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SCHREGER BANDS AND THEIR APPEARANCE  
IN MICRORADIOGRAPHS OF HUMAN  
DENTAL ENAMEL

by

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INTRODUCTION

Despite several separate studies the nature of the Schreger bands of dental enamel is still not agreed upon. Thus, the oldest, and most commonly held, opinion that the bands represent a phenomenon caused by the changing in direction of the enamel rods, is sometimes questioned. Instead various properties, such as intrinsic differences in mineralisation, are ascribed to the alternating bands. The strongest evidence quoted in favour of this relatively new opinion is the appearance of Schreger bands in microradiographs of enamel, which was first illustrated by *Hollander et al.* (1935).

In a recent study, however, results have been published (*Sundström*, 1966) which show that changes in the direction of the enamel prisms easily influence the wearing away of the enamel substance during grinding and polishing of the specimen. Thus thickness differences, which may account for the microradiographic appearance of the bands, may be produced in relation to the Schreger bands.

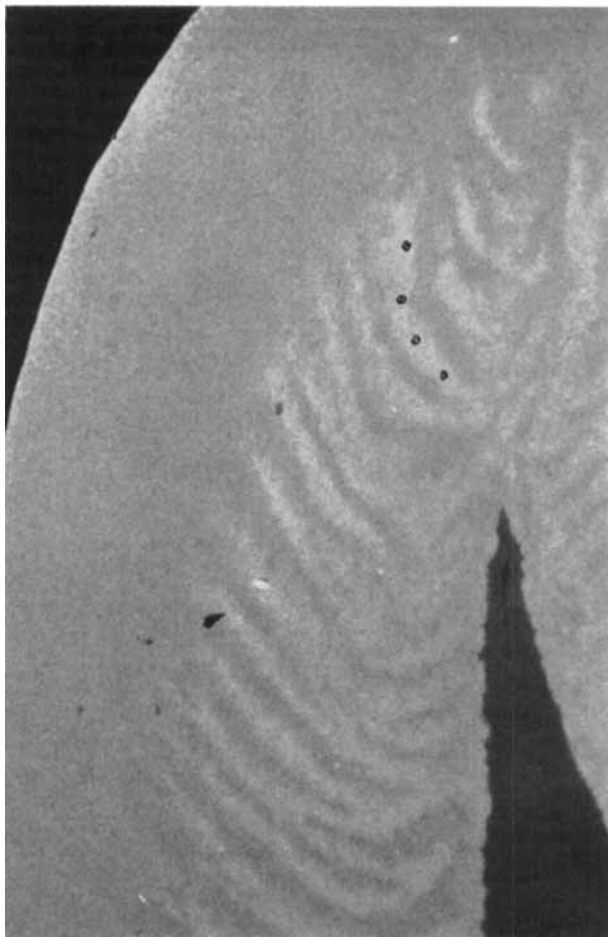


Fig. 1. Microradiograph (12 kV, 35 mA) of a thin ( $< 10 \mu$ ) ground specimen of adult human enamel showing emulsion density variations in relation to Schreger bands.

In this communication the relationship between Schreger bands and density variations in microradiographs of ground enamel specimens will be discussed. The density mentioned here will always be that of the microradiographic emulsion and does not refer to the density of the enamel. Specific differences in the appearance of the bands will be considered first, followed by a discussion on the frequency of occurrence of the bands.



Fig. 2. Transmitted light view of the specimen in Figure 1, photographed after etching and staining.

## RESULTS

### Description of band appearance

A typical microradiograph and the corresponding transmitted light image of a very thin (less than  $10 \mu$ ) tooth specimen prepared with the technique given earlier (Sundström, 1966) are shown in Figures 1 and 2 respectively. In this specimen minute differences in thickness relative to the Schreger bands have been

