

The mid-palatal suture in young adults. A radiological-histological investigation

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SUMMARY The aim of the present study was to analyse which histological-histomorphometric findings correspond to a radiologically diagnosed open (group I) or closed mid-palatal suture (group II) on occlusal radiographs. For this purpose, 30 radiological regions of interest (rROI) from specimens obtained from 10 subjects ranging in age from 18 to 38 years were evaluated, and compared with the suture morphology, mean sutural width, and degree of suture closure on stained sections (3/rROI).

The results showed that whether or not a radiologically visible suture can be classified as 'open' depends predominantly on the main oronasal suture course in relation to the X-ray path, rather than on factors such as suture width and degree of obliteration. The mean sutural width was 231 μm in group I ($n = 10$ rROI) and 201 μm in group II ($n = 20$ rROI). The degree of obliteration in relation to the total oronasal suture length was 0.45 in group I and 1.30 per cent in group II. No significant differences were found between the corresponding parameters of the two groups. The term 'suture obliteration' or 'fusion' should be avoided if a suture is radiologically not visible, since in 11 of the 20 rROI in which the suture was not visible no obliteration was recorded morphometrically.

Introduction

If conventional rapid maxillary expansion is intended in young adults, the status of the mid-palatal suture is most frequently evaluated on occlusal films.

In a radiographic study, Revelo and Fishman (1994) compared the status of the mid-palatal suture on occlusal films with the skeletal maturity indicator (SMI according to Fishman, 1982) assessed by means of hand-wrist films in patients ranging from 8 to 18 years of age. At maturational age SMI 11, the end of adolescence, only approximately 50 per cent of the total antero-posterior suture length was assessed as radiologically approximated or fused, respectively. The variations in the same SMI group were, however, relatively large.

In this context, the question arises as which real morphological findings are associated with a radiologically evaluated suture approximation or fusion, i.e. how reliable is the radiological

interpretation of suture status on occlusal films?

Melsen (1975) analysed palatal growth and mid-palatal suture morphology in humans from 0 to 18 years of age. The morphological development was divided into three stages. In the first stage, the suture was short, broad, and Y-shaped, in the second more sinuous, and in the third heavy inter-digitation occurred.

In a histological study, Persson and Thilander (1977) investigated palatal suture closure in man from 15 to 35 years of age. The authors demonstrated that palatal sutures may show obliteration during the juvenile period, but a marked degree of closure was rarely found until the third decade of life. Furthermore, broad variations existed in different parts of the suture in the same individuals and in the degree of closure between subjects of the same age group.

As the chronological age in young adulthood does not seem to be a reliable indicator for real morphological mid-palatal suture closure, it is of

interest to investigate whether or not occlusal films may contribute to the assessment of individual mid-palatal suture morphology.

The aim of the present study was to determine which histological findings can be expected in patients with an open or closed mid-palatal suture area diagnosed by means of occlusal radiographs in young adults.

Material and methods

Materials

The material consisted of tissue blocks of autopsy material from 10 subjects, between 18 and 38 years of age. Figure 1 presents the distribution according to age and sex. All subjects died suddenly. The specimens comprised the median palatal region usually from 5 to 10 mm behind the incisive foramen to the posterior hard palate. Autopsy and sample gaining were only carried out if the required authorization given by the legal person responsible was present.

Radiography

Each tissue block was positioned on an X-ray film (dimension: 5 × 7 cm) and then radiographed with a dental X-ray unit (Heliodent, Siemens, Bensheim, Germany). The projection of the X-ray path was adjusted as follows: within the mid-sagittal plane from anterior of the specimens with an angle of approximately 70 degrees to the palatal surface/X-ray film. This X-ray path corresponds to that of occlusal films in patient radiography (Manson-Hing, 1979).

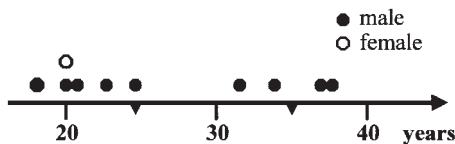


Figure 1 Age distribution of material and sex: nine males and one female.

