Zvi Metzger, [1] *D.M.D. and Amos Buchner,* [2] *D.M.D., M.S.*

The Application of Tetracyclines in Forensic Dentistry

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ABSTRACT: Therapeutic administration of tetracyclines, widely used antibiotic drugs, permanently labels layers of dentin that are calcifying at the same time. A method is described for detecting and photographing these stained layers of dentin. The presence of tetracycline-labeled dentin layers in the teeth of subjects of a forensic science investigation can be used for the individualization of specimens as well as to provide information about the age of the individual. When compared to medical records, the tetracycline-labeled dentin layers can also assist in establishing the identity of the subject. The interpretation of tetracycline-labeled dentin layers and its pitfalls are discussed.

KEY WORDS: odontology, tetracycline, human identification

A dentist taking part in an effort to identify a corpse usually collects all the information available from the jaws and teeth and compares these findings with data obtained from the antemortem dental records. Some information, however, cannot be derived from a routine visual or roentgenographic examination and requires specific methods of investigation. One such area of information includes the effects of tetracycline on developing teeth.

Tetracyclines, when administered as a medication, also label tissues that are calcifying at the time of administration. However, whereas bone is constantly remodeling, dentin does not remodel, and thus the label can be observed and interpreted throughout the patient's lifetime and after his death [*1-4*]. This phenomenon can be used in forensic dentistry [*5,6*] in a manner similar to the use of a tree's annual rings to investigate the history of that tree.

The purpose of this paper is to demonstrate a method for the application of tetracyclines in a forensic dental investigation and to discuss its interpretation and pitfalls.

Methods

The layers of enamel and dentin that are calcifying on the days of tetracycline administration incorporate the tetracycline as a complex [*2,3,7*]. These layers can be identified by examining a longitudinal section of the tooth.

When the longitudinal section is being prepared, an effort should be made to assure that the plane of the section will be at the widest diameter of the root and root canal.

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[1]Director of research laboratory, School of Dental Medicine, Tel Aviv University, Ramat Aviv, Israel; currently, National Institute of Dental Research, Bethesda, Md.

[2]Professor of pathology, Sackler School of Medicine, and head, Section of Pathology and Oral Medicine, School of Dental Medicine, Tel Aviv University, Ramat Aviv, Israel.

This is essential for achieving accurate results when different teeth are compared with each other. Since many teeth have curved roots, a Carborundum® wheel mounted in a straight dental handpiece is used for cutting. The tooth is ground gradually on its mesial surface, and the plane of the cut surface is established along the plane of the root canal.[3]

The layers stained by tetracycline appear as yellow-brown lines when examined in daylight. A more accurate method for detecting even very thin layers involves the use of ultraviolet illumination[4] in a darkroom [*5,6*]. In this method, the stained layers appear as brilliant gold-yellow lines on a dark bluish background and can be photographed. The use of photography permits better contrast and accuracy than can be achieved with a visual examination in the darkroom. The use of a yellow filter[5] and a color reversal film[6] provides transparencies in which the lines are seen in high contrast.

Application and Interpretation

To interpret the pattern of tetracycline labeling, one needs a basic knowledge of the schedule of the development and calcification of the dentition. One can use the data published by Moorrees et al [*8*] and by Schour and Massler [*9*] as a guideline. However, since these data are averages, there are limitations in their application to individual cases. Thus, a given developmental stage can only suggest an estimated age, not provide an accurate one.

The calcification of the human deciduous dentition starts at four months in utero and continues until the age of three years. The permanent dentition starts its calcification at birth and is completed at 18 years of age [*9*]. Any episode of tetracycline therapy during these periods is recorded as a stained layer in the enamel and dentin of the teeth, marking their stage of development at the time of drug administration.

Tetracyclines were widely used during the last two decades and the incidence of teeth stained by tetracycline is rather high. Egan et al [*10*] reported the incidence to be as high as 80%, and an incidence of 70% was reported by Stewart [*1*]. The high probability of finding tetracycline marks in the teeth of young persons, combined with developmental data, can be used in forensic dentistry in several ways. Examples of such uses are given below.

