

ABSENCE OR PRESENCE OF MID-PALATAL SUTURE IN PATIENTS WITH COMPLETE UNILATERAL CLEFT LIP AND PALATE, (A RETROSPECTIVE STUDY)

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ABSTRACT

Background: The absence/presence of the mid-palatal suture in patients with cleft lip and palate has never been well investigated, although this is essential for the rapid palatal expansion and maxillary growth modification. The aim of this study was to test the hypothesis that the mid-palatal suture is present in patients with unilateral complete cleft lip and palate (UCLP).

Methods: Twenty-three consecutive growing patients with UCLP who received cone beam computed tomography (CBCT) and maxillary growth modification at the bone age of cervical vertebral maturation stage 2 (CVS2) from 2007-2013 were included. For each patient, the CBCT axial sections right before the treatment were examined for the prevalence of presence, extent of suture in maxilla, and maturation of mid-palatal suture at the basal and alveolar bone levels. The data were analysed statistically.

Results: The prevalence of presence of mid-palatal suture was 100.00% at the basal-bone levels but decreased significantly ($p < 0.001$) to 60.87% at the alveolar levels. The incidence of late stage suture maturation was 86.96% at the basal-bone levels and decreased significantly ($p < 0.001$) to 14.29% at the alveolar levels when the mid-palatal suture is present. The extent of suture in the maxilla was $72.00 \pm 20.52\%$ at the basal-bone levels and decreased significantly ($p < 0.001$) to $28.54 \pm 27.00\%$ at the alveolar levels.

Conclusions: Although the mid-palatal suture in patients with UCLP is present, it fades away sharply and matures gradually from the basal bone down to the alveolar bone level of maxilla at the bone age of CVS2.

INTRODUCTION

Growing patients with Class III malocclusions have been cited as strong candidates for maxillary expansion and opening of the mid-palatal suture with rapid maxillary expansion if they have maxil-

lary constriction or posterior crossbite¹⁻³. The separation of the mid-palatal suture has been documented clinically by the opening of a diastema between the maxillary central incisors^{4,5}, radiographically⁶ and histologically^{7,8}.

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Although studies report on different sequence and timing of treatment in patients with cleft lip and palate (CLP), almost all treatment protocols include some types of expansion of the maxillary dental arch. In complete UCLP, the mid-palatal suture has an abnormal position lateral to the midline and the segment on the cleft side has no sutural connection with the maxilla on the non-cleft side. Some studies were conducted to either expand the maxilla before⁹⁻¹¹ or after alveolar bone grafting^{12,13}. Most of these studies relied on the fact that the maxillary opening was demonstrated clinically by the diastema between the maxillary central incisors, which reveals splitting of the maxillary processes in the premaxillary mid-palatal suture. It has been postulated that since the alveolar cleft crosses the region corresponding to the tooth bud of the maxillary lateral incisor, thus not interfering with the possible formation of an intermaxillary suture (mid-palatal suture) at the region of the premaxilla¹⁴. Therefore, there may be a mid-palatal suture in the premaxilla of patients with complete alveolar clefts. Although there is no agreement regarding the existence of the premaxillary suture in human beings, studies showing the nonexistence of a totally independent premaxillary suture have described the “incisive fissure”^{15,16}. The incisive suture is located in the anterior region of the premaxilla and originated embryologically from the primary palate¹⁷.

The mid-palatal suture has been described as an end-to-end type of suture^{18,19} with characteristic changes in its morphology during growth^{20,21,22,23}. In the infantile period, it has been reported that the mid-palatal suture is broad and Y-shaped in its frontal sections^{23,24}, however in patients with cleft lip and palate, the palatal suture system is disturbed²⁵.

From the above mentioned, it shows that only anecdotic case reports and limited clinical radiographic studies were published discussing expansion in complete UCLP patients however the question of whether the mid-palatal suture is present or absent in patients with cleft remains controversial.

To our knowledge, the absence or presence of the mid-palatal suture in patients with cleft lip and palate has never been well investigated, although this is essential for the treatment of maxillary growth modification in cleft patients. The objective of the present study is to conduct a pilot study to test the null hypothesis that there is no mid-palatal suture in patient with unilateral complete cleft lip and palate patients.