Radiographic evaluation

Three radiological regions of interest (rROI) with an anteroposterior length of 1 mm were selected from the radiographs of each specimen: the first from the anterior, and the other two from the central and posterior parts of the mid-sagittal palatal area. In these rROI ($n = 30$), which were marked on the occlusal films, the suture was assessed according to the following radiological findings:

- (1) mid-palatal suture visible;
- (2) mid-palatal suture not visible.

Two weeks later, the same rROI were re-evaluated by two further examiners in order to assess the inter-examiner error. In 28 of the 30 rROI there was a complete agreement of the three examiners. The remaining two rROI were assigned to that finding which was determined by two of the three examiners.

Histological preparation

Transformation of the rROI to the corresponding areas of the specimens was achieved by measuring the distance from the mid-sagittal anterior or posterior bony border to the selected rROI on the radiographs using a slide gauge. The results of these measurements were then transferred to the specimens. From these morphological regions of interest (mROI) three parallel ground sections with a distance of up to 0.4 mm and a thickness of 5–7 μm were prepared in the transversal plane according to the micro-section technique of Donath (1988). This enabled the findings within each of the selected rROI ($n = 30$) to be compared with three histological sections from the same area.

Histomorphometrical assessment

As it was assumed that a low suture width or a high degree of suture obliteration might have an impact on the classification of the findings in the rROI, these two parameters were analysed morphometrically.

Morphometric measurement of the sections was carried out using a microscope (DMRX, Leica, Wetzlar, Germany) connected to an adapted colour video camera (Sony, Tokyo, Japan) interfaced with a computerized morphometric unit (Quantimed 600 S, Leica, Cambridge, England). The software allowed *inter alia* lengths, distances and areas of structures to be measured. All measurements were made at a magnification of $\times 25$.

The mean suture width (MSW) of each section was measured by drawing a central suture line between the oral and palatal end of the suture (Figure 2a). By carrying out 10 relatively equidistant measurements between the palatal and oral side perpendicular to the course of this line in the respective suture areas (Figure 2b), the mean suture width was assessed in each section. The sum of the corresponding three sections of the same rROI was then divided by three to determine the MSW in each rROI.

The obliteration index was measured according to the method of Persson and Thilander (1977). The length of the central suture line (Figure 2) represents the shortest distance of the suture from the oral side of the palate. When a Y-shaped suture was present two length measurements were made; the shorter was then used for further calculations. The obliteration index in each section was calculated as the relationship between the obliterated suture length and the total suture length. For calculation of the mean obliteration index (MOI) of each rROI the sum of the measurements of the three sections was divided by three.

The mean values of each rROI were then assigned to the respective radiological finding 'suture visible' (group I)/'suture not visible' (group II). Statistical analysis was carried out using the paired *t*-test at a 0.05 confidence level. Figure 3 shows the methodological procedure.

To determine the measurement error, 10 sections were selected and double measurements were carried out by the same operator. The calculations were made according to the Dahlberg formula $s = \sqrt{\Sigma(x_1 - x_2)^2/2n}$. The percentage

errors for the MSW was ± 3.41 per cent and that for the MOI 0.21 per cent.

Results

Radiological findings

From the 30 rROI, 10 were classified as mid-palatal suture clearly visible (group I). Most frequently the suture ran in the mid-palatal area. In some rROI, however, the suture was identified somewhat laterally to the mid-palatal area. In the remaining 20 rROI the palatal suture was not visible (group II).

Radiological-histological comparison

In general, the three parallel histological sections from the same rROI were relatively similar with respect to oronasal suture course and suture width, as well as amount and location of suture inter-digitation. When partial areas of inter-digitation were present these were located predominantly within the nasal or middle third of the sections.

Group I: suture visible

The radiological finding 'suture visible' ($n = 10$) was associated with the following histological observations and histomorphometrical results:

- (1) predominant part of the suture running relatively straight and projecting into the X-ray path (sagittal plane),

most frequently combined with

- (2) a relatively small zone of inter-digitation with respect to the total vertical palatal bone height (Figure 4a).

The calculated MSW in this group was 231μ (SD 97; min 131; max 421μ m). The MOI was 0.45 per cent (SD 0.90; min 0, max 2.8 per cent). In seven of the 10, ROI no obliteration was measured.

