

*Review article***Medico-legal aspects of postmortem pink teeth****H. Borrman¹, A. Du Chesne², B. Brinkmann²**¹ Faculty of Odontology, University of Göteborg, Göteborg, Sweden² Institute of Legal Medicine, University of Muenster, Von-Esmarch-Strasse 86, D-48149 Muenster, Germany

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Summary. While the phenomenon of pink teeth has been known since 1829, when it was first described by Bell, its application in forensic medicine has been limited. Recently, however, attention was again focused on pink teeth in legal cases. The medico-legal implication was the use of pink teeth as a possible means of evaluating the cause of death. Pink teeth can occur during life and postmortem. Except for very few and poorly documented exceptions, they develop earliest after 1 to 2 weeks postmortem. Their chemical analogy is seepage of hemoglobin or its derivatives into the dentinal tubules. Prerequisites are hyperemia/congestion and erythrocyte extravasation of the pulp capillaries, furthermore autolysis and a humid milieu. Therefore, they are most often associated with water immersion. The intensity of characteristics varies between different cases and also between different teeth in an individual case. Since the ante-mortem prerequisites are non-specific and can be replaced by certain postmortem conditions, there exist until now no specific correlation to the cause of death. The phenomenon is very often seen in victims of drowning where the head usually lies in a head-down position. From this it can be assumed that pink teeth even if not identical to postmortem lividity can, at least to some extent, be considered as analogous. Since, there is no obvious connection between the occurrence of pink teeth and the cause of death, it may be concluded that pink teeth are not pathognomonic for a specific cause of death and this is therefore an unspecific phenomenon.

Key words: Pink teeth – Postmortem – Medico-legal aspects

Zusammenfassung. Das zuerst 1829 von Bell beschriebene Pink Teeth-Phänomen hat seither wiederholt bei der Untersuchung von Tötungsdelikten eine Rolle gespielt. Die postmortale Pinkfärbung der Zähne ist in der Regel frühestens 1–2 Wochen nach dem Tod zu beobachten. Dem Phänomen liegt das Einsickern von Hämoglobin oder von Hämoglobinderivaten in die Dentinkanälchen zugrunde. Voraussetzungen sind Hyperämie bzw. Stauungszustände, eine Erythrozytenextravasation aus den Pulpakapillaren, ferner Autolyse und feuchtes Milieu. Das

Phänomen ist daher meist bei Wasserleichen beobachtet worden. Die Intensität der Verfärbung variiert von Fall zu Fall und, innerhalb eines Falls unter Umständen von Zahn zu Zahn. Eine spezifische Assoziation des Phänomens mit bestimmten Todesursachen ist nicht nachweisbar. Postmortale Bedingungen spielen für die Entstehung der Pinkfärbung eine wesentliche Rolle. Nicht selten ist sie bei mit abhängendem Kopf treibenden Wasserleichen zu beobachten. Insofern ist Analogie zur postmortalen Hypostase naheliegend. Da das Phänomen in Verbindung mit ganz unterschiedlichen Todesursachen (Ertrinken, Verbrennen, CO-Intoxikation, Strangulation u.a.) beobachtet wurde, kann es keinesfalls als pathognomisch für eine spezielle Todesursache angesehen werden.

Schlüsselwörter: Pink teeth – Postmortale Veränderungen – Rechtsmedizinische Aspekte

Introduction

We do not know when the phenomenon of postmortem “pink teeth” (Figs. 1 and 2) was first observed. However, the first description of pink teeth in victims of hanging or drowning was made by Bell in 1829. However, little attention was paid to this phenomenon for many years and it was not until about one hundred years later, in 1941 that it was again observed by Kato.