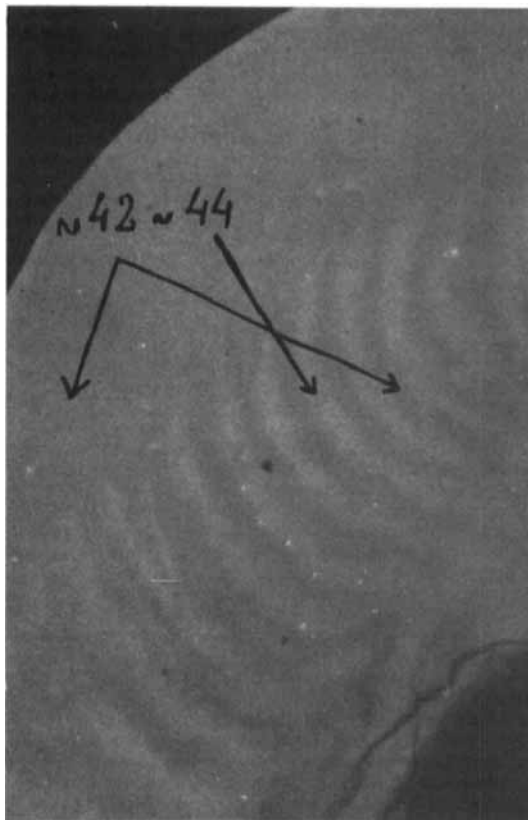


Fig. 3. Microradiograph (18 kV, 20 mA) of a 45  $\mu$  thick, wedge-shaped ground specimen of adult human enamel. Labial enamel, giving an appearance of white bands on a gray background. Figures refer to thickness in  $\mu$ .

found, a greater thickness existing in those alternating bands showing prisms oriented perpendicular to the specimen surfaces. This explains the white and dark bands seen in the microradiograph (exposure: Philips X-ray unit PW 1009, Cu target, 0 filter, 12 kV, 35 mA).

There is, however, something rather unusual about the microradiograph seen in Figure 1. This will be apparent if a comparison is made with the single microradiographic picture published by *Hollander et al.* (1935). Their enamel picture gives the general impression of alternating dark bands on a lighter background,

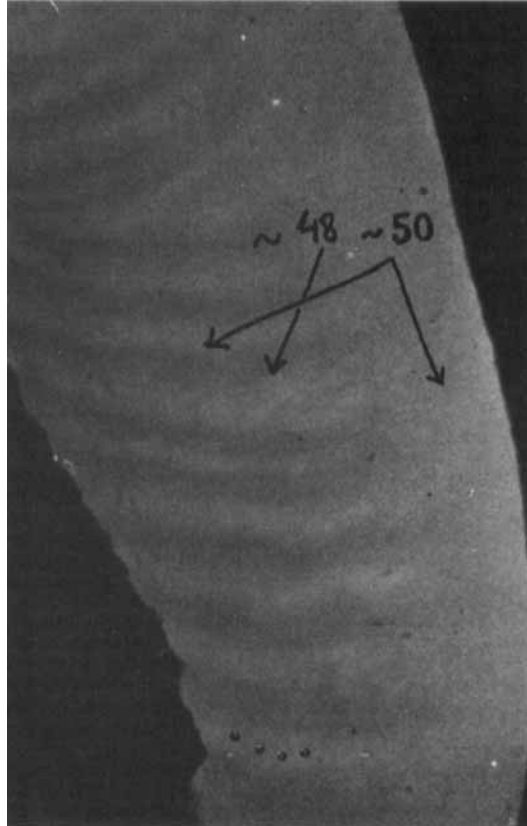


Fig. 4. Same specimen and microradiograph as in Figure 3. Lingual enamel, giving an appearance of dark bands on a lighter background. Figures refer to thickness in  $\mu$ .

whereas in Figure 1 the impression is exactly reversed. There may be a number of explanations for this difference in appearance.

#### 1. Influence of specimen preparation

One explanation of the problem of emulsion density differences outlined above can be given in relation to specimen thickness differences caused during specimen preparation (*Sundström, 1966*).

The specimen in Figure 1 was glued to a plane, non-resilient

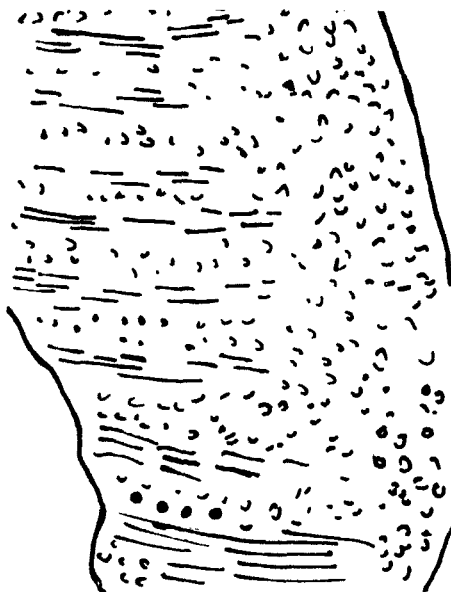


Fig. 5. Schematic drawing of possible prism arrangement within the specimen in Figure 4.

