The qualitative assessment of median and transverse palatal sutures in various age groups – a CBCT analysis

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Objectives: To detect age-related morphological changes occurring in the median and transverse palatal sutures that could affect the outcome of rapid maxillary expansion. Determined by Cone-Beam Computed Tomography (CBCT) scans.

Material and methods: CBCT scans were retrospectively analysed of 325 patients aged from 5.9 to 82 years (mean = 27.3 +/- 17.9), comprising 144 males and 181 females who underwent CBCT scanning of the maxillary region. The median and transverse palatal sutures were assessed at four topographic points using a grading scale created for the purpose of this study to attempt to assess the shape and the amount of calcified tissue within the examined sutures.

Results: At each of the assessed topographic points, the median palatal suture evolved from a straight/polyline shape to a more tortuous outline with a concomitant increase in the amount of calcified tissue most significantly identified in the middle and posterior regions of the suture. Patients older than 20 years showed significant suture obliteration at all points evaluated. No age-dependent increase in the transverse suture calcification could be established.

Conclusion: Patients younger than 15 years should be treated with more predictable effect by means of an RME if no factors other than median palatal suture morphology are considered. Patients between 15 and 20 years old can be described as borderline cases in which an individual assessment by CBCT scans may prove clinically relevant. Patients older than 20 years showed significant suture obliteration at all points evaluated and therefore could be considered as patients at high risk of RME failure.

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Introduction

Rapid maxillary expansion is a treatment option capable of correcting skeletal transverse maxillary deficiencies; however, the efficacy of this method appears to be largely dependent on a patient's age. This can be attributed to several factors but the role and maturation of the cranial sutures is paramount. The 'evolution' of the median palatal suture has been described by Melsen et al., who implied that age-dependent changes in overall suture shape and the connections between the maxillary bones are to be expected. Knaup et al. and Korbmacher et al. revealed that the width of the suture was larger in younger patients, but the amount of ossification within the suture was low regardless of age. Although most of the current research indicates very large individual differences in the pattern of maturation of the median palatal suture, there are many areas of commonality. Confirmed at the final stage of maturation is the creation of cancellous bone.

A CBCT examination can provide a clinician with accurate, undistorted, three-dimensional data
representing a patient’s facial skeleton without the risk of misinterpretation due to overlying structures. Should certain anatomic age-dependent features of the palatal sutures be identified, it may prove possible to estimate the risk of RME failure prior to management. Apart from an assessment of the median palatal suture, the transverse palatal suture was also examined in the present study, as its morphology may affect the force distribution and overall rigidity of the hard palate. The aim of the present study was to evaluate the morphological changes within the palatal sutures in different age groups by means of CBCT scanning.

Material and methods

CBCT scans performed for other clinical purposes of 325 patients were retrospectively analysed. Exclusion criteria were: signs of congenital/traumatic deformation of the maxillary region, and a prior history of transverse skeletal expansion. The patients were divided into four groups, of which Group I consisted of patients less than 15 years, Group II of patients between 15 and 20 years, Group III of patients between 21 and 35 years and Group IV of patients greater than 35 years. The diagnostic data were acquired using the iCAT scanning machine (Imaging Sciences International, PA, USA) resulting in a 0.125 mm voxel size and FOV exceeding the maxillary area. Each scan was opened in Vision software and the volumetric dataset was explored using the MPR tool. Subsequently, the volume was rotated to obtain repeatable alignment in all three planes. Four frontal and four sagittal sections were captured from each scan. Frontal views were exported from the following topographic points: at the anterior margin of the incisive foramen (FIA), at the posterior margin of the nasal exit of incisive canal (FIP), 10 mm distally from point FIP (FIP+10) and 20 mm distally from point FIP (FIP+20) (Figure 1 Panel A). Sagittal projections were recorded on both sides at 5 mm and 10 mm from the midline (Figure 1 Panel B). A total number of 2560 projections were recorded.