The first application of pink teeth in forensic medicine was the Christie murder case with a possible association with strangulation and carbon monoxide poisoning. The pink teeth from one of the victims were subjected to extensive histochemical and spectroscopical analyses (Miles et al. 1953). Since then, there have been several reports on pink teeth (Beeley and Harvey 1973; Clark and Law 1984; Koreyuki et al. 1993). During the last few years, the interest in retrospectively studying the occurrence of pink teeth has increased (Furuhata and Yamamoto 1967; Bröndum and Simonsen 1987; Van Wyk 1988a). It is interesting to notice the difference in occurrence or rather the registration of pink teeth cases because Kirkham et al. (1977) noted 10 cases over a period of 6 months, while Beeley and Harvey found 5 cases over a period of 3 years. Moreover, pink



teeth have been described in victims of drowning, hanging, knifing, barbiturate poisoning, carbon monoxide and CO₂ poisoning. In addition, pink teeth have also been observed in many cases, where the cause of death was not known.

Although in our experience, more attention has been paid to pink teeth in the forensic community recently, it is not believed to be a common occurrence (Pilz et al. 1980). Some references do claim that Gustafson, who published his book on Forensic Odontology in 1966, stated that pink teeth are a constant finding. However, recent personal communication with Gustafson in 1993 revealed that he stated that postmortem red colouration is seen in drowned victims and that the colour is dependent on time. Moreover, he strongly points out that he has not performed a systematic study with the specific aim to investigate the "pink teeth" phenomenon. In this context another relevant and interesting case described in the literature is the Christie case (Camps 1953) in which only one of the eight strangled victims had pink teeth at the time of the analysis. It is also interesting that Whittaker et al. (1976) noted that the pigmentation was more marked in strangled hamsters than in poisoned animals. Undoubtedly, the forensic pathologists must have observed the phenomenon more than occasionally in humans, presumably most often in highly decomposed bodies especially relative to drowning/water immersion and carbonmonoxide-poisoning, but they have rarely commented about it in their reports (Whittaker et al. 1976).

Therefore, the aim of this review was to collect information from the literature regarding postmortem pink

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Fig. 1. Pink teeth in a drowned victim. (Courtesy Dr B. Woxberg, Göteborg, Sweden)



Fig. 2. Pink teeth in a victim found in the woods. (Courtesy Dr B. Woxberg, Göteborg, Sweden)

teeth. The questions that will be dealt with are: what, when, and why?

Pigmentation of teeth

Antemortem data

Permanent or transient pigmentation of teeth can appear due to extrinsic or intrinsic causes (Padayachee 1989). The changes can be generalized or localized. In clinical practice, the most commonly observed discolourations are brown, grey or black. In a living person, pink discolouration of teeth can also occur in single teeth in patients suffering from typhoid disease (Miller 1957). Transient pink discolouration of single teeth can occur during dental treatment in connection with preparations involving dentine, which may cause disturbances in the microcirculatory system of the pulp. This could in turn result in vascular stasis and/or hemorrhages leading to a further increase of vascular stasis in the pulp (Grayson et al. 1986; Bergenholz 1991). Transient pink/red discolouration due to tooth trauma can also be found (Giunta and Tsamtouris 1978). In these cases, the tooth eventually becomes permanently grey or black because of necrosis of the pulp. Furthermore, permanent pink teeth can occur in isolated teeth during life by internal resorption due to the formation of pathological granulation tissue and giant cell accumulation within the dental pulp (Auslander 1967; Grossmann 1984). As stated by Ingle (1985), an isolated tooth can appear pink when the pulp is visible because of the destruction of the hard tissue of the crown. The synonym for internal resorption is also in this case "pink tooth". However, it has to be remembered that a permanent pink or red discolouration of isolated teeth is quite a rare phenomenon in clinical dentistry, which was shown by Stanley et al. (1978). They reported red discolouration in only 2 teeth (2.5%) in their material comprising 79 teeth. It is however, a well known fact, that tooth discolouration can be induced by endodontic sealers. This was demonstrated by Van der Burght and Byrne (1986) in their studies on staining patterns in dental hard tissues experimentally discoloured with endodontic sealers through the pulp tissue. Their results show that, Diaket and Tubli-Seal caused a mild pink discolouration while Riebler's paste caused a severe dark red stain of the dentine without involvement of the enamel.