surface as support during grinding. This way of preparation has been shown to result in a very nearly plano-parallel specimen, the most important thickness variations occurring in the inner half of the enamel. If, however, a specimen is ground by hand without any extra support a high pressure will easily be exerted on the middle part of the specimen. This part is worn away rapidly and a microradiograph of the resultant specimen will show low emulsion density regions at the periphery of the enamel and increasingly higher density towards the dentine. This could simulate a higher degree of intrinsic mineralisation of the periphery. The emulsion density differences due to thickness variations of alternating Schreger bands will naturally still exist, but that at the enamel periphery will most readily equal those alternating bands which show low emulsion density. Thus an appearance similar to that given by *Hollander et al.* will be found.

A microradiograph (18 kV; 20 mA) of a wedge-shaped specimen will be used here as an illustration. Thus Figures 3 and 4

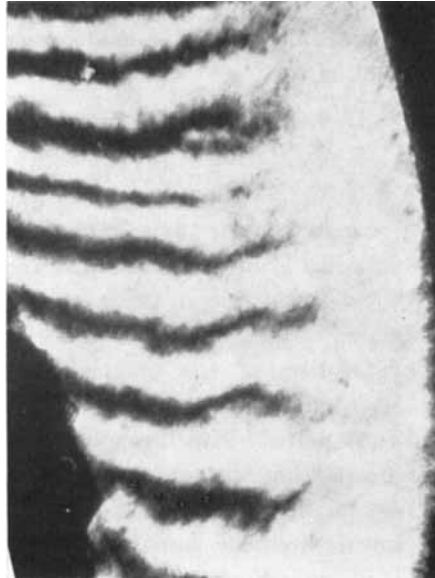


Fig. 6. Same specimen as in Figure 4, photographed between crossed nicols. Prisms arranged strictly perpendicular to the specimen ground surfaces are present only in the inner part of the enamel.

are parts of the same microradiograph, showing respectively the buccal (thin side) and the lingual (thick side) enamel of a pre-molar tooth specimen. Figure 3 has a general appearance similar to Figure 1, while Figure 4 resembles the picture of Hollander et al. (1935). The thickness distribution (in  $\mu$ ) of interest within the present specimen is indicated on the respective figures.

It might be argued that a plano-parallel specimen, which only shows thickness differences that equal those given for the specimen seen in Figures 1 and 2 could account for an appearance such as that seen in Figure 4. This is theoretically possible. The prism arrangement within a specimen could be supposed to be as shown in Figure 5, that is, with perpendicularly cut prisms also in the outer part of the enamel. This was certainly not the case with the specimen presented in Figure 4 (see polarised light photomicrograph of the same area, Figure 6). Furthermore, all trials made by the present author to prepare a bucco-lingual or mesio-distal specimen with prism arrangement as in Figure 5

have been unsuccessful. Prisms which are oriented most nearly perpendicular to the ground surfaces will always be found in the inner areas of the enamel.

### 2. Influence of etching

There is another way of specimen treatment which will readily account for the microradiographic appearance shown by *Hollander et al.* (1935). Thus if a ground specimen is treated with acid, even if this is only accidental due to the embedding material or to the staining, the resultant depth of etching will be strongly influenced by the direction of the prisms (*Gustafson, 1945*). Prisms which are oriented perpendicular to the ground surfaces will allow the acid to penetrate into the specimen and here etching may therefore be particularly marked. The loss of mineral will naturally counteract the original higher amount of mineral, due to greater thickness, in these same areas and thus at a certain stage reverse a microradiographic appearance such as that in Figure 1.

