

## 牙颌面畸形专题

## 翼腭缝宏观解剖及其发育模式研究

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**[摘要]** **目的**·利用锥形束计算机断层扫描 (cone-beam computed tomography, CBCT) 技术分析中国人群中翼腭缝 (pterygopalatine suture, PPS) 的解剖及宏观形态特征, 并初步探讨其发育模式及其与矫正上颌发育不足之间的关联。**方法**·纳入2023年7月—8月在上海交通大学医学院附属第九人民医院拍摄的134例CBCT影像资料, 根据年龄分为6组。以PPS标志点为依据, 计算得出PPS整体的横向位置 (transverse position of PPS,  $X_{PPS}$ ), PPS整体的矢状向位置 (sagittal position of PPS,  $Y_{PPS}$ ), 以及PPS的锥突嵌入角 (insertion angle of PPS, IAP)、锥突嵌入宽度 (insertion width of pyramidal process, IWP) 和锥突嵌入深度 (insertion depth of pyramidal process, IDP), 并通过多平面观察确定翼上颌联合情况。采用回归分析评估各参数与年龄、性别的相关性, 并通过两两比较确定参数变化的稳定年龄段。采用配对  $t$  检验及配对  $\chi^2$  检验分析双侧参数的差异性。**结果**· $Y_{PPS}$ 、IDP与年龄无显著相关性, 而 $X_{PPS}$ 、IAP、IWP、翼上颌连接的发生率均与年龄呈显著正相关 ( $P<0.01$ )。性别差异仅在 $X_{PPS}$ 中显著, 男性大于女性 ( $P<0.01$ )。参数的年龄变化趋势分析表明:  $X_{PPS}$ 在组1 (6岁≤年龄<9岁) 和组2 (9岁≤年龄<12岁) 间差异显著 (女性:  $P=0.006$ ; 男性:  $P=0.004$ ); IAP在组2与组3 (12岁≤年龄<15岁) 间差异显著 ( $P=0.042$ ), 98.5%样本的IAP大于45°; IWP在组1与组3间差异显著 ( $P=0.016$ ); 翼上颌联合情况在组1、2、3间差异显著 (组1、2间  $P<0.001$ , 组2、3间  $P=0.037$ , 组1、3间  $P<0.001$ ), 成人发生率高于90%。各项指标双侧比较均未见统计学差异。**结论**·6岁以后 $Y_{PPS}$ 及IDP未表现出明显改变, 上颌骨与翼突趋于融合。PPS整体横向位置在12岁左右趋于稳定, 而IAP及IWP持续增长, 至15岁左右达到稳定且翼腭缝锥突嵌入翼切迹的方向偏向矢状向。

**[关键词]** 翼腭缝; 形态学; 生长发育; 上颌扩弓; 上颌前方牵引**[DOI]** 10.3969/j.issn.1674-8115.2024.08.002 **[中图分类号]** R783.5 **[文献标志码]** A

## Study on macroscopic anatomy and developmental model of pterygopalatine suture

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**[Abstract]** **Objective**·To analyze the anatomical and macroscopic characteristics of the pterygopalatine suture (PPS) in Chinese population using cone-beam computed tomography (CBCT) technology, and to preliminarily investigate its developmental pattern and its association with the correction of maxillary underdevelopment. **Methods**·A total of 134 CBCT images, taken from July to

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August 2023 at Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, were categorized into six age groups. The PPS landmarks were utilized to determine the overall transverse position ( $X_{PPS}$ ), sagittal position ( $Y_{PPS}$ ), insertion angle (IAP), insertion width of the pyramidal process (IWP), and insertion depth of the pyramidal process (IDP). The pterygomaxillary junction was identified through multiplanar observations. Regression analysis was performed to assess the correlation of these parameters with age and gender, and pairwise comparisons were made to determine the stable age range for parameter changes. Paired t-tests and paired chi-squared tests were conducted to analyze the bilateral parameter differences. **Results** Results showed that  $Y_{PPS}$  and IDP did not exhibit significant correlation with age, whereas  $X_{PPS}$ , IAP, IWP, and the incidence of pterygomaxillary fusion were significantly positively correlated with age ( $P<0.01$ ). Gender differences were only significant for  $X_{PPS}$ , with males demonstrating greater values than females ( $P<0.01$ ). Analysis of age-related trends indicated significant differences in  $X_{PPS}$  between group 1 (6 years $\leq$ age $<$ 9 years) and group 2 (9 years $\leq$ age $<$ 12 years) (female:  $P=0.006$ , male:  $P=0.004$ ); significant differences in IAP were observed between group 2 and group 3 (12 years $\leq$ age $<$ 15 years) ( $P=0.042$ ), with 98.5% of samples having an IAP greater than 45 degrees; IWP differences were significant between group 1 and group 3 ( $P=0.016$ ), and the pterygomaxillary fusion incidence was significantly different among group 1, 2, and 3 (group 1 vs. 2:  $P<0.001$ , group 2 vs. 3:  $P=0.037$ , group 1 vs. 3:  $P<0.001$ ), with an incidence rate exceeding 90% in adults. No significant bilateral differences were found for all parameters. **Conclusion** No significant changes were observed in  $Y_{PPS}$  and IDP after the age of 6, indicating a trend towards fusion of the maxilla with the pterygoid process. The overall transverse position of the PPS tends to stabilize around 12 years of age, while the IAP and IWP continue to increase and reach stability around 15 years of age, with a sagittal insertion orientation of the pyramidal process into the pterygoid notch.