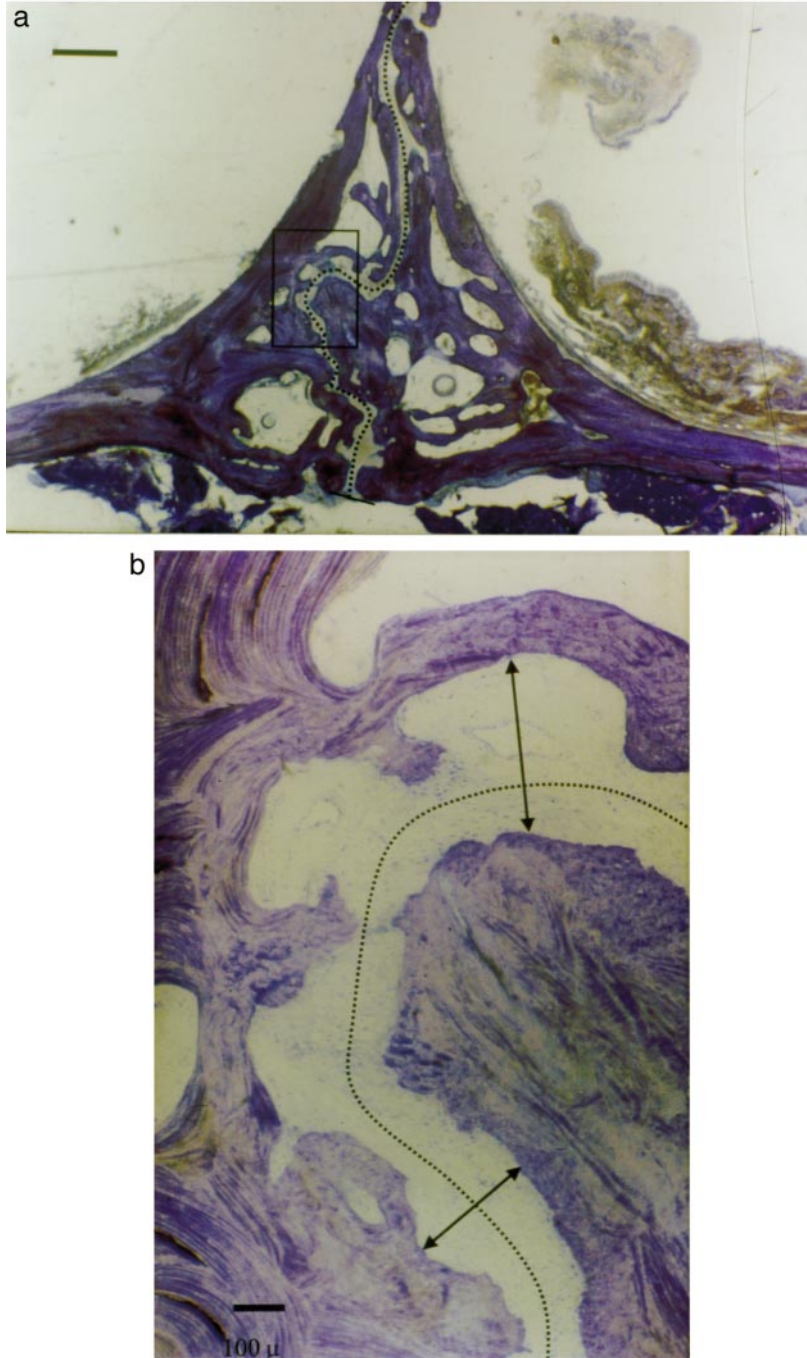


Figure 2 (a) Transversal mid-palatal section with central suture line (dotted) drawn between oral and nasal end of mid-palatal suture. Bar = 1000 μm . (b) Magnification ($\times 10$) of Figure 2a (inserted rectangle) showing two exemplary suture width measurements (arrows) in this area. Measurements were carried out perpendicular to the individual course of the central line (dotted) within the different suture areas. Bar = 100 μm .