The influence of etching is shown here in Figures 7, 8 and 9. This 45  $\mu$  thick, labio-lingual specimen was taken from a premolar. To rule out any possible influence from enamel tufts the specimen was deliberately taken from an area away from the midline of the tooth, and so tufts could be easily recognized in the finished specimen. The first microradiograph (Figure 7) was exposed (18 kV; 20 mA) directly after specimen preparation. Then the specimen was etched and stained, photographed in transmitted light (Figure 8) and once again microradiographed under the same conditions as earlier (Figure 9). In Figure 7 the cross-marked area of the microradiograph, where the prisms are oriented perpendicular to the specimen surface (Figure 8), has a lower emulsion density as compared with its surroundings. In Figure 9 the appearance is reversed.

### 3. Influence of prism orientation per se

There is now still another possibility to account for a microradiographic appearance such as that of *Hollander et al.* (1935) and which is not linked to any specific specimen treatment such as the way of preparation or the use of acids in etching. This

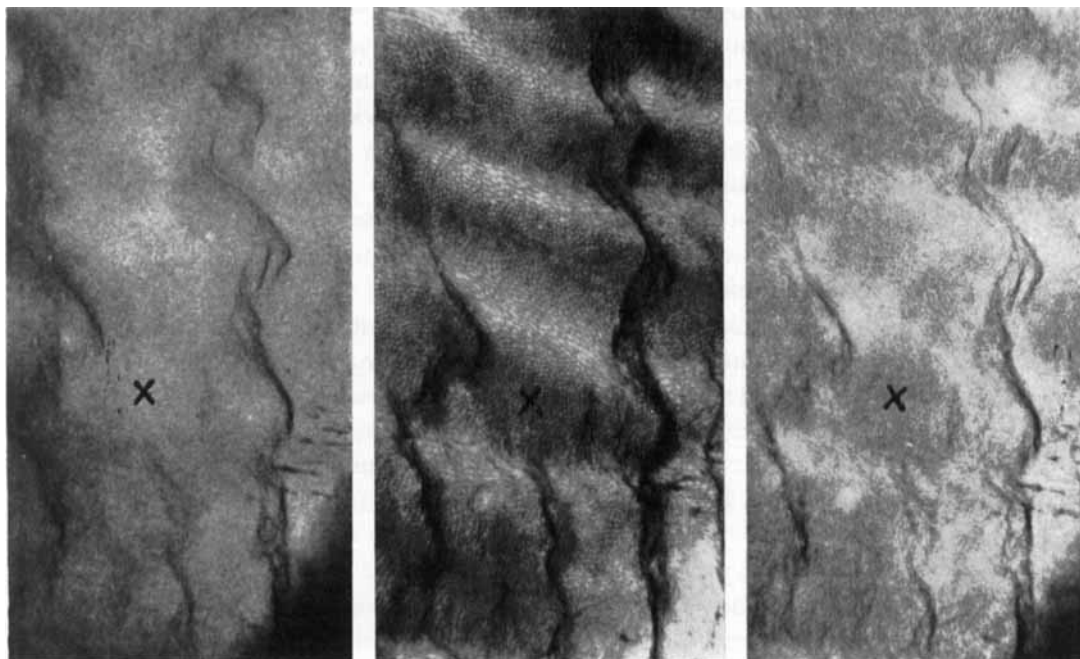


Fig. 7.

Fig. 8.

Fig. 9.

Fig. 7. Microradiograph (18 kV, 20 mA) of a  $40\ \mu$  thick labio-lingual ground specimen of adult human enamel. Cross-marked area is part of a Schreger band where the enamel prisms are oriented perpendicular to the specimen surfaces and shows up with relatively lower emulsion density than its surroundings.

Fig. 8. Transmitted light view of the specimen in Figure 7, now etched and stained.

Fig. 9. Microradiograph (18 kV, 30 mA) from the same specimen in Figures 7 and 8, but taken after etching and staining. Cross-marked area shows relatively higher emulsion density than its surroundings.

possibility is that a mere change of direction of the prisms will — in itself — be enough to explain the emulsion density differences in the microradiographs and implies, that *prisms oriented perpendicular to the specimen surfaces give rise to a relatively higher emulsion density.*

This opinion was expressed for the first time by *Krüger & Raktittis* in 1952. They wrote: "Werden jetzt in einem Zahnlängsschliff Prismenschichten etwa parallel zur Schliffoberfläche und andere mehr schräg oder senkrecht zu derselben verlaufend ge-

troffen, so ändert sich auch die anteilig verschieden getroffene Menge der Prismenscheiden, in denen ja die organische Substanz angereichert ist. Es gibt also das Durchstrahlungsbild bezüglich der Hunter-Schreger-streifen nur relative Verkalkungsunterschiede (auf den Schliff bezogen) wieder, die sich bei der Beurteilung der Kalkverteilung im Schmelz (als ganzes sehen) wieder ausgleichen". Whether areas, where the prisms were cut perpendicular to the specimen surface should give rise to a high or to a low microradiographic density was not, however, specifically stated.