Individualization

Every tooth that has not completed its formation when tetracycline was taken will exhibit a tetracycline mark at the level corresponding to its stage of development at that time. The following cases will demonstrate three different situations possible in a forensic dental examination.

Teeth from One Individual—Two teeth were obtained from an individual who had taken eight doses of tetracycline until about the age of six years and two additional doses at ten years of age. In both teeth, eight lines appear in the coronal dentin formed up to the age of six years, and two additional lines are seen in the root, corresponding to the developmental stage of these teeth at the estimated age of ten years (Fig. 1). Since the reported incidence of tetracycline-marked layers in teeth of young populations is rather high [*10,11*], there is a probability that two children may have had tetracycline therapy at the same age; thus, if only one or two lines are seen, it is impossible to draw a final conclusion as to whether the two teeth belong to the same individual. However, when

[3]Z. Metzger and M. Tagger, unpublished data.
[4]Intensive ultraviolet source, 366 nm; C. Desaga GmbH, Heidelberg, W. Germany.
[5]No. 15 filter, Eastman Kodak Co., Rochester, N.Y.
[6]Ektachrome, Eastman Kodak Co., Rochester, N.Y.

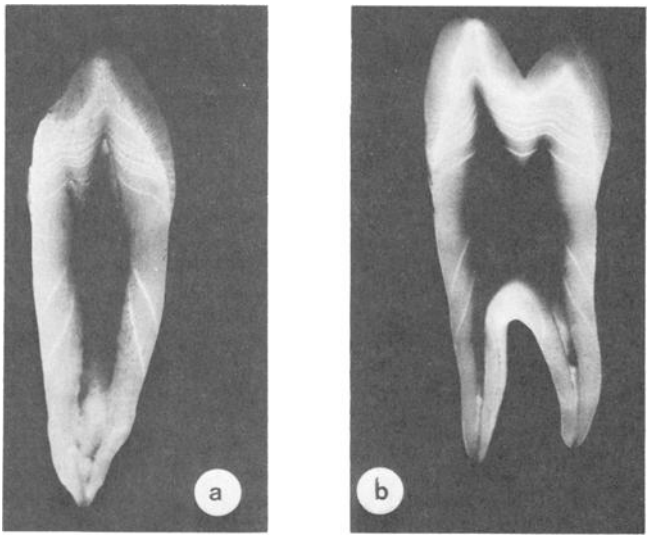

FIG. 1—*Two teeth, a mandibular left first premolar* (a) *and a maxillary right first premolar* (b) *revealing an identical pattern of tetracycline lines. Eight doses of tetracycline were taken between the ages of three and six years and two additional doses were taken at the age of ten years.*

several lines are found, the same pattern in both teeth provides more conclusive data (Fig. 1).

Teeth from Different Individuals—Remnants of an unknown human cadaver were found in the desert in Israel. The remnants included a fragment of a left mandible and a fragment of a right maxilla. After the specimens were studied, there was some suspicion that the remnants were from two different individuals. In an attempt to solve this problem, it was decided to look for tetracycline marks in the available teeth. The maxillary right central incisor and the mandibular left cuspid were extracted from the jaws and cut buccolingually through the long axis of the tooth to reveal the layers of dentin. The sections were examined in a darkroom under ultraviolet illumination. The incisor (Fig. 2a) had four thin brilliant yellow layers, the first in the coronal dentin close to the cemento-enamel junction (CEJ), the second 1 mm apical to the CEJ, and two layers halfway down the root. These lines indicated four episodes of tetracycline therapy. By using the data of Schour and Massler [*9*], it was estimated that the individual had been treated with tetracycline at the ages of 3.5 and 4 years, and twice at the age of 7 years. The cuspid (Fig. 2b), on the other hand, revealed no signs of tetracycline. Therefore, the segments of the maxilla and mandible belonged to two different individuals, and by using the data described in the section Age (below) we concluded that the person to whom the maxilla belonged was not older than 31.5 years.