PATIENTS AND METHODS

This was a retrospective clinical cohort study and was approved by the Suez canal university research ethical committee. Twenty-three consecutive growing patients with complete unilateral complete cleft lip and palate who received cone beam computed tomography (CBCT) and maxillary growth modification for their maxillary hypoplasia at cervical vertebral maturation stage 2 (CVS2) from 2007-2013 were included. For each patient, the CBCT images were obtained with i-CAT cone-beam

3-dimensional imaging system (Imaging Sciences International, Hatfield, Pa, USA). Image evaluation was performed using i-CAT vision system. All images were evaluated by one trained examiner in a darkened room with a high definition monitor after a memory washout period of at least 4 weeks.

Evaluation of the absence/presence of the mid-palatal suture

The CBCT images right before the maxillary growth modification of all the patients were oriented so that the palatal plane in the sagittal sections, the plane between the right and left supraorbital margins in the coronal sections, and the plane between the right and left pterygoid plates in the axial plane are parallel to the floor. The axial sections were then examined for the presence/absence of the mid-palatal suture at the levels of 3 mm below the anterior nasal spine (3mm-below-ANS) (Figure 1), root-apex (Figure 2), middle-third (Figure 3), and coronal-third of the root of right maxillary incisor



Fig. (1) (Left)Sagittal and (Right) axial sections at the level of 3 mm below ANS, showing mid-palatal suture

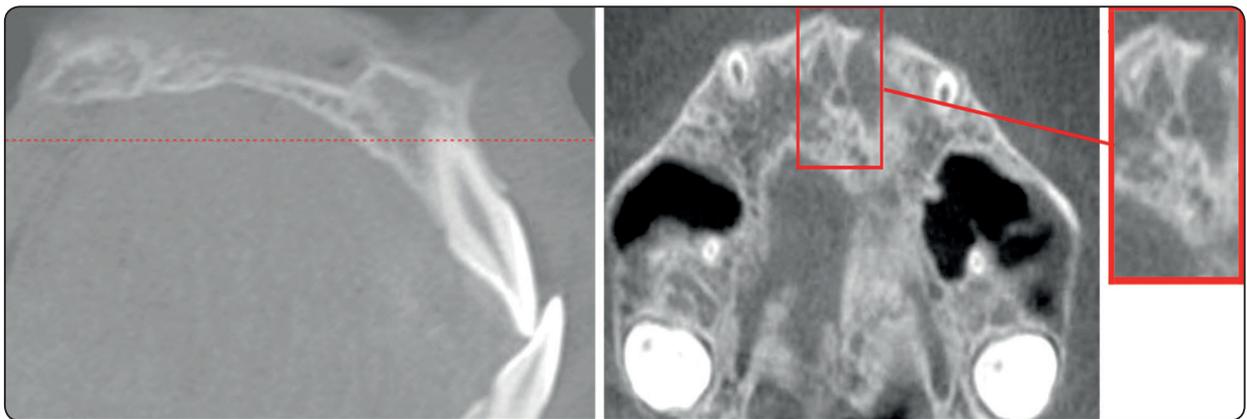


Fig. (2) (Left) Sagittal and (Right) axial sections at the level of root apex, showing mid-palatal suture



Fig. (3) (Left) Sagittal and (Right) axial sections at the level of root middle third, showing mid-palatal suture.

The presence of suture was defined as visible observation of a lined-suture or/and a spaced-suture on the CBCT images no matter the length is. The absence of suture was defined as no visible observation of a lined/spaced suture on the CBCT images. A lined-suture is a straight/scalloped high-density suture line on the CBCT image, which represents the early stage suture maturation²⁶ and a spaced-suture is a two parallel, straight/scalloped, high-density lines separated by small low-density spaces on the CBCT image, which represents the late stage suture maturation²⁶. The following 5 measurements were measured:

1. *Prevalence of presence of suture (%)*: It is the ratio of cases number with presence of suture/ total cases number multiplied by 100 %.
2. *Prevalence of absence of suture (%)*: It is the ratio of cases number with absence of suture/ total cases number multiplied by 100 %.
3. *Incidence of lined-suture (%)*: It is the ratio of cases number with lined-suture/cases number with presence of suture multiplied by 100 %.
4. *Incidence of spaced-suture (%)*: It is the ratio of cases number with spaced-suture/cases number with presence of suture multiplied by 100 %.

5. *Suture length index (%)*: It is the ratio of suture length/maxillary bone length multiplied by 100 %. The suture length is the perpendicular length of mid-palatal suture, and the maxillary bone length is the median perpendicular distance between the most anterior and posterior points of the bone revealed on the examined axial section. This was for the evaluation of the extent of mid-palatal suture in maxilla.