The change of a normal feature, in this case the change of colour 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. As visual inspection was the method of choice in the past, this has not been a matter of great concern. Other important factors to consider are the types of teeth that are examined and whether these teeth have restorations or not. Let us assume, that a tooth has an extensive restoration, which caused the pulp to decay which in turn could result in a change in colour of the tooth to grey, if it is not properly treated. If on the other hand, an obliteration of the pulp occurs the tooth will turn yellow. Thus, some teeth may not respond as the others

with a development of postmortem pink colour. The differential diagnosis of ante-and postmortem pink discolouration 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 discolouration.

Postmortem data

The term "pink tooth" in this article, refers to a pink to dark red ("port wine") postmortem discolouration of the dentine in usually more than one tooth (Van Wyk 1987). The discolouration is most pronounced in the cervical part of the tooth both in experimental studies and human case work (Whittaker et al. 1976). The pigmentation, as evaluated by histology, is seldom found in the apical part of the root. The distribution of pink teeth can vary in a mouth and it is not necessary that all teeth are involved (Whittaker et al. 1976; Van Wyk 1988a). This is in accordance with the results from experiments with hamsters who were strangled or given an overdose of pentobarbitone (Whittaker et al. 1976). Their results show that pigmentation was not seen in all animals, the degree of pigmentation was not constant and the pigmentation usually decreased in the more posterior teeth. The latter is in accordance with the description by Van Wyk (1987). He noted that the pigmentation was more prominent in the anterior teeth in some of his 21 cases. On the other hand, according to our experience, completely unstained teeth can be found in "pink teeth cases" (Kirkham et al. 1977). Interestingly, anterior teeth (incisors) could be unpigmented (Clark and Law 1984). However, for some of these cases, it cannot be excluded that lateral incisors for example without pigmentation could be non-vital due to necrosis of the pulp. This is not uncommon for lateral incisors due to their anatomy (deep palatal groove leading to short distance/or communication into the pulp). As has been shown by Whittaker et al. (1976), the variation in colouration of adjacent teeth is difficult to explain. However, as was pointed out by Van Wyk (1988a), the handling of the body after death might be a factor to consider if one assumes that the accumulation of blood due a prone position of the body, is the cause of the staining of the teeth. He described unstained teeth even though those teeth were vital and mentioned that if the bodies had remained in one position after death the staining patterns might have been more uniform. He also states that if pink teeth are part of the "livid stain" manifestation, several adjacent teeth should have similar pulpal features.

Under special circumstances (dry and light conditions), the pink colour will change to brown, grey or dark blue (Miles et al. 1953; Kirkham et al. 1977; Clark and Law 1984). Also, it has been found that after prolonged storage for as long as a year at low temperature, the postmortem pink tooth colour gradually fades away (Sognaes 1977). Furthermore, the author describes that certain types of fixative, such as 70% alcohol, may cause a pinkish discolouration of the teeth due to "the blood production that will seep into the dentine because of a delay in

pulp-tissue penetration and fixation". Nonetheless, if oxygen is added, the colour can disappear (Kirkham et al. 1977). On the other hand, according to Kirkham et al. (1977) and Clark and Law (1984) the red colour can persist without change for 6 months in a carbon dioxide atmosphere. Recently, Koreyuki et al. (1993) reported that the pink discolouration of the teeth remained for one week under refrigeration while the discolouration faded in 1 day if the teeth were exposed to room temperature.

However, it has to be pointed out that we do not know the actual frequency of the phenomenon because in some of the retrospective studies not all jaws/teeth might have been examined thoroughly. It should therefore be stated in the forensic report that the teeth have been examined and the findings are negative. Furthermore, it can be assumed that the method applied in the retrospective studies and in the case reports has been examination with the naked eye. We are not aware of any recommendations for light sources if the investigation is performed under artificial light. As is known from other fields of investigation, e.g. judgement of livores, reddish discolourations can easily be masked and therefore overseen if inappropriate artificial light is used. Furthermore, as suggested by Van Wyk (1988a) 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.

Pink teeth – causes

Pink teeth have most often been observed in victims of drowning where the head is usually positioned below the trunk. Therefore, it can be assumed that pink teeth, if not completely identical to livores can at least to some extent, be considered as their analogy (Simpson 1974; Whittaker et al. 1976; Van Wyk 1987, 1988a). In this context, it could be important to consider the fact that the blood vessels of the dental pulp are closed in the tooth.