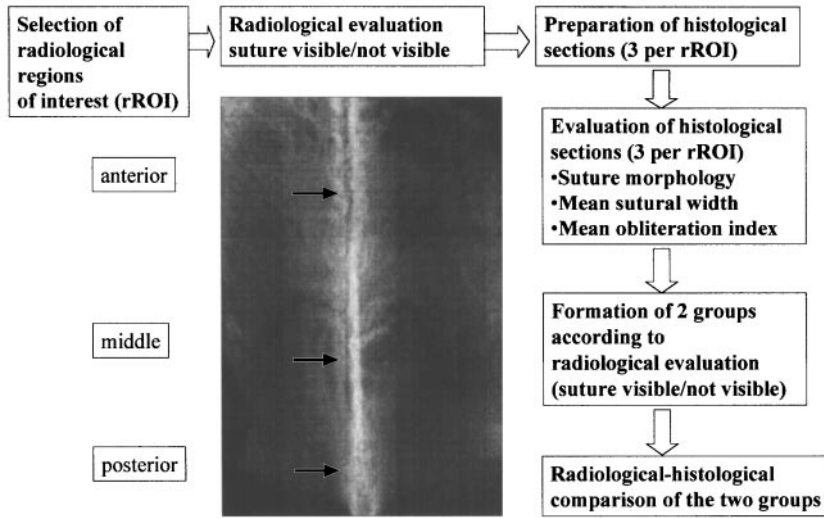


Figure 3 Methodological schedule of the study.

Group II: suture not visible

In this group the histological findings were more varied than in group I. The radiological finding 'suture not visible' corresponded to:

- (1) a relatively large zone of inter-digitation in relation to the total vertical palatal bone height (Figure 4b);
- (2) relatively large parts of the suture running relatively straight, but in an oblique direction to the X-ray path (Figure 4c);
- (3) broad and compact vomer projecting above a remaining straight suture and running within the X-ray path (Figure 4d).

In this group the calculated MSW was 201 μ (SD 75; min 120; max 401 μ m) and the MOI 1.30 per cent (SD 1.95; min 0, max 6.69 per cent) of the mean oronasal suture length. In 11 of the 20 ROI, no obliteration at all was recorded by histomorphometric measurement.

Histomorphometric comparison of groups I and II

The distribution of the values measured per rROI for groups I and II with respect to MSW and MOI are presented in Figures 5, 6, and 7,

respectively. Inter-group comparison of MSW and MOI revealed no significant differences ($P > 0.05$) for either parameter.

Discussion

Most investigations on assessment of sutures of the cranium have been carried out using histological, micro-radiographic, and radiographic methods, as well as macroscopic inspection of dry skulls (Davida, 1926; Singer, 1953; Cobb, 1955; Christensen *et al.*, 1960; Hansman, 1966; Schmitt and Tamaska, 1970; Herring, 1972; Melsen, 1975; Kokich, 1976; Persson and Thilander, 1977; Mann *et al.*, 1991; Revelo and Fishman, 1994). The aim of these studies was to find a method for age estimation for forensic purposes or to document changes in suture morphology with age.

Each method, however, has its inherent limitations. Histological and micro-radiographic analysis represents only a small part of the whole anteroposterior suture length even if a number of serial sections from one area are available. Macroscopic inspection allows the total anteroposterior suture length to be evaluated superficially. However, the internal suture morphology cannot be analysed. Conventional radiographs only deliver a two-dimensional image of a three-