Median palatal suture assessment

An evaluation was performed according to a scale created for the present study and based on the shape of the suture and the presence of radiopaque tissue within the suture. The shape of the suture on the frontal sections was divided into four types:

1. similar to a straight line
2. similar to a polyline
3. similar to a tortuous line with numerous curves
4. the connection between the maxillary bones could not be distinguished from the surrounding tissues.

The tissue visible within the suture space was described as:

A) radiolucent – with a visible space within the suture along the entire intermaxillary interface with only single islets of radiopaque tissue.
(B) partially radiopaque – with a space within the suture seen in approximately 50% of the interface
(C) mostly radiopaque – without a visible space within the majority of the suture or with only minor radiolucent spaces within the suture space.
A summary of diagnosed median suture types can be found in Figure 2.

Transverse palatal suture assessment

Transverse palatal suture space could either be fully (i.e., along the whole thickness of the hard palate; coded as ‘1’), or partially (‘2’) distinguishable from the surrounding hard tissue. A lack of visible suture space between the maxillary and palatal bones was coded as ‘3’. A summary of detected transverse palatal suture types can be found in Figure 3.

To validate the method, the following protocols were applied: a second researcher underwent 1.5 hours of training with the main researcher and focused on establishing diagnoses. Seven days later, a PowerPoint presentation consisting of 240 randomly chosen projections of median and transverse palatal sutures from the scanned database was created. A second researcher was handed an assessment card that was filled with images of various suture diagnostic stages.

![Diagram of midpalatal suture types](image)

**Figure 2.** Morphological forms of midpalatal suture. Arabic numbers indicate an observed shape of the suture: 1 – straight, 2 – similar to the polyline, 3 – tortuous shape, 4 – the shape cannot be distinguished from the surrounding hard tissues. Letters indicate the amount of calcified tissue detected within the suture space: [A] radiolucent – with a visible space within the suture along the whole intermaxillary connection with only single isles of radiopaque tissues, (B) partially radiopaque – with a space within the suture seen in approximately 50% of the connection, (C) mostly radiopaque – without the visible space within the suture or with only minor radiolucent spaces within the suture space. Final diagnosis for each point is a combination of the above, with the exception of the diagnosis 4, which was not attributed with a letter.

![Diagram of transverse palatal suture diagnoses](image)

**Figure 3.** Diagnoses of the transverse palatal suture: 1 – suture space could be distinguished from the surrounding hard tissue along the whole thickness of the hard palate, 2 – suture space could be distinguished from the surrounding hard tissue along part of the thickness of a hard palate, 3 – suture space could not be distinguished from the surrounding hard tissues.
The obtained data was subsequently compared with the results from the database by means of the Kappa coefficient. Calculated inter-rater agreement could be described as very good (Altman classification) as the Kappa = 0.83 (95% CI 0.79–0.87).

**Statistical analysis**

The relation between qualitative features of the suture's morphology and patient's age was assessed with a Chi-squared test. In cases in which non-parametric statistical testing was required, a Mann-Whitney test was applied. All calculations were performed with Statistica 12 (Statsoft) software with a significance level of $p < 0.05$.

**Results**

A total number of 325 patients from 5.9 to 82 years (mean = 27.3 +/- 17.9 years, median = 23.2; 144 males) were analysed (Table I).

**FIA**

A statistically significant, strong relation ($p < 0.001$) was found between the patients’ age and suture morphology at point FIA (Table II). In Group I, the most prevalent observation was 1B (38.5%), then 2A (16.7%), 1A (15.4%) and 2B (11.5%). In Group II, the 3B observation was the most common finding (32.1%), with 2B being the second most common (22.0%), followed by 1B (13.6%) and 2C (10.2%). In Groups I and II, no diagnosis of 4 was detected. In Group III, a 3C observation was identified in 40.2% of patients, followed by 3B (25%). Three percent of the examined group was identified as '4'. In the group of patients older than 35 years, almost half (49.1%) were diagnosed as 4. Similarly, a significant percentage of this group was identified as 3C (30.9%).