In order to study the local causes of pink teeth, the dental pulp as well as the dental hard tissues have been studied. But, as was pointed out by Bell in 1829, the enamel was totally free from discolouration. This is in accordance with Van Wyk (1988b) who states that the enamel is too dense to stain. The phenomenon is more pronounced in younger individuals because the dentinal tubules become narrower and/or obliterated with age and become less penetrable due to this occlusion process. Thus, the staining pattern in the dentine and the pulp can be explained on morphological grounds (Van Wyk 1987). In fact, using scanning electron microscopy and electron probe X-ray microanalysis, Ikeda et al. (1988) found that pink teeth could occur more easily in teeth in which the dentin was less compact and contained more dentinal tubules.

The phenomenon is more common in victims where sudden death occurred (Van Wyk 1988a), because the blood will remain liquid. It has been suggested that either the coagulation process is inhibited or fibrinolysis is activated after sudden death (Mizutani et al. 1978). The mechanisms behind this phenomenon were further investigated by Schleyer (1950), Harms (1971), Chaumont et

al. (1982), Berg (1984), Takeichi et al. (1985) and Ikeda et al. (1988) in experimental animals and in deceased persons. They found an increase in fibrinolytic activity which was affected by the method of sacrifice and also in human cadavers after rapid death the fibrinolytic activity and the catecholamine levels were high. Furthermore, it was concluded that the fibrinolytic activity and the catecholamine level were higher after death from O₂ deficiency than after death from other causes.

The increased pressure of the blood vessels in the pulp will initiate an extravasation of red blood cells. After lysis of intra- and extravascular red blood cells, the haemoglobin and its derivatives will penetrate the dentine tubules by diffusion leading to red colouration. Beeley and Harvey (1973) confirmed the identity of haemoglobin or its derivatives by iso-electric focusing. They also stated that spectral data indicated the presence of carbon dioxide, but not carbon monoxide. Furthermore, they commented that the preparation of the sample for spectral analysis resulted in a loss of pink colour. Using thin layer chromatography and spectrophotometry, Clark and Law (1984) demonstrated the pigmentation to be protoporphyrin. In this context, it is interesting to note that Van Wyk (1989), using histochemical techniques, ruled out staining from hemosiderin, bile and bile-related pigments, and porphyrins. Based on their experiments on dogs, Kirkham et al. (1977) stated that heat and cold would accelerate the haemolysis. Camps (1953) and Beeley and Harvey (1973) suggested that carbon monoxide, which forms unstable complexes with postmortem haemoglobin, could be involved in the development of pink teeth.

Thus, the blood accumulation in the head is either caused by congestion or by a postmortem head-down position (Brøndum and Simonsen 1987). Similarly, Van Wyk (1987) stated that drowned victims often float with their head in a downward position. There are two reasons why bodies immersed in water have congestion in the head. Pre-final insufficiency of the right heart leads to congestion relative to the vena cava superior. A downward position of the head leads to the same result postmortem. Also, as mentioned by Sainio et al. (1990) pink teeth, as seen in drowning cases, is explained by "hypotonic haemolysis, outside pressure of the water and head-down position of the drowned person". However, it has to be remembered that in cadavers immersed in the water the outside pressure is equivalent to the inside pressure.

The condition of the surroundings, for example humidity and temperature of the bodies with pink teeth, has been proposed to favour the diffusion of the blood (or a fluid containing haemoglobin or its degradation products produced by postmortem decomposition) in the pulp (Clark and Law 1984) into the tubules of the dentine, thus increasing the discolouration (Kirkham et al. 1977; Pilz et al. 1980; Brøndum and Simonsen 1987; Van Wyk 1988a; Sainio et al. 1990). Thus, in summary, to cite Van Wyk (1988a), certain events must occur causing the pink teeth to appear; accumulation of blood in the pulp followed by haemolysis of the red cells and seepage of the haemoglobin into the pulp whereafter diffusion into the dentine takes place. Furthermore, Van Wyk (1988b) after interpreting the results from his *in vitro* study, states that au-

tolysis of vessels cannot be the only explanation as to why the pigment leaves the blood vessels so soon after death. He proposed that there is an increased permeability of the capillaries soon after death which allows seepage of the pigment into the pulp and dentine.