In Fig. 3, the mandibular left first bicuspid (Fig. 3a) belongs to a person who had two doses of tetracycline at the estimated age of ten years. If the second tooth (maxillary left lateral incisor, Fig. 3b) belonged to the same person, one should expect a tetracycline line at its apical area (Fig. 3c). The absence of a line in this area indicates that these teeth belong to two different individuals.

Inconclusive Data—The maxillary right second molar (Fig. 4a) exhibits two lines at the apical region, which correspond to the stage of development of this tooth at 13 years of age. The maxillary left lateral incisor (Fig. 4b) does not show any tetracycline line. No conclusion can be drawn, however, since the medication was given at an age in which the formation of the maxillary lateral incisor had already been completed.

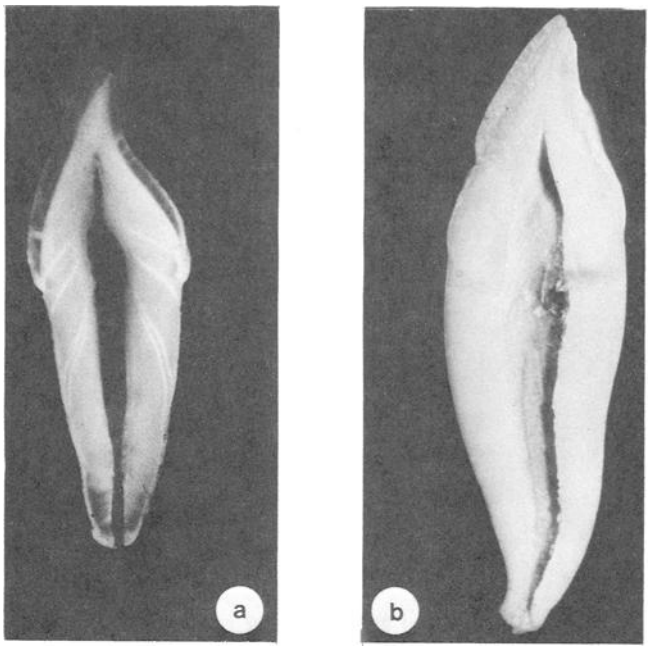

FIG. 2—(a) *Maxillary right central incisor from the segment of the maxilla, revealing four tetracycline lines—two near the cemento-enamel junction and two at the middle area of the root.* (b) *Mandibular left canine from the segment of the mandible, revealing no tetracycline lines.*

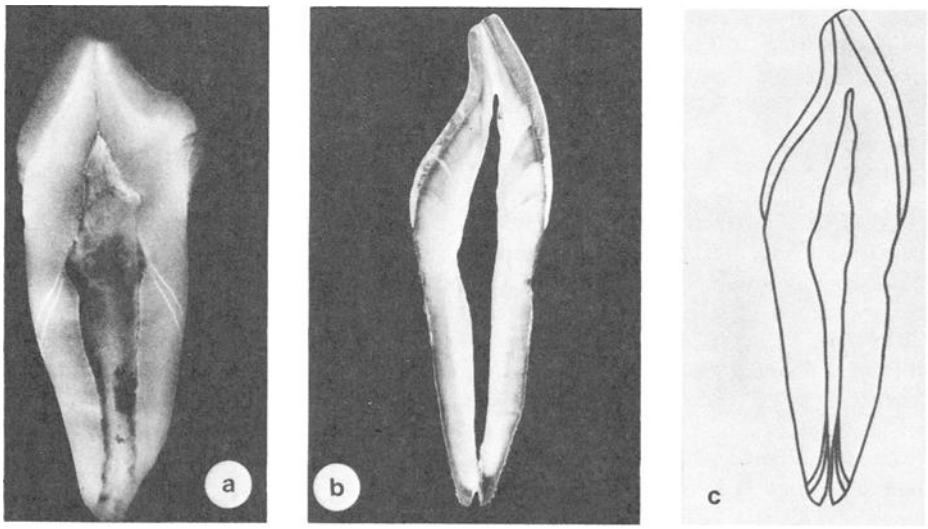

FIG. 3—*Two teeth which cannot belong to the same individual. The mandibular left first premolar* (a) *is from a person who had two doses of tetracycline at the age of ten years. The maxillary right central incisor* (b) *cannot be from the same individual because it does not reveal any tetracycline lines. If this central incisor had been from the same person, it would demonstrate two tetracycline lines at its apical area, as shown in the theoretical graphic illustration* (c).