**FIP**

A statistically significant, strong relation ($p < 0.001$) was found between the patients’ age and suture morphology at point FIP (Table II). In Group I, the 2B observation was most often detected (38%), followed by 3B (20.2%) and 1B (11.4%). In the second group, a 3C observation was apparent in the majority of cases (44.1%), with 2B and 3B accounting for 22.0% and 15.2%, respectively. Only two observations of 4 were recorded in Groups I and II. In the third group of patients 44.7% of observations were labelled as 3C, whereas 20.4% were identified as 3B. Interestingly, 18.9% of observations were recognised as 4. In the group of oldest patients, more than half (52.7%) of projections were classified as 4, with 3C being the second most common finding (29.1%). Only one patient was diagnosed as 1C in this group (1.8%) and no observations of 1A, 1B and 2A were found.

**FIP+10**

A strong statistical relationship was found between the suture morphology at FIP+10 point and patients' age ($p < 0.001$; Table II). The group of youngest patients had significantly more signs of 2B (34.2%) and 3B (26.6%). Patients in Group II were most often identified with a 2B diagnosis (28.8%) and with 3C (27.1%) followed by 2C and 3B (both 13.6%). In Group III 38.9% of patients were diagnosed as 3C and 26.7% as 4. In the oldest patients enrolled into the study, 60% were diagnosed as 4. Over 27% of patients in this group were categorised with a 3C diagnosis. No cases of 1A, 1B, 1C, 2A, 2C or 3A identification were observed.

**FIP+20**

A statistically significant, medium-strong relation between patients’ age and median palatal suture morphology at point FIP+20 was identified ($p < 0.001$, Table II). In Group I, all observations were detected, with 2B being most common (39.2%) followed by 3B (16.5%) and 2A (15.2%). Patients aged between 15 and 20 years were most often identified with 2B (30.5%) and 3C (20.3%) diagnoses. Patients in the third group were diagnosed as 3C in 32.1% of cases, as 4 in 20.6% of cases and as 3B in 16% of cases. Group IV was most commonly identified as 4 (67.3%) and 3C (14.5%). In the FIP+20 group, no diagnoses of 1A, 1B, 1C, 2A, 2C or 3A were observed.

| Group/Age | No. of patients | %  |
|-----------|----------------|----|
| I <15     | 79             | 24.3 |
| II 15–20  | 59             | 18.2 |
| III 21–35 | 132            | 40.6 |
| IV >35    | 55             | 16.9 |
| Total     | 325            | 100.0 |

Table I. Characteristics of included studies.
Table II. Relation between patients’ age and median palatal suture morphology in topographic points FIA (at the anterior margin of incisive foramen), FIP (at the posterior margin of incisive foramen), FIP+10 (10 mm distally from the posterior margin of incisive foramen) and FIP+20 (20 mm distally from the posterior margin of incisive foramen).