Pink teeth – time dependency

From the abovementioned observations it is obvious that the time of detection of the pink teeth is possibly not the same as the time of occurrence. The time of registration of postmortem pink teeth has been very variable; 24 hours – 94 years (Kirkham et al. 1977; Camps 1953; Van Wyk et al. 1990). It is said that pink teeth do not occur immediately after death. In support of this statement 17 bodies recovered from the sea at a depth of 200 feet, 96 hours after a civilian helicopter crash, did not have pink teeth (Sims 1983). Indeed, according to Whittaker and MacDonald (1989), the evidence suggests that pink teeth are not apparent in the first week and 1½–2 weeks after death. In connection with this, it should be mentioned that Van Wyk (1988b) demonstrated pink teeth experimentally on day 6 and found a peak in the colour up to the 18th day. In order to imitate pulpal autolysis, Van Wyk (1988b) produced pink teeth *in vitro* with cadaver blood (postmortem period 8–58 hours) to stain longitudinally sectioned teeth. From that study, it was concluded that pink staining can only occur after haemolysis and that the phenomenon becomes macroscopically obvious after about 6 days. This is due to the fact that the haemolysis is at its peak at this time. However, Sainio et al. (1990) found an increasing amount of “hemosiderin” in the dental pulp of rats 24 hours after death. In this context, it is interesting to note that De Jager (1963) found ruptures of the capillaries in the subodontoblastic layer from victims of hanging and in rats. Furthermore, since the incisor teeth of the rat are constantly growing ameloblasts also remain active and De Jager also demonstrated subameloblastic capillary ruptures. He did point out the difficulty in comparing results from animal experiment to human research data. Experimental research on animals has shown that specimens stored in the presence of moisture will stain faster and more intensely than if stored in a dry environment (Whittaker et al. 1976; Kirkham et al. 1977). However, this has been a well known fact, for many centuries. In addition, according to Laiho and Penttilä (1981) and Penttilä and Laiho (1981) who studied autolytic changes in blood cells and other tissue cells of human cadavers, red blood cells may remain viable for a long time in cadavers kept at +4°C. But, it is important to point out that systematic information on the temperature conditions for example is only available for the experimental studies. For this reason, comparisons between the results from the human case work and the experimental studies are not advisable.

Thus, the time of occurrence of pink teeth differs from one experimental study to the other. This might be due to differences in experimental design (extracted teeth, laboratory animals, cadaver temperature, environment temperature etc). For example, Whittaker et al. (1976) made their analysis on the occurrence of pink teeth from 1 week to 3

months after death. Therefore, from their data we do not know if pink teeth developed at an earlier time in their hamsters. However, interestingly, the pigmentation was more intense in the animals that were allowed to putrefy for 2–3 months compared to the results obtained after one month. Also, the colour was more intense in the animals that were allowed to putrefy in saline compared to those who were buried in earth. Since, there are factors and circumstances relating to the cause of death that may predispose the teeth to colour pink, the time aspect will be further discussed.

Pink teeth – cause of death

Studies on humans

In the published case reports, the reported time of discovery is of course not the same as the time of occurrence. The time has to be considered as the time of analysis, because we have no evidence of the presence of pink teeth before or after that time. This is an important legal consideration.