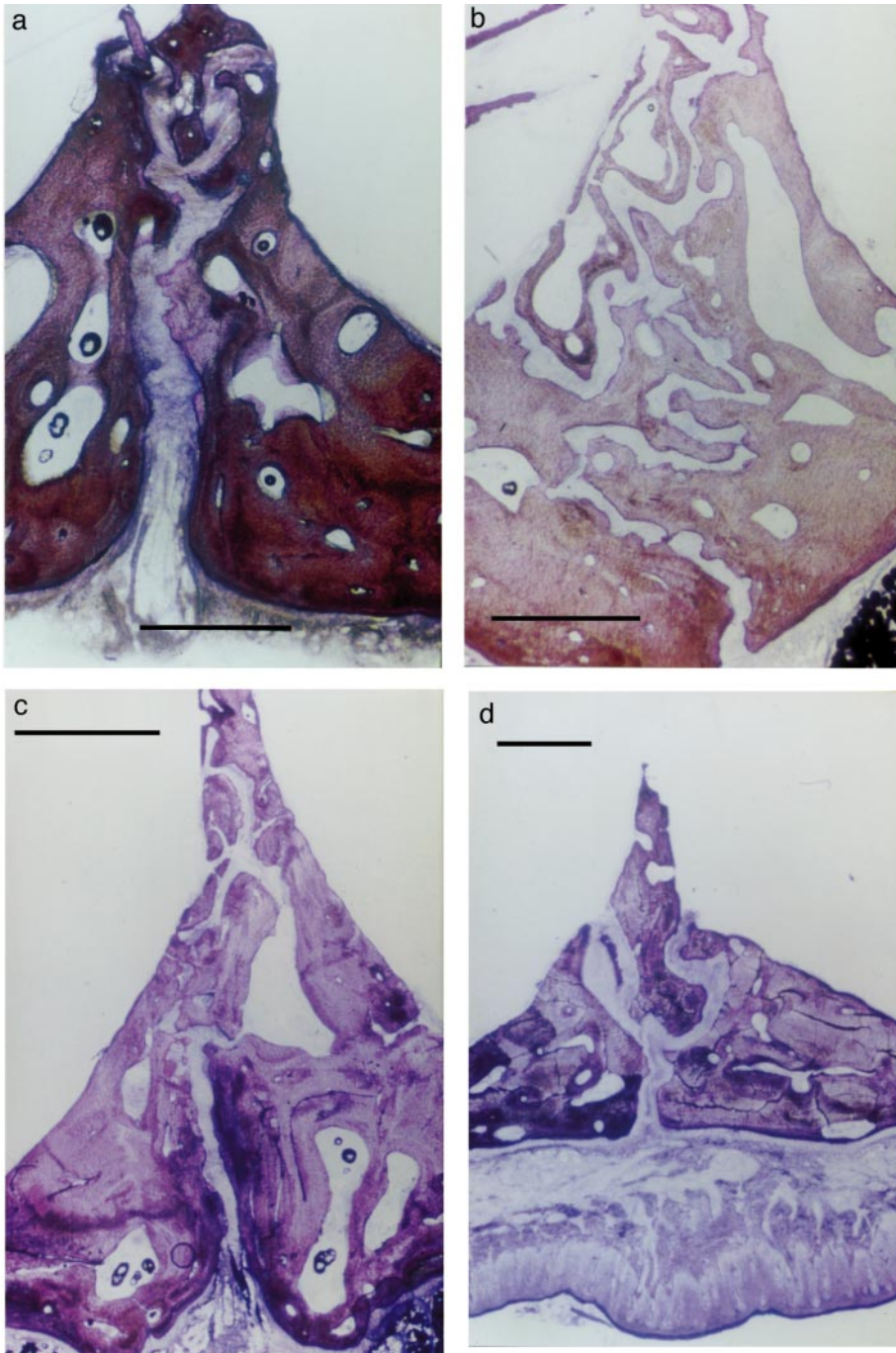


Figure 4 (a) Histological section of a radiologically visible mid-palatal suture area; 32-year-old male, anterior palate: predominant part of the suture course is relatively straight and projected into the X-ray path (sagittal plane). Small area of beginning inter-digitation in the nasal part of the specimen. Staining: toluidine blue. Bar = 1000 μ m. (b) Histological section of a radiologically not visible mid-palatal suture area; 32-year-old male, posterior palate: in the largest part of the oronasal palatal bone height inter-digitation is present. Staining: toluidine blue. Bar = 1000 μ m. (c) Histological section of a radiologically not visible mid-palatal suture area; 25-year-old male, posterior palate: no marked inter-digitation, but oblique course of the suture in relation to the X-ray path (sagittal plane). Staining: toluidine blue. Bar = 1000 μ m. (d) Histological section of a radiologically not visible mid-palatal suture area; 20-year-old female, anterior palate: Y-shaped suture course; a compact vomer is projecting above a suture running straight and within the X-ray path in the oral third of the section (below). Staining: toluidine blue. Bar = 1000 μ m.