Statistical analysis

Post-hoc power analysis was performed using the prevalence of presence of suture as the primary outcome, since there is no published data in literature for priori-power analysis. Repeated measurements of five randomly selected cases at two different

times were performed for the intra-examiner error by using the Dahlberg's formula²⁷.

The measurements were analysed statistically for the differences among the 4 different bone levels with the Friedman's test, and the Wilcoxon signed-rank test for the pair-wise comparisons between any 2 different bone levels when the Friedman's test revealed significant difference. The multiple pair-wise comparisons were adjusted by the Bonferroni's correction. The level of significance was set at $p \leq 0.05$.

RESULTS

The power of the post-hoc power analysis of this retrospective cohort study was 99.0%. This was based on the average prevalence of presence of mid-palatal suture 89.2%, sample size of 23 consecutive cases, and 0.05 type I error. The analysis of intra-examiner errors revealed that there were no significant statistical differences between the two measurements. The technical errors of measurement were calculated from 5 randomly selected cases. The eight suture linear measurements were reassessed by one examiner after a memory washout period of at least 4 weeks. The method error for the measurements was calculated using Dahlberg's formula²⁷. There was no systematic error for any of the 8 measurements with P-value > 0.05.

The *prevalence of presence of suture* (Table 1) revealed the mid-palatal suture is present at the basal bone level but might be absent at the alveolar level in patients with unilateral cleft lip and palate. It was 100.00% at the levels of 3 mm-below-ANS and root-apex, 95.65% at the middle-third, but it decreased significantly ($p < 0.001$) to 60.87% at the coronal-third level of the maxillary incisors (Table 1). The *incidence of lined-suture* (Table 2) was 13.04% at the level of 3mm-below-ANS and gradually increased to 85.71% at the level of coronal-third, when the mid-palatal suture is present. On the contrast, the *incidence of spaced-suture* (Table

2) was 86.96% at the level of 3mm-below-ANS and gradually decreased to 14.29% at the level of coronal-third, when the mid-palatal suture is present (Table 2). The lined-suture represents the early stage and the spaced-suture represents the late stage of mid-palatal suture maturation.

The *suture length index* (Table 3) measured the extent of suture in the maxilla. The extent of suture was not 100% in the maxilla. It was $72.00 \pm 20.52\%$ and $67.40 \pm 16.60\%$ at the level of 3mm-below-ANS and root-apex respectively, and significantly decreased to $59.91 \pm 19.48\%$ and $28.54 \pm 27.00\%$ at the levels of middle-third and coronal-third.

TABLE (1) The prevalence of presence /absence of suture of mid-palatal suture at four different bone levels in patients with unilateral cleft lip and palate.

| Prevalence % (ratio) | 3mm-below-ANS | Root-apex | Middle-third | Coronal-third | P-value |
|----------------------|-----------------------------|-----------------------------|----------------------------|----------------------------|---------|
| Presence of suture | 100.00 (23/23) ^a | 100.00 (23/23) ^a | 95.65 (22/23) ^a | 60.87 (14/23) ^b | <0.001* |
| Absence of suture | 0.00 (0/23) | 0.00 (0/23) | 4.35 (1/23) | 39.13 (9/23) | |

Friedman test followed by Wilcoxon signed-rank test

* Significant at $P \leq 0.05$, Different superscripts are statistically significantly different

TABLE (2) The incidence of lined-suture (early stage of suture maturation) and the incidence of spaced suture (late stage of suture maturation) at four different bone levels in patients with unilateral cleft lip and palate when the mid-palatal suture is present.

| Incidence % (ratio) | 3mm-below-ANS | Root-apex | Middle-third | Coronal-third |
|---------------------|---------------|---------------|---------------|---------------|
| Lined-suture | 13.04 (3/23) | 34.78 (8/23) | 59.09 (13/22) | 85.71 (12/14) |
| Spaced-suture | 86.96 (20/23) | 65.22 (15/23) | 40.91 (9/22) | 14.29 (2/14) |

TABLE (3) The *suture length index* of mid-palatal suture (suture length/maxillary bone length X 100%) at four different bone levels in patients with unilateral cleft lip and palate.

| Prevalence % (ratio) | 3mm-below-ANS | Root-apex | Middle-third | Coronal-third | P-value |
|--|--------------------------------|--------------------------------|--------------------------------|--------------------------------|---------|
| Suture length index (%) Mean \pm SD | 72.00 ± 20.52 ^a | 67.40 ± 16.60 ^a | 59.91 ± 19.48 ^a | 28.54 ± 27.00 ^b | <0.001* |