In the literature, there is not a strict connection between pink teeth and cause of death. Therefore, it is obvious that pink teeth could also occur in natural deaths, if circumstances are favourable. However, people who die a natural death are not usually placed with their head in a prone position to allow for the blood to drain to the teeth (Van Wyk 1988). It should be noted that the majority of the cases described in the literature were recovered from the sea or from a damp environment (Clark and Law 1984; Brøndum and Simonsen 1987). This is in accordance with experimental studies on animals (Whittaker et al. 1976; Kirkham et al. 1977). They have reported that the presence of moisture around the stored specimens greatly increases the rate of colouration and the incidence of pink teeth. Additionally, it has been proposed from animal experiments (Kirkham et al. 1977) and human data (Brøndum and Simonsen 1987), that heat may be a causative or contributing factor for the development of pink teeth. However, as demonstrated by Clark and Law (1984) heat from fire did not cause pink teeth in their series of 50 human cases. In this context, it should be noted that natural death was not reported in any of the red discolouration cases described by Brøndum and Simonsen (1987). According to Beeley and Harvey (1973) all their cases had met a violent death. In most of the cases reported, the cause of death was said to be drowning (Bell 1829; Beeley and Harvey 1973; Whittaker et al. 1976; Pilz et al. 1980; Brøndum and Simonsen 1987; Whittaker and MacDonald 1989). In fact, Van Wyk (1988a) reported that he observed pink teeth in all victims of drowning. But, it has to be emphasized that bodies recovered from water have not necessarily been drowned. 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. Furthermore, the fact that humidity may play a role in the development of pink teeth is supported by the fact that red colouration was found in the 10 cases of unknown death recovered from the water in the study by Brøndum and Simonsen (1987).

Pink teeth have also been described in victims of strangulation (Bell 1829; Kato 1941; Katsura and Shinomiya 1958; Whittaker and MacDonald 1989). However, in the 10-year retrospective study of 26 cases by Brøndum and Simonsen (1987) no known case of strangulation was noted. But, as pointed out by Clark and Law (1984), the variation in appearance of pink teeth and the fact that the phenomenon does not occur in all cases suffering similar causes of violent death is presently not known. Van Wyk (1988) concluded that "when teeth appear pink clinically they represent the most prominent form of postmortem staining and that a spectrum of minor staining patterns of the pulp and dentine exists". It has to be pointed out that only experimental studies, i.e. in vitro and in vivo, the latter involving animals, can be performed under controlled standardized conditions. In the retrospective studies, which are based on small and selected materials, the condition has also been found in victims of hanging, knifing, barbiturate and carbon monoxide poisoning (Beeley and Harvey 1973; Brøndum and Simonsen 1987; Van Wyk 1987). In these studies, pigmentation was found in one or more teeth from the victims. The complexity of the matter was demonstrated in the study by Van Wyk (1988) in which sections of teeth that were removed for age determination from unidentified bodies were reviewed 1–21 days after death. The causes of death were: natural causes, gunshot wounds, fires, train accidents, murders, explosions and unknown causes. In that study, no statistical correlation could be found between the cause of death, period after death or any of the pulpal features associated with the staining.

Conclusions

1. Pink teeth constitute a postmortem phenomenon which needs at least days or weeks to develop. A further post-mortem prerequisite is the existence of water or a high concentration of aqueous solution in the intimate surrounding of the teeth involved. After a year or so the pink teeth discolouration can gradually fade away.
2. The occurrence is obviously correlated with vital or postmortem congestion/hyperemia of pulp capillaries with or without extravasation of blood. – Further prerequisites are haemolysis either by autolysis or by osmosis leading to subsequent diffusion of haemoglobin into the dentinal tubules.
3. Since the process of haemoglobin penetration into the tubules is diffusion this will further require a highly humid milieu.
4. Since all prerequisites can occur postmortem as well as intravital and since many causes of death are congestion-related it is unspecific as to the cause of death.
5. The occurrence of pink teeth might be associated with causes of death correlated with prefinal congestion of the head but only in cases where postmortem congestion can be excluded. It's absence on the other hand cannot exclude such a condition.
6. In cases where early postmortem external examination of the corpse by an expert has revealed congestion of the face, pink teeth is not an appropriate tool to confirm or to exclude this observation.
7. In cases where early postmortem autopsy has been performed it is improbable that pink teeth will occur because the congestion of pulp capillaries will disappear as with the soft tissue of the face.
8. So far, the occurrence of the pink teeth phenomenon has not yet been observed under the circumstances of a dry milieu e.g. incipient mummification.

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