioned in the report [60]. But, perhaps, on account

of misinterpretation of the statement, the study by Franco et al. considered the count as 26 by only considering the teeth visible in image of the report by Mittal et al. while in fact all [n= 32] the teeth depicted PTP [49,60]. [Author's [PM] Personal Case File].

The presence of numerous/all pink teeth mandates further explanations, as, as far as traceable from the available literature, no other cause of death is reported with such a dramatic observation [6,11,13,49,60,61]. Although in cases of drowned or immersed corpses, an identical observation is expected and multiple pink teeth has been also the finding in a number of cases but despite all these facts, an outstanding and a complete pink teeth count equaling strangulation is far behind [6,13,49,60]. Furthermore a careful count of the pink teeth in non-strangulation deaths reveals an almost uniform gradation depicting either the presence of a single or few pink teeth up to a maximum of 40% when excluding drowning while the drowning cases have gained a maximum peak of nearly 60%, after consideration of pink teeth/teeth present in the jaw [6,13,14,18,49,60,62]. Although even if the missing teeth are supposedly labeled as pink teeth, the percentage reaches to a maximum of 65% [6,13,14,18,49,60,62]. Furthermore in autopsy cases with isolated or few pink teeth, a possibility of presence of an antemortem pink tooth cannot be ruled out with certainty.

The presence of numerous pink teeth [viz. > 80%] along with their presence at non hypostatic locations, mandates further explanations to rule out a strong congestive asphyxial mode of death such as strangulation, traumatic asphyxias and hanging [atypical] in particular [4,11,12,49,62] while if the whole count [n=32] constitutes pink teeth, the suspicion becomes more stronger [Refer to Figures 4 and 5]. Attention is required towards involvement of whole tooth count in PTP among deaths from strangulation [11,49,60,62].

It is further worth mentioning here that not many studies have mentioned upon the total number and/or anatomical location of pink teeth [4,5,6,11,13,18,60,62]. A separate dental chart that may help in evaluating important anatomical and statistical parameters is largely unavailable.

Furthermore the comprehensive details of site of the body discovery and circumstances surrounding the death, even in known and identified bodies, are broadly lacking.

Brites et al. studied 21 cases of mechanical asphyxia that died from drowning, hanging and strangulation and found one case of complete hanging with pink teeth belonging to a 26 years old male [7]. Although no mentioning of postmortem interval or general status of the body was made, an early postmortem



Notes: Circumstances: Victim was murdered at his residence, body subsequently tied by means of a plastic rope in a right lateral position (with head in similar position) and disposed off in a dried up, deep ditch. **Cause of death** - Homicidal ligature strangulation. **Important observation:** All the permanent teeth (i.e., 32; hypostatic as well as non-hypostatic) depicted Pink Teeth Phenomenon. Post-mortem interval: 30 days (confession by the perpetrators).

Figure 4. (Case 2) Pink teeth in a heavily putrefied and decayed body, belonging to a 23 years old male.



(a) Free hanging with an atypical knot over left occipital-mastoid region.



(b) Pink teeth phenomenon. An intense pink coloration of most of the anterior and right posterior and a few left posterior teeth was present.

Notes: Place of hanging: Jungle with shaded and slightly humid surroundings and free access of air. Head and neck regions (above ligature) showed changes of partial mummification. Post-mortem interval: 6 days.

Figure 5. (Case 3) Pink teeth in a case of death from Suicidal hanging; 45 years old male. Suicide note found in the pocket.

interval could be presumed on the basis of study design [7]. Furthermore, no information was available regarding the number of teeth depicting PTP while at the same time no efforts were made to confirm the underlying etiology, so the possibility of an antemortem pink tooth could not be completely ruled out [7,22-25]. But in a medico-legal scenario, similar observations instruct further

evaluation, in search for likely possibilities. Furthermore, the study supported the rare occurrence of pink tooth phenomenon [7].

An increased number of pink teeth in strangulation deaths may be on account of significant degree of cranial congestion [4,12,17,33,63]. While at the

same time, involvement of a few or absent pink teeth in neck pressure deaths may be due to involvement of a non-congestive mode of death such as carotid sinus reflex, predominant arterial occlusion, airway compression, different [slim versus obese] individual constitutions, as well as from the variable display of multiple mechanisms at the same time [33,39,49]. In this context it is further pertinent mentioning here that the infliction of a significant bleeding trauma or any instance compromising congestive mechanism before the strangulation process, as occurs in combined homicides, may largely dilute the possibility of cranial congestion [64]. This fact in combination with the anatomical hampering of tissues that usually takes place in putrefied and decayed corpses, may lead to an underestimation and thereby escaping detection of such situations.

A few and isolated pink teeth may also be the sole manifestation of putrefaction and humid surroundings in such cases [17]. The statement of hypostatic phenomenon in the occurrence of PTP is, however, not a hassle free conclusion [4] (Figures 4 and 5).