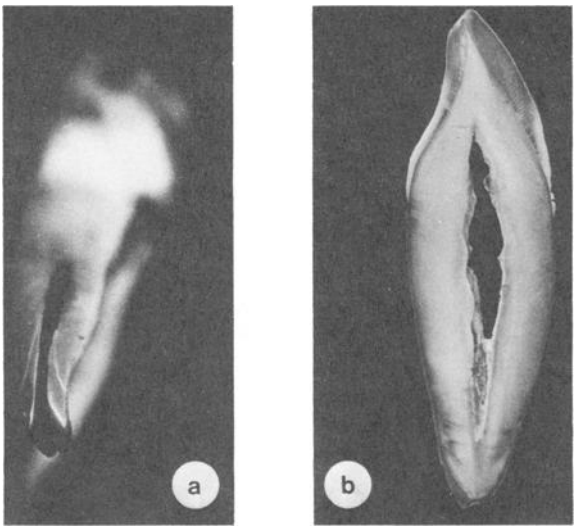

FIG. 4—(a) *Palatal root of a maxillary right second molar; two tetracycline lines are seen in the apical area.* (b) *A maxillary left lateral incisor with no tetracycline marks. No conclusions can be drawn since the lateral incisor had finished its formation three years before the medication was taken at an estimated age of 13 years.*

Although the data that have been used for interpreting the tetracycline labeling have been known for a long time [*9*], misinterpretations are not uncommon. For example, in the paper by Wallman and Hilton [*4*], a longitudinal section of a tooth is shown in which four tetracycline lines, two in the coronal dentin and two in the apical area, can be seen. The authors refer to these lines as resulting from two doses of tetracycline with a four-week interval in between, producing two separate lines in the dentin, both in the crown and in the root. Actually, these lines indicate that tetracycline was taken in four doses: one immediately after birth, a second four weeks later, and two additional doses between the ages of 1 and 1.5 years.

Age

Tetracyclines were first used for therapeutic purposes in 1948, and their use has become widespread since 1950. In Israel, the medication was first used in 1950 and since 1960 it has been widely used by the "Labor Sick Fund," which provides medical care to 80% of the population of Israel. This information can be very useful in a forensic dental examination. For example, in the case of the unidentified fragment of a right maxilla presented above, a realization that the first treatment was given at the age of 3.5 years (maxillary cental incisor, Fig. 2a) and the knowledge that 28 years had passed since tetracyclines had first been used on a large scale made it possible to conclude (with reasonable accuracy) that the person from whom the tooth was extracted could not have been older than 31.5 years [*6*].

Identification

In those cases in which medical records of a missing person are available, information regarding tetracycline therapy can help in identification. The tetracycline lines observed in the dentin should be compared with the data from the medical records. There is a

chance, however, that tetracycline was taken without this information being recorded, and this possibility should be taken into consideration.

Because data in the literature are averages, a more accurate parameter for comparison with the medical records is the period between treatments. This period can be compared with the period calculated from the tooth. The calculation is made by dividing the distance between adjacent lines (measured along the dentinal tubules) by the daily rate of dentin apposition [*12*]. However, one should be careful in using the published information concerning the rate of dentin formation.

The case investigated by Cameron [*5*] is a good example to demonstrate the limitations of the data available in the literature. Cameron tried to correlate the pattern of the tetracycline labeling with the dates of tetracycline administration obtained from a missing person's medical records. In this case, one dose was given at nine months and three additional doses were given between 6 and 7.5 years. Using the kind of calculation mentioned above, he tried to match the tetracycline lines in the lower first molar with the recorded data but was not able to do so. Only when using half the reported rate of dentin formation could he match the lines with the records. His conclusion was that there is a discrepancy between the rate of dentin apposition in his case and the data published in the literature.