* Significant at $P \leq 0.05$, Different superscripts are statistically significantly different

Friedman test followed by Wilcoxon signed-rank test

DISCUSSION

Literature has proven that expansion in UCLP before or after alveolar bone grafting seems possible^{9, 10, 11, 12, 13}. However evidences were only available clinically, as evident by diastema between maxillary two centrals, and radiographically as represented by occlusal radiographs. Growth of facial sutures was found by Bjork²⁸ to be intimately related to growth in height. Bjork's data consequently demonstrate a range in boys between 14 and 20 years of age as regards the end of the growth of sutures. It is logical to presume that skeletal age also influences the start of closure of sutures; this in turn explains the use of CVM²⁹ and skeletal method as a mean for determining age of the sample used in our study. In addition, a study³⁰ in non-cleft cases concluded that the ideal time for proceeding with rapid maxillary expansion would be CVM4. They evaluated mid-palatal suture ossification by computerized tomographic scan and were able to show gradual increase of ossification of the suture at complete skeletal maturation. For this reason and for better growth modification results, patients in our sample were chosen at the stage of cervical vertebral maturation stage 2 (CVS2)

Searching the literature, we found some histologic and microcomputed tomography analyses to document changes in mid-palatal suture morphology or maturation with age in non-cleft patients^{21, 31, 32}. Each method has its inherent limitations as they were assessing small sections of the total anteroposterior suture length only, even if several serial sections from one area were available. In histologic studies, only frontal sections have been evaluated^{21, 22, 23, 33} which makes data not reliable for clinical application as the maturation of the mid-palatal suture takes place from posteriorly and on forwards to the anterior region^{21, 22, 32}. Conventional radiographs like occlusal ones deliver a two dimensional image of a three dimensional structure. Also they are not reliable for analysing the suture's morphology because the vomer and

the structures of the external nose overlay the mid-palatal area and thus might lead to false radiographic interpretations³³. We relied on Cone-beam computed tomography (CBCT) as it overcomes the short outcomes of conventional methods and it provides 3-dimensional visualization of the oral and maxillofacial structures with no superimposition of adjacent structures and low radiation exposure³⁴.

Our work is the first to evaluate the overall presence or absence of mid-palatal suture in UCLP patients using CBCT. The indices used in our study, were calculated to get more reliable data about the suture length and suture space in relation to the bone, due to the variation in both bone and suture length. The data on sutural space reported here must therefore be accepted as indices rather than absolute values.

In non-cleft patients, the sutural system of the hard palate comprises premaxillary, mid-palatal, palatomaxillary and interpalatal articulation. The premaxillary suture exists between the premaxillary bones and the maxilla^{35, 36}. The mid-palatal suture extends from the incisive canal to the transverse palatine (palatomaxillary) suture posteriorly. In the present study, the suture presence was evaluated at four different levels with reference to the right central incisor. This was conducted to be able to detect the presence or absence of the suture from the maxillary bone base level (Nasal) to the alveolar bone level (Oral). The first level of measurement was set 3-mm below a line joining ANS-PNS (Palatal plane) to avoid including the suture between vomer bone and the maxilla and to identify its presence/absence clearly.

We were able to detect the mid-palatal suture as evidenced by *prevalence of presence of suture (%)* which showed highly significant values at the level 3 mm- below ANS and above the root apex of maxillary incisors (100%), but it fades away and obliterates sharply at the tooth level, root middle third and coronal third (95.65% and 60.87%)

respectively, as a result of the cleft presence but they are not completely absent. In a study³⁷ that described the histologic-radiologic picture of the mid-palatal suture, a radiologically invisible suture corresponds histologically to either 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. In turns, it could be concluded that *Prevalence of absence of suture* does not mean a true absence of the suture. The results of the present investigation concur with the embryologic findings that the “incisive fissure” have been described in some studies^{15, 16} instead of a “premaxillary suture”. Embryologically, the alveolar cleft crosses the region corresponding to the tooth bud of the maxillary lateral incisor, thus it does not interfere with the possible formation of an intermaxillary suture (mid-palatal suture) the region of the premaxilla. As a result, a conclusion was drawn that there may be a mid-palatal suture in the premaxilla of patients with complete alveolar clefts^{12, 14}