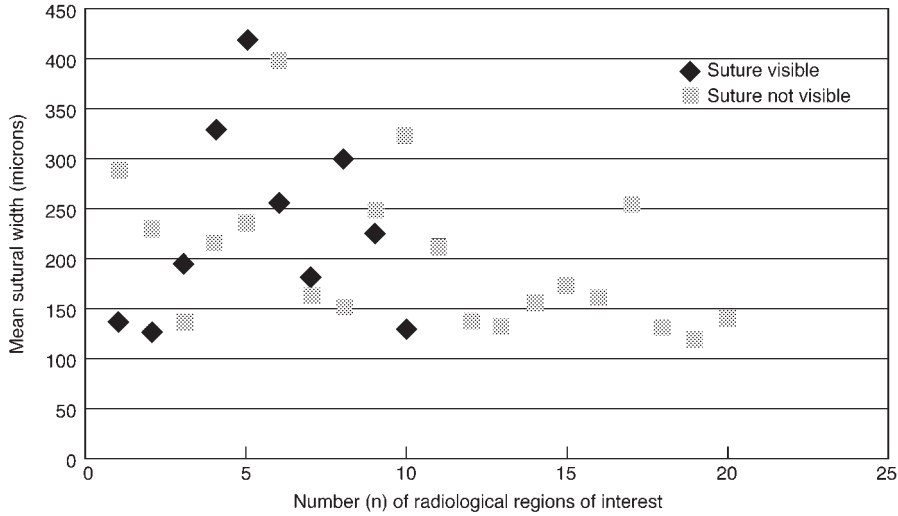


Figure 5 Distribution of radiological regions of interest (rROI) demonstrating suture visible (group I, $n = 10$)/not visible (group II, $n = 20$) in relation to mean sutural width (MSW). Each MSW value is based on measurement of three histological sections out of the same rROI. Note the relatively large variation of MSW in both groups.

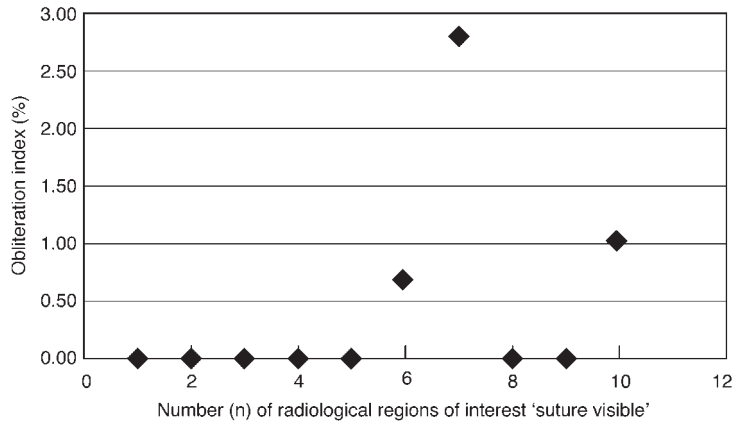


Figure 6 Distribution of radiological regions of interest (rROI) demonstrating 'suture visible' (group I, $n = 10$) in relation to mean obliteration index (MOI).

dimensional structure. In the present study, some of these aspects also have to be taken into consideration.

Christensen *et al.* (1960) compared the appearance of a cranial vault suture closure on cephalograms with the anatomy. Persson and Thilander (1977) judged this method to be unreliable because of the complexity of the

whole facial skeleton with its many overlapping structures. As far as occlusal films are concerned, a compact vomer or structures of the external nose may overlie the mid-palatal area and thus lead to false radiological interpretation of the real morphological finding (Figure 4d).

Despite these limitations, occlusal films are still today the most frequently used technique for

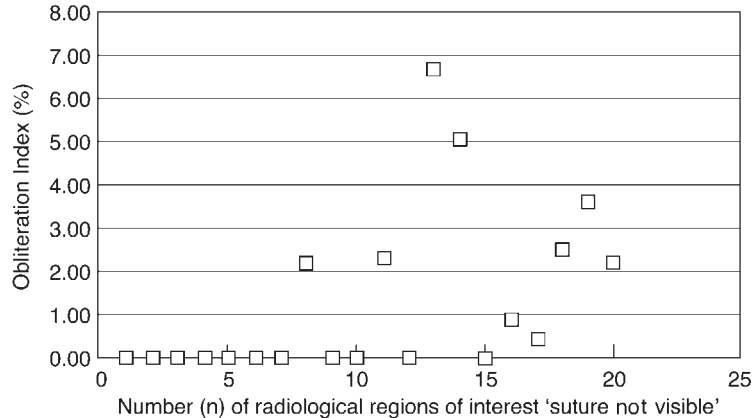


Figure 7 Distribution of radiological regions of interest (rROI) demonstrating 'suture not visible' (group II, $n = 20$) in relation to mean obliteration index (MOI). Note the relatively high number of MOI values showing no obliteration at all in this group.