Brondum and Simonsen have stated *".....this might well be explained by venous congestion resulting from compression of the neck in cases of mechanical strangulation, though it is not always the case. The fact that the phenomenon does not occur in every case of strangulation or different forms of congestion, for example, acute fatal heart failure, indicates that factors other than mere blood congestion in the head must be presupposed. The present study shows that the time factor and the resulting postmortem decomposition undoubtedly play an important role, too [12]."*

Conclusion and Suggestions

It is difficult to propose any definite criteria that may enable the use of pink teeth in medico-legal context; still some important and hopeful indications may be given:

1. The possible mode of formation of pink teeth is a rapid increase in venous pressure in the pulp leading to extravasation of erythrocytes into pulp tissue and/or pulp haemorrhage. This is followed by autolysis of the pulp with diffusion of hemoglobin into the dentinal tubules.
2. A moist and humid environmental milieu seems to be necessary for the pink teeth formation, although the discovery of finding in mummified and dry corpses raises doubt over the exact prerequisite conditions.
3. In this regard, even minute details of the changes of decomposition in the head and neck area, as well as local atmospheric conditions in which the body has been found should be recorded and graded if possible, in search of a better understanding of the external factors that may influence the occurrence of PTP. An idea of average climatic conditions of the past few days, a month or so may be gained from local weather monitoring stations.
4. In cases of doubt, an effort must be made to ascertain the nature of crime scene [i.e., whether primary or secondary]. This may have an important bearing in criminal context. The help of a forensic taphonomist may prove helpful.
5. The occurrence of PTP is related to either a strong vital or post mortem congestion/hyperemia of pulp capillaries. This is presumably due to the fact that most of such cases belong to asphyxial deaths especially drowning where bodies are often positioned in a head down position. However the hypostatic dependence cannot be given an exception-free consideration, as few instances involving contra lateral pink teeth are on records; including our personal observations (Figures 4 and 5). Suspicious factors/circumstances may be present and require an exhaustive evaluation.
6. A strong congestive mode of death may lead to the development of PTP in several and even all the teeth and mandates a careful approach, particular if a hypostatic possibility can be definitely ruled out and/or several contralateral/non-hypostatic pink teeth are present. The attention may be focused towards an asphyxial deaths possibly strangulation and/or traumatic asphyxia and the autopsy mandates a careful approach accordingly.
7. In cases of deaths with a [likely] non congestive mechanism such as bleeding and shock, craniocerebral trauma and intoxications etc., certain parameters such as position of head, stage of putrefaction as well as calculation of probable time since death from postmortem findings and witness accounts should be made and documented. In cases of strangulation deaths with unstained teeth, possibility of a non-congestive mode of death and/or significant trauma priori cannot be completely ruled out.
8. An invariable allocation or presumption of head down posture in a drowned or any other body depicting PTP [esp. in multiple teeth] is a non-justifiable and unsound approach. A detailed evaluation of the scene including information regarding step by step body transportation from scene to the mortuary must be available. Although, the body position in a submerged corpse is multifactorial.
9. In cases of unstained teeth among pink teeth, the presence of artificial restorations, dental procedures, pathologies, anatomical variations, as well as a recent or old-healed dental trauma should be sought wherever possible. These factors may impart a different stain or even prevent pink pigmentation.
10. Minimum time duration of at least one week seems to be essential for the pink teeth staining with a peak in intensity reaching at about one month that may increase thereafter. However this is strongly dependent upon the factors that primarily affect the rate of tissue decomposition. Furthermore the time of pink teeth observation must be labeled as time of analysis and/or a minimum postmortem interval rather than a definite/total one. The phenomenon cannot appear immediately post mortem.
11. The fallen pink tooth may rapidly lose color upon air exposure if not properly preserved. Furthermore, the teeth may have loosened and fallen away in the decompositional context or during body uplifting as well as transportation. An effort should be made to search and recover as many teeth as possible in the body's vicinity as well at the scene, especially when the available teeth depict pink discoloration.
12. An extensive forensic research and studies concerning the effects of asphyxia and neck pressures on human dental tissues is the need of the situation. Cases with suspicious asphyxial deaths, particularly those brought in early postmortem interval should be subjected to a detailed dental examination for recording the possible pathological changes. Livores related effects of multiple postures on human teeth in different environmental milieu require thorough evaluation via experimental studies
13. The increased fibrinolytic activity in the pulp chamber in sudden modes of death, such as asphyxia and natural deaths keeps blood in a fluid state in the pulp chamber that further augments/enhances the formation of pink teeth. Cases of PTP in sudden natural deaths have not been reported or may be hidden in cases with unknown cause of death.
14. The phenomenon cannot be related to a definite cause of death due to non-specificity and multiple independent variables affecting pink tooth formation. However, from the scene evaluation and circumstances, including consideration of police and witness stories, and perpetrator confession[s], if available, it may be associated with the cause/manner of death, especially in the presence of numerous [viz. 80-90% of total count] and intense pink teeth that may possibly suggest a violent asphyxial death. This fact may carry important bearing in suspicious/ documented unnatural deaths. A definite conclusion in unknown/unidentified bodies where no relevant history and circumstances are available is not possible in this regard. Attention is required towards involvement of whole tooth count in PTP in cases of deaths involving fatal neck pressures.
15. Documentation of the pink teeth should at least contain a total as well as location specific count. A subjective grading of color intensity will be encouraging. It mandates inclusion in routine postmortem work. Preparation of a separate dental chart for such a process is highly recommended.
16. The finding needs to be viewed from as many directions as possible. Reporting of the observations that are based on sound medical grounds, through journals, books, conferences and other modes of publications such as magazines and newspapers may result in hopeful outcomes.
17. Putrefied corpses require a thorough and diligent autopsy equivalent to the fresh ones. Even an isolated finding in such cases, if interpreted on a sound and meaningful ground and in the hands of experienced forensic personnel, may emerge with a truthful revelation.

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