*Amprino & Camanni* (1956) concluded that the explanation of *Krüger & Rakuttis* appeared convincing. *Amprino* and *Camanni* did, however, extend the base for the discussion in writing: "A difference in calcification exists between the prism proper and the interprismatic substance . . .", and continued: "As the orientation of prism bundles is different in contiguous Schreger bands, the X-ray absorption of enamel should vary therefore according to whether the prisms are cut perpendicular or parallel to their length, even if all the prisms in enamel are equally calcified and the thickness and the mineralisation of the interprismatic matter is the same everywhere". Though not specifically stated the pictures given by *Amprino* and *Camanni* points to the possibility that areas where prisms are cut perpendicular to the specimen surface would give rise to high microradiographic densities. In other words, a histological appearance exactly similar to Figure 2 in this communication, should sometimes actually give rise to a microradiograph with higher emulsion density in relation to cross cut prisms.

It remained for *Gustafson & Gustafson* (1962) to give an illustration where the direct relationship between the orientation of the prisms and the resultant emulsion density was for the first time clearly displayed. These authors investigated human dental enamel in polarised light and contact microradiography. Their picture, in which illustrations of the two techniques are directly combined, shows that areas where the prisms are oriented perpendicular to the specimen surfaces give rise to a higher emulsion density in the microradiograph than adjacent areas, where the prisms are oriented parallel to the specimen surface. These authors also presented a schematic drawing to explain the phenomenon. No distinction between the contribution of prism

sheaths and interprismatic substance was made, the prisms proper being schematically separated from another by "organic structure". They wrote: "Because of the way in which enamel is built up of prisms whose outer layer (prism sheath) is less mineralised than their centres, the degree of darkening of the microradiograph depends on whether the rays pass through the sides of the prism or via its long axes".

The unique illustration in the work of *Gustafson & Gustafson* thus combines areas of prisms oriented perpendicular to the specimen surface with high emulsion density, that is a histological appearance similar to that in Figure 2 combined with a microradiograph, which unlike Figure 1 shows higher emulsion density in relation to the cross cut prisms.

Several attempts by the present author to duplicate this finding have been unsuccessful. I have had the opportunity to study the particular specimen and the accompanying microradiograph and I have to conclude that any suspicion that the enamel tufts should have contributed to the presented appearance has to be ruled out. It may be that the appearance shown by *Gustafson & Gustafson* is present only when for some reason or other there is a unique difference in mineralisation or relative thickness of prism sheath and prism core.

If such specimens show the same general thickness deviations due to grinding and polishing as the specimens used in the present investigation, that is an increased thickness in relation to cross cut prisms, several possibilities for the resultant variations of the emulsion density may exist. Three possibilities are outlined here: an increased thickness may give rise to a lower emulsion density (Figure 10 a), it may be compensated (Figure 10 b) or completely overcome (Figure 10 c) by a radiolucency of the orientation per se.

The same specimens may, however, show a different thickness distribution, that is cross cut prisms may here be associated with decreased thickness. In this case (Figure 10 d), the finding of a relatively higher emulsion density in relation to cross cut prisms can be ascribed to the lesser thickness and thus be the result of specimen preparation. A radiolucency of the orientation per se could here naturally give rise to an even higher emulsion density than should be expected from the thickness variation alone.