assessment of the mid-palatal suture area before rapid maxillary expansion (RME) in routine orthodontic practice. As chronological age in young adulthood seems not to be sufficiently reliable for assessment of the individual suture status, it would be beneficial to analyse which potential histological finding may be associated with a radiologically diagnosed visible or invisible mid-palatal suture in this age group.

In the study by Revelo and Fishman (1994) the mean anteroposterior percentage of 'mid-palatal suture fused or approximated' was analysed by means of occlusal films up to the end of skeletal growth (8–18 years). As previously stated, a mean 50 per cent of the anteroposterior suture length was classified as fused at the end of skeletal growth. The results of the present study, however, show that in approximately 50 per cent of the rROI of the young adult sample in which the suture was radiologically not visible ($n = 20$), i.e. which would have been radiologically classified as fused, no obliteration at all was found. Therefore, the term 'fusion' should be avoided when occlusal films are used for suture status assessment.

Based on the results of this study it has to be concluded that whether or not a suture is radiologically visible in young adults depends on how the main course suture runs in relation to the X-ray path rather than on factors such

as percentage of oronasal suture obliteration or suture width, because:

- (1) the obliteration values measured in group II (suture radiologically not visible) were low (mean 1.30; min 0 and max 6.69 per cent obliteration of total oronasal suture length);
- (2) no significant differences between the two groups were found with respect to mean suture width.

The results of age distribution and percentage of oronasal suture obliteration in the present sample corroborate those of Persson and Thilander (1977). Those authors found the earliest obliteration in the posterior palate of a 15-year-old girl and no obliteration at all in a 27-year-old woman. The earliest obliteration in this sample was recorded in the posterior region of 21-year-old male and no obliteration at all in a 32-year-old male.

With respect to percentage of oronasal suture closure, Persson and Thilander (1977) measured most frequently values below 0.1 per cent in individuals below the age of 25 years, whereas for older individuals the majority of the values ranged between 0.1 and 10 per cent. The range of the values measured in the present investigation is relatively similar.

Concerning RME procedures, it has to be presumed that whether or not obliteration

is present is not of utmost importance, but percentage of obliteration in the individual is. Based on the results of their sample, Persson and Thilander (1977) speculated that if 5 per cent of suture closure is to be set as the limit for splitting the mid-palatal suture by conventional RME this is not reached in most patients below 25 years of age. Transmitted to the present results that would mean that in nine of the 10 individuals (age: 18–38 years) RME should be successful because the obliteration index in these individuals was below 5 per cent.

Clinical experiences, however, show that in patients over 25 years of age conventional RME is often difficult to achieve although the obliteration may be small. Therefore, factors such as a heavy inter-digitation of the mid-palatal and other maxillary sutures, as well as an increased rigidity of the maxillary bones with age may be the reasons for resistance to separation (Isaacson and Ingram, 1964; Wertz 1970; Melsen 1975; Kokich 1976).

Conclusions

The conclusion is to be drawn from analysing the palatal suture status on occlusal films of young adults ranging from 18 to 38 years of age are:

1. A radiologically visible mid-palatal suture corresponds histologically to a predominantly straight running oronasal suture, which projects largely into the sagittal X-ray path. Only small areas of inter-digitation, if any, are to be expected and the percentage of suture obliteration is low.
2. A radiologically invisible suture corresponds histologically to a relatively large area of inter-digitation, an oblique running suture course in relation to the X-ray path or bone structures projecting above the suture course, respectively. The percentage of suture obliteration to be expected is also low in this group.
3. A radiologically invisible mid-palatal suture is not the histological equivalent of a fused or closed suture, respectively. Therefore, as far as radiologic terminology is concerned, the term 'suture fusion' should be avoided.

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