| Age/Study Group (years) | <15 (I) | 15–20 (II) | 21–35 (III) | >35 (IV) |
|------------------------|--------|-----------|-------------|---------|
|                        | N    | %        | N   | %  | N   | %  | N   | %  |
| **FIA point diagnosis** |       |          |     |    |      |    |      |    |
| 1A                     | 12   | 15.4     | 1   | 1.7 |       |    |       |    |
| 1B                     | 30   | 38.4     | 8   | 13.6| 7    | 5.3| 1    | 1.8 |
| 1C                     | 5    | 6.4      | 3   | 5.1 | 6    | 4.6|       |    |
| 2A                     | 13   | 16.7     | 4   | 6.8 |       |    |       |    |
| 2B                     | 9    | 11.5     | 13  | 22.0| 18   | 13.6|       |    |
| 2C                     | -    | -        | 6   | 10.2| 11   | 8.3 |       |    |
| 3A                     | 1    | 1.3      | 1   | 1.7 |       |    |       |    |
| 3B                     | 8    | 9.0      | 19  | 32.1| 33   | 25.0| 10   | 18.2|
| 3C                     | 1    | 1.3      | 4   | 6.8 | 53   | 40.2| 17   | 30.9|
| 4                      | -    | -        | -   | 4   | 3.0  | 27  | 49.1 |    |
| **FIP point diagnosis** |       |          |     |    |      |    |      |    |
| 1A                     | 5    | 6.3      | -   | -   |       |    |       |    |
| 1B                     | 9    | 11.4     | 4   | 6.8 | 1    | 0.8 | 1    | 1.8 |
| 1C                     | 4    | 5.1      | -   | -   | 1    | 0.8 | 1    | 1.8 |
| 2A                     | 6    | 7.6      | -   | -   |       |    |       |    |
| 2B                     | 30   | 38.0     | 13  | 22.0| 13   | 9.8 | 3    | 5.5 |
| 2C                     | 4    | 5.1      | 3   | 5.1 | 6    | 4.6 | 1    | 1.8 |
| 3A                     | 5    | 2.5      | 3   | 5.1 |       |    |       |    |
| 3B                     | 16   | 20.2     | 9   | 15.2| 27   | 20.4| 5    | 9.1 |
| 3C                     | 2    | 2.5      | 26  | 44.1| 58   | 44.7| 16   | 29.1|
| 4                      | 1    | 1.3      | 1   | 1.7 | 25   | 18.9| 29   | 52.7|
| **FIP+10 diagnosis**   |       |          |     |    |      |    |      |    |
| 1A                     | 5    | 6.3      | -   | -   |       |    |       |    |
| 1B                     | 8    | 10.1     | 3   | 5.1 | 2    | 1.5 |       |    |
| 1C                     | -    | -        | 1   | 1.7 |       |    |       |    |
| 2A                     | 8    | 10.1     | 2   | 3.4 |       |    |       |    |
| 2B                     | 27   | 34.2     | 17  | 28.8| 13   | 9.9 | 2    | 3.6 |
| 2C                     | -    | -        | 8   | 13.6| 11   | 8.4 |       |    |
| 3A                     | 4    | 5.1      | -   | -   |       |    |       |    |
| 3B                     | 21   | 26.6     | 8   | 13.6| 19   | 14.5| 5    | 9.1 |
| 3C                     | 6    | 7.6      | 16  | 27.1| 51   | 38.9| 15   | 27.3|
| 4                      | -    | -        | 4   | 6.8 | 35   | 26.7| 33   | 60.0|
| **FIP+20 diagnosis**   |       |          |     |    |      |    |      |    |
| 1A                     | 5    | 6.3      | -   | -   |       |    |       |    |
| 1B                     | 8    | 10.1     | 3   | 5.1 | 2    | 1.5 |       |    |
| 1C                     | -    | -        | 1   | 1.7 |       |    |       |    |
| 2A                     | 8    | 10.1     | 2   | 3.4 |       |    |       |    |
| 2B                     | 27   | 34.2     | 17  | 28.8| 13   | 9.9 | 7    | 12.7|
| 2C                     | -    | -        | 8   | 13.6| 11   | 8.4 |       |    |
| 3A                     | 4    | 5.1      | -   | -   |       |    |       |    |
| 3B                     | 21   | 26.6     | 8   | 13.6| 19   | 14.5| 3    | 5.5 |
| 3C                     | 6    | 7.6      | 16  | 27.1| 51   | 38.9| 8    | 14.5|
| 4                      | -    | -        | 4   | 6.8 | 35   | 26.7| 37   | 67.3|
| **Total**:             | 79   | 100.0    | 59  | 100.0| 132  | 100.0| 55   | 100.0|
A moderately-strong statistically significant relation was found between the transverse palatal suture morphology at point R+5 and the patients’ age ($p < 0.001$; Table III). In Groups I, II and IV, a diagnosis of 2 was most commonly encountered with a prevalence of 49.4%, 44.1% and 62.3%, respectively. Conversely, in Group III (patients aged between 21 and 35), a diagnosis of 1 (47.7%) was the most frequently observed. At point R+5 in Groups I and II, an occurrence of 3 was noted and considered similar (32.9% vs 33.9%), while in the older patients from Group III and IV, 3 accounted for 20.3% and 9.4%, respectively.