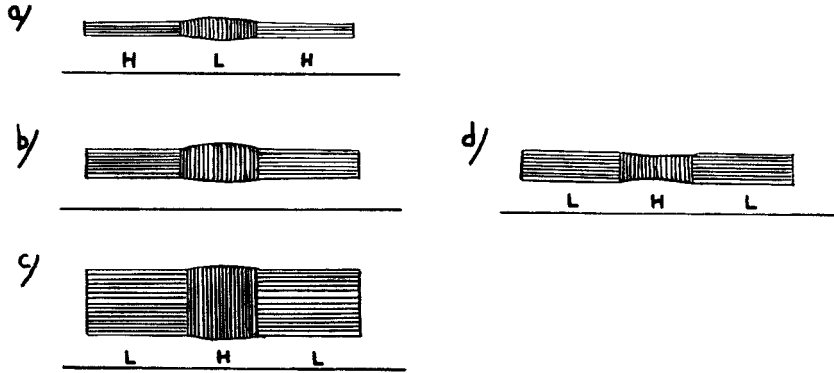


Fig. 10. Schematic drawing of cross-section through specimen and micro-radiographic plate. H = relatively higher emulsion density. L = relatively lower emulsion density. — Possible, combined influence of thickness differences and radiolucency due to orientation per se on the microradiographic emulsion density of cross cut prisms. An increased thickness a) producing a lower emulsion density, b) being compensated by radiolucency, c) being overcompensated by radiolucency. A decreased thickness, d) producing a higher emulsion density, which furthermore may be increased by radiolucency per se.

#### Frequency of the appearance of Schreger bands

A review of the published literature about X-ray absorption studies of dental enamel reveals an additional problem which concerns the appearance of the Schreger bands in microradiographs. This is that the bands in fact are very infrequently noted. Thus, recently, *Darling & Crabb* (1956) found only two longitudinally ground specimens among one hundred in which "differences in calcification were seen which appeared to correspond to the bands of Schreger".

This circumstance probably often may have been due to underexposure. Such a failure is naturally more often encountered during examination of thick specimens, but it can also be detrimental for the analyses of thin specimens. Thus Figure 11 shows an underexposed microradiograph, taken with the same kilovoltage and milliamperage as earlier (Figure 4) but with shorter exposure. The enamel appearance is quite different in the two radiographs. To facilitate orientation a Schreger band in Figure 4 has been "pinned through" on to Figure 11.

Besides underexposure, there are other explanations which

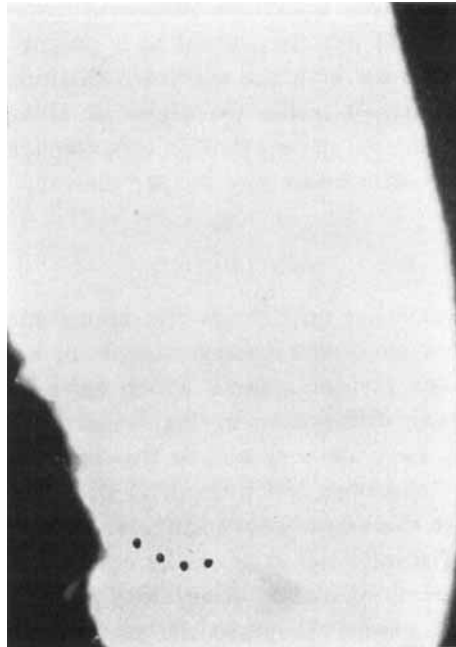


Fig. 11. Underexposed microradiograph (18 kV, 20 mA) from the specimen also seen in Figures 4 and 6. No density variations in relation to Schreger bands are seen.

might sometimes have been overlooked. One explanation can thus be related to the difference in occurrence of the Schreger bands in different types of illumination in light microscopy. Bands are almost always seen in ground sections of the enamel when these are investigated with for instance polarised or obliquely incident light. In ordinary transmitted light the bands are less frequently seen, chiefly because then directional variations in the horizontal plane do not interfere. Whereas this difference between frequency of occurrence as well as differences in actual number of registered Schreger bands in a specific section when examined with different types of illumination has been fully treated (for a recent discussion see *de Boer & Stiebelingen, 1958*) cross references to the microradiographic appearance of the bands seem not to have been stressed. Obviously a relationship should safely be expected only between transmitted light microscopy and microradiography, but even then discrepancies can exist. It is quite pos-

sible that the increase in specimen thickness associated with perpendicularly oriented prisms present at a prepared surface may be too small compared with the specimen thickness to be micro-radiographically demonstrable (*Wallgren & Holmstrand, 1957*). It may also in some cases be more or less compensated by a radiolucency of the orientation per se (see above).