Our investigation of the literature revealed that this discrepancy could be expected because most of the data published by Massler and Schour [*12*], which were used by Cameron [*5*], refer to deciduous teeth. The information available from these authors concerning the permanent dentition is limited to the coronal dentin of the first permanent lower molar. No data are presented in their paper regarding the rate of apposition of the dentin in the roots of this tooth or in any part of other permanent teeth. According to their data, the rate of apposition of dentin in deciduous teeth differs at different levels of the tooth; the rate of apposition at the middle third of the root is about half the rate of apposition of coronal dentin. Therefore, one should be careful in using the rate of apposition of coronal dentin when doing calculations involving the radicular dentin. The possibility exists that the phenomenon reported in deciduous teeth may also be applicable to permanent teeth, which may explain Cameron's results.

Our review of the literature revealed no information regarding the rate of apposition of dentin in the human permanent dentition (except the coronal part of the first permanent molar). It is our opinion that these missing data are important for practical purposes in the field of forensic dentistry, as well as being interesting from a scientific point of view. Such an investigation could be carried out by using extracted teeth from persons whose medical records reveal several tetracycline treatments in the past.

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References

[*1*] Johnson, R. H. and Mitchell, D. F., "The Effects of Tetracycline on Teeth and Bones," *Journal of Dental Research*, Vol. 45, No. 1, Jan. 1966, pp. 86–93.

[*2*] Milch, R. A., Rall, D. P., and Tobie, J. E., "Bone Localization of the Tetracyclines," *Journal of the National Cancer Institute*, Vol. 19, No. 1, July 1957, pp. 87–93.

[*3*] Milch, R. A., Rall, D. P., and Tobie, J. E., "Fluorescence of Tetracycline Antibiotic in Bone," *Journal of Bone and Joint Surgery (American Volume)* (Boston), Vol. 40A, No. 4, July 1958, pp. 897–910.

[*4*] Wallman, I. S. and Hilton, H. B., "Teeth Pigmented by Tetracycline," *The Lancet*, Vol. 1, No. 7234, April 1962, pp. 827–829.

[5] Cameron, J. M., *Forensic Dentistry*, Churchill-Livingstone, Edinburgh, 1973, pp. 42-45.
[6] Lunt, D., "Identification and Tooth Morphology," *International Journal of Forensic Dentistry*, Vol. 2, No. 3, Jan. 1974, pp. 3-7.
[7] Urist, M. R. and Ibsen, K. H., "Chemical Reactivity of Mineralized Tissue with Oxytetracycline," *Archives of Pathology*, Vol. 76, No. 5, Nov. 1963, pp. 484-496.
[8] Moorrees, C. F. A., Fanning, E. A., and Hunt, E. E., Jr., "Age Variation of Formation Stages of Ten Permanent Teeth," *Journal of Dental Research*, Vol. 42, No. 6, Nov. 1963, pp. 1490-1502.
[9] Schour, I. and Massler, M., "The Development of the Human Dentition," *Journal of the American Dental Association*, Vol. 28, 1941, pp. 1153-1160.
[10] Egan, J. H., Tring, F. C., and Pront, R. E. S., "Tetracycline Deposits in Children's Teeth. Is It Related to Atmospheric Pollution?" *Journal of Dental Research*, Vol. 51, No. 5, Sept.-Oct. 1972, p. 1270.
[11] Stewart, D. J., "Prevalence of Tetracycline in Children's Teeth—Study II: A Resurvey After Five Years," *British Medical Journal*, Vol. 3, No. 5875, Aug. 1973, pp. 320-322.
[12] Massler, M. and Schour, I., "The Appositional Life Span of the Enamel and Dentin-Forming Cells," *Journal of Dental Research*, Vol. 25, No. 3, June 1946, pp. 145-150.

Address requests for reprints or additional information to
Zvi Metzger, D.M.D.
Bldg. 30, Rm. 325, L.M.I.
National Institute of Dental Research
National Institutes of Health
Bethesda, Md. 20014