A moderately-strong statistically significant relation was identified between the suture morphology at L+5 and the patients’ age ($p < 0.001$; Table III). Similarly, in the evaluation at point R+5 in Groups I, II and IV, a diagnosis of 2 was most commonly encountered with a prevalence of 49.4%, 45.8% and 51% respectively. Notably, in the third group, the most frequent observation was labelled as 1 (43.0%). At point L+5 in Groups I and II, the occurrence of 3 was similar between the groups (37.9% vs 33.9%), whereas in the older patients from Group III and IV, 3 accounted for 17.2% and 12.2%, respectively.

No statistically significant relation between the diagnosis at topographic points R+10 and L+10 and patients’ age was identified.

To the best of current knowledge, the present study is the first to assess the relationship between a patient’s age and the morphology of the median and transverse palatal sutures based on CBCT images. Furthermore, the present findings are based on a relatively large study population. A previous CBCT study evaluating median palatal suture by Angelieri et al. 7 focused on axial projections, whereas the present study analysed frontal sections. Frontal sections were also used in the majority of the histological studies. On the basis of the present findings, it may be generalised that the median suture changes with age from straight to curved/tortuous with an increasing amount of calcified tissue deposited within the suture space. It is also vital to emphasise that there were very few observations of a straight suture (1). It has been assumed that diagnoses 3C and 4 represent the most mature morphological form of the suture, with 1A and 1B representing the most immature state. This was reflected in the recorded results as median suture morphology in each topographic point evolved from 1B/2B to 4 (Table IV). The tortuous shape (3) had been universally observed in young patients from Group II (Table IV). The amount of calcified tissue appears to be changing at different speed at each of the topographic points. There were no cases of a fully fused suture in the anterior palatal region in patients younger than 20 years. However, even in this group, a fully radiolucent suture space was rarely observed. The present findings also indicate that suture maturation occurs from posterior to the anterior area, which confirms the findings of previous studies. This relation is more apparent in Groups III and IV; however, it may also

| Age (years) | <15 (I) | 15–20 (II) | 21–35 (III) | >35 (IV) |
|------------|--------|------------|-------------|---------|
| N | % | N | % | N | % | N | % |
| Diagnosis at R+5 |
| 1 | 14 | 17.7 | 13 | 22.0 | 61 | 47.7 | 15 | 28.3 |
| 2 | 39 | 49.4 | 26 | 44.1 | 41 | 32.0 | 33 | 62.3 |
| 3 | 26 | 32.9 | 20 | 33.9 | 26 | 20.3 | 5 | 9.4 |
| Diagnosis at L+5 |
| 1 | 10 | 12.7 | 12 | 20.3 | 55 | 43.0 | 18 | 36.8 |
| 2 | 39 | 49.4 | 27 | 45.8 | 51 | 39.8 | 25 | 51.0 |
| 3 | 30 | 37.9 | 20 | 33.9 | 22 | 17.2 | 6 | 12.2 |
| Total: | 79 | 100.0 | 59 | 100.0 | 128 | 100.0 | 53 | 100.0 |
be identified in Group I. In Group IV, the frequency of observation 4 increased from point FIP+20 to FIA. However, the sum of the diagnoses 4 and 3C in this group remained similar for each topographic point (Table IV). In Group III, an analogous relation can be identified. In Groups III and IV, the common observations indicating suture ossification (either 3C or 4) were noted in the middle to posterior points FIP and FIP+10. The lowest values were in cases recorded for the most anterior point of FIA (Table IV). Patients in Group IV were most commonly observed with 4 regardless of the topographic point evaluated. Significant suture ossification in Group III at points FIP+10 and FIP+20 may indicate difficulties during conventional RME therapy. It can also be observed that the frequency of the observations of 4 and 3C for each point in Group I was very low (Table IV). Group II showed similar values only in the most anterior point of FIA, whereas the remaining observations were similar to those encountered in Group III, which exceeded the threshold of 30% for each of the remaining topographic points. For this reason, it can be assumed that the amount of radiopaque tissue increases with age at all evaluated points but is more pronounced at points posterior to the incisive foramen. Despite a relatively similar age of patients in Groups I and II (<15 vs 15–20 years), the observed difference in the level of calcification within the suture in points FIP, FIP+10, FIP+20 is striking (Table IV). This may explain clinically-experienced failures in achieving RME skeletal expansion in patients after their growth spurt is finished. The second group of patients aged between 15 and 20 could be described as borderline RME patients, with diagnoses of ‘C’ occurring in the posterior and middle areas of the suture.