In our study, although it is a preliminary study, the findings presented here can be considered optimistic. The body of our knowledge is particularly small as regards the presence or absence of the mid-palatal suture in UCLP. We searched the literature and found no one single article describing the mid-palatal suture in UCLP. The ones found were only discussing Separation of the mid-palatal suture in the premaxillary area in response to orthopaedic expansion after secondary bone grafting^{12, 13}. They diagnosed both, clinically and radiographically, splitting of the suture of the maxillary processes in the premaxillary mid-palatal suture after grafting. Separation of the suture was diagnosed only in 42.8% of their sample¹². They explained unequal percentage of behaviour of the mid-palatal separation suggesting that anterior area of the mid-palatal suture could be normal in patients with CLP, even though separation of the suture is not always observed. They relied only on occlusal radiographs

for evaluation of the expansion and suture separation in the anterior premaxillary area. However, the introduction of CBCT played an important role in imaging and describing the morphology of the mid-palatal suture, fusion and maturation²⁶. Angelieri et al.²⁶ managed to describe the maturational stages of mid-palatal suture in 5 stages (A to E) in non-cleft patients. In UCLP patients, it is not possible to differentiate between stage C (two parallel high density lines) and D (fusion of mid-palatal suture has occurred in the palatine bone). Therefore, the stages of maturation in cleft patients could only have 4 stages, A, B, C/D, E. In our study, we tried to describe topographically and follow the mid-palatal suture along its course as well as its maturation from basal bone to tooth level, both nasal and oral parts. If we to correlate our findings, *the Incidence of lined suture* (early stage of maturation) was low (13.04%) at 3 mm-below ANS. This stage is equivalent to A or B in non-cleft patients²⁶. The incidence of suture maturation increase as we approach the tooth level, root apex (34.78%), root middle third (59.09%) followed by the coronal third (85.71%). The evaluation ratio of suture length to bone length (*suture length index*) revealed significance at the level of 3 mm below ANS (basal bone level of maxilla) with the highest percentage of extent (72%) and the percentage decreased as we approach the tooth level (28.54%). Both findings strengthen the fact that the mid-palatal suture is present as a lined suture (Stages A, B in non-cleft patients) and matures gradually from basal bone towards the tooth level. Mid-palatal suture has been proved to be exceptionally sensitive in its response to mechanotransduction. In animal studies, any minor changes (incisor extraction, amount of solid food consumed) can affect the suture metabolism and in-turns its morphology^{38, 39, 40}. These results could explain and verify why suture's closure progresses more rapidly in the oral than in the nasal part of the palatal vault²¹. Suture fusion and maturation has been also proved to be under the control of extrinsic

functional demands affecting specific suture area and functional forces acting on sutural articulations^{21, 41, 42}. Worth mentioning that, suture maturation in non-cleft patients was also proved to vary in anterior from posterior part^{21, 30}. Histologically, the ossification process in the mid-palatal suture starts with bone spicules from suture margins along with “islands” (i.e.: masses of acellular tissue and ill-defined calcified tissue) in the middle of the sutural gap⁴³. The formation of spicules takes place at many areas along the suture’s course, with the number of spicules increasing with maturation^{21, 31} and forming many scalloped areas that are close to each other and separated in some areas by connective tissue^{21, 37}. As a result fusion occurs earlier in the posterior area of the suture, with progression of ossification taking place from posterior to anterior^{21, 22}. This explains why the maturation and ossification of the mid-palatal suture in our study in the oral part of the suture was 85.7% (coronal third) where the functional forces and demands are higher than the nasal part 13.04% (3 mm below ANS).

Comparisons with previous studies were impossible since this is a novel study that has not been considered so far. Among the limiting factors of our study design was that it is not a prospective one and absence of a control group compatible with the patients in this study. Further studies by other colleagues, to detect *the Percentage of suture prevalence* in bone (%) in a larger sample in both UCLP and BCLP and to compare *incidence of lined and spaced sutures (%)* before and after expansion and with growth modification in cleft patients, are under investigation.

Among the ancient Greeks, several of the Pythagorean school believed in the rotation of the earth. This was not accepted immediately until many years after where the idea has been studied when based on theories rather than observations. The earth spins around its own axis in a counter-clock wise direction, from the west towards the

east. In this article and the ones to follow, we are challenging the conventional practice. Although this is a preliminary study, the findings presented here can be considered optimistic as we have proved the presence of mid-palatal suture in UCLP at the bone age CVS2 and mostly non- mature above the root apex of maxillary incisors and along its course it fades away sharply and mature gradually as it approaches alveolar bone level.

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