#### CONCLUSIONS

The above discussion on the specific appearance and the frequency of occurrence of the Schreger bands in microradiographs obviously includes several aspects which have to be considered whenever intrinsic differences in the mineralisation of enamel are investigated. Erroneous results in this respect which are due to variations in specimen thickness can naturally be estimated through accurate thickness measurements. Especially, thin specimens of enamel should not a priori be considered as plano-parallel. Density variations due to orientation per se are less readily assessed, and it is evident that any further analyses of these problems have to be made as separate experimental studies, where microscopical well defined specimens of enamel are used as material.

#### SUMMARY

In this communication the appearance of Schreger bands in microradiographs of human dental enamel is discussed. Illustrations are given which show that those bands which are composed of prisms oriented perpendicularly towards the specimen surfaces can give rise to either a relatively lower or a relatively higher microradiographic emulsion density as compared to bands with prisms oriented in the same plane as the section. A relatively lower emulsion density in relation to these particular bands is ascribed to specimen thickness differences where the cross cut prisms are less affected by the grinding procedure. A relatively higher emulsion density may be caused by etching when the cross cut prisms are preferentially affected. Further evidence is quoted from the literature to show that variation in the emulsion density of these bands might appear without relation to specimen treat-

ment, and is due to prism orientation per se. Finally, the frequency of the appearance of Schreger bands in microradiographs is briefly discussed.

## RÉSUMÉ

## LES BANDES DE SCHREGER ET LEUR ASPECT SUR LES MICRORADIOGRAPHIES DE L'ÉMAIL DENTAIRE HUMAIN

Dans ce travail, l'aspect microradiographique des bandes de Schreger de l'émail humain dentaire est discuté. Sur certaines figures, on observe que les bandes, composées de prismes orientés perpendiculairement à la surface du spécimen, peuvent provoquer une densité microradiographique d'émulsion relativement plus basse ou relativement plus élevée que celle de bandes dont les prismes sont situés dans le même plan de section. Une densité d'émulsion relativement plus basse, en rapport avec ces bandes particulières, semble due aux différences d'épaisseur du spécimen, aux endroits où les prismes coupés transversalement sont moins affectés par la technique d'usure. Une densité d'émulsion relativement plus élevée peut être liée au traitement acide ("morsure"), lorsque les prismes coupés transversalement sont attaqués préférentiellement. Des faits, signalés dans la littérature, montrent de plus qu'une densité d'émulsion relativement plus élevée de ces mêmes bandes peut quelquefois apparaître sans aucun rapport avec le traitement du spécimen et semble due à l'orientation des prismes per se. Enfin, la fréquence d'apparition des bandes de Schreger en microradiographie est brièvement envisagée.

## ZUSAMMENFASSUNG

## DIE SCHREGER STREIFEN UND IHR AUSSEHEN IN MIKORADIOGRAMMEN VON MENSCHLICHEN ZAHNSCHMELZ

Die Erscheinung der Schregerschen Streifen in Mikroradiogrammen vom menschlichen Zahnschmelz wird diskutiert.

Es wird gezeigt, dass diejenigen Streifen, die aus senkrecht zur Schlißfläche orientierten Prismen bestehen, entweder durch relativ schwächere oder durch relativ stärkere Schwärzung des Mikroradiogrammes representiert werden können.

Eine relativ geringere Schwärzung dieser Streifen kommt vor,

wenn der betreffende Abschnitt dicker ist als die Umgebung. Dies ist so, weil senkrecht zur Schliffläche orientierte Prismen widerstandsfähiger sind als Prismen, die parallel zu dieser Fläche stehen. Die senkrecht stehenden Prismen werden deshalb weniger abgerieben.

Eine relativ stärkere Schwärzung kann nach Ätzung mit Säuren vorkommen, weil die senkrecht zur Schliffläche stehenden Prismen leichter von der Säure angegriffen werden als die parallel orientierten Prismen.

Aus der Literatur geht ferner hervor, dass eine relativ stärkere Schwärzung dieser Schregerschen Streifen im Mikroradiogramm durch die Orientierung der Prismen zustandekommen kann, vielleicht ohne etwaigen Zusammenhang mit der Herstellung der Schliffe.

Die Häufigkeit des Vorkommens der Streifen wird auch diskutiert.

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