There is very little scientific data regarding the morphology of the transverse palatal sutures. Younger patients (Groups I and II) showed, in the majority of cases, a partially visible sutural structure (2), whereas in the oldest patients the suture structure was commonly visible. The criteria created for the purpose of the present study were based on the assumption that changes in the transverse palatal suture in the final stages involved its obliteration. This could not be confirmed as a clearly visible suture space was often encountered in the oldest patients. This may be explained by the fact that the detection of the transverse palatal suture depends on the amount of calcification of the suture area and the amount of cancellous and compact bone in the surrounding area of the maxilla and palatal bone. Therefore, it may be hypothesised that the present observations reflecting both of these characteristics indicate a limited age-related increasing amount of calcified tissue within the transverse palatal suture, and also might suggest an age-related increase in the amount of compact bone within the maxillary and palatal bones. An augmented rigidity of the cranial bones may increase the resistance to external therapeutic forces.11

**Conclusion**

Contrary to the numerous histological studies, age-related features in both median palatal and transverse suture morphology were identified. CBCT scans proved to be accurate and a distortion-free method of visualisation of the palatal area. The findings of the present study could therefore be summarised as:

1. The shape of the median palatal suture at each point revealed changes from a straight/polyline shape to a more tortuous arrangement with age. The changes were already visible in the group of patients older than 14 years.

2. The level of suture calcification also increased with age and was most pronounced in the middle and posterior part of the maxillary portion of

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**Table IV. Summary of the most often-detected diagnoses and the sum of the total percentages of 3C and 4 diagnoses in each study group and topographic point.**

|          | FIA | FIP | FIP+10 | FIP+20 |
|----------|-----|-----|--------|--------|
| Most frequent diagnoses | Total of 3C & 4 | Most frequent diagnoses | Total of 3C & 4 | Most frequent diagnoses | Total of 3C & 4 |
| I 1B (2A/1A) | 1.3% | 2B (3B) | 3.8% | 2B (3B) | 7.6% | 2B (3B) | 10.2% |
| II 3B (2B/1B) | 6.8% | 3C (2B/3B) | 45.8% | 2B (3C) | 33.9% | 2B (3C) | 32.2% |
| III 3C (3B) | 43.2% | 3C (3B/4) | 63.6% | 3C (4) | 65.6% | 3C (4) | 52.7% |
| IV 4 [3C] | 80% | 4 [3C] | 81.8% | 4 [3C] | 87.3% | 4 (3C) | 81.8% |

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11. Note: The citation number 11 is not visible in the image.
the median palatal suture. Significantly, more observations of the fused (4) or almost fused (3C) suture traits were observed in patients >14 years.

3. The fusion of FIA point was not observed in patients less than 20 years old.

4. A fully radiolucent space within the median suture space was a rare finding.

5. Patients greater than 20 years old showed significant suture obliteration at all points evaluated and therefore could be considered as patients at high risk of RME failure if no factors other than median palatal suture morphology were considered.

6. The group of patients less than 15 years old could be treated with more predictable effect using an RME if no factors other than median palatal suture morphology are considered. Patients between 15 and 20 years may be described as borderline cases in which an individual assessment of CBCT scans may prove clinically relevant.

7. The transverse palatal suture did not show progressive calcification occurring with age.

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