**[Key words]** pterygopalatine suture; morphology; growth and development; maxillary expansion; maxillary protraction

上颌矢状向发育不足及横向发育不足是口腔正畸临床中常见的骨性错殆类型,二者常常同时出现<sup>[1]</sup>。为纠正此类畸形,临床常采用上颌前牵引及上颌扩弓治疗手段,以促进上颌骨的前移及宽度增加,从而优化咬合与颌骨的关系。腭骨锥突是腭骨垂直板后部向后外侧延伸的结构,其位置介于蝶骨翼突与上颌骨之间;而翼腭缝(ptyerygopalatine suture, PPS)是腭骨锥突与蝶骨翼切迹之间的骨性连接,位于上颌复合体的后部,是连接颅底与上颌复合体的关键部位,属于上颌周缘骨缝的一部分。PPS在三维空间中呈现向上突起的拱形结构,形态存在显著的个体差异<sup>[2]</sup>。其独特的稳固嵌合结构使得PPS与其他上颌周缘骨缝明显区分开来。此外,PPS区域的双向骨沉积对上颌相对于颅底前方移位起着至关重要的作用<sup>[2]</sup>。

在实施上颌扩弓治疗过程中,PPS已被证实为核心骨性阻力之一,其紧密锁结机制极大限制了腭后区域骨骼的扩展<sup>[3-4]</sup>。研究<sup>[5-6]</sup>指出,上颌周缘骨缝的松解是提高前牵引疗效的关键所在。正畸医师需深入理解PPS的结构特性,以充分利用其生长与分离的潜力,为患者带来实质性的治疗益处。随着锥形束计算机断层扫描(cone-beam computed tomography, CBCT)技术在正畸领域的广泛应用,大样本的翼腭缝形态学定量研究得以开展。本研究借助CBCT技术,对PPS的形态特征与位置分布进行了探究,并初步揭示了其发育规律,旨在为确定上颌扩弓与前牵引

治疗相结合的方案及最佳治疗时机提供新的理论依据。

## 1 对象与方法

### 1.1 研究对象

本研究回顾性分析了2023年7月—8月在上海交通大学医学院附属第九人民医院口腔颌面外科就诊患者的CBCT影像资料。研究对象排除了唇腭裂、颅面部综合征以及有正畸正颌治疗史或颌面部外伤史的患者,最终纳入134例(男性67例、女性67例)。样本年龄范围为6~25岁,平均年龄为(15.0 $\pm$ 5.3)岁。依据年龄特点,将样本划分为6组,如表1所示,覆盖了从童年期至成年期的范围。

表1 研究对象的分组( $N=134$ )

Tab 1 Demographic characteristics of subjects ( $N=134$ )

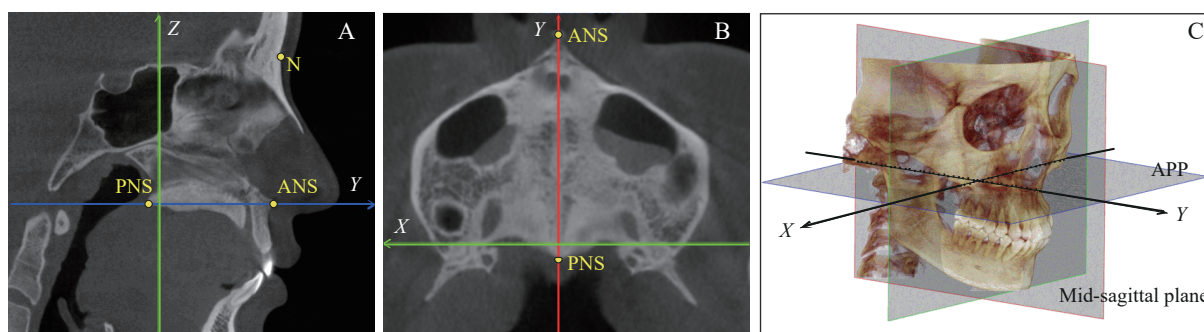
| Group | Age/year             | Male ( $n=67$ ) | Female ( $n=67$ ) |
|-------|----------------------|-----------------|-------------------|
| 1     | 6 $\leq$ Age $<$ 9   | 11              | 11                |
| 2     | 9 $\leq$ Age $<$ 12  | 11              | 11                |
| 3     | 12 $\leq$ Age $<$ 15 | 11              | 11                |
| 4     | 15 $\leq$ Age $<$ 18 | 12              | 12                |
| 5     | 18 $\leq$ Age $<$ 21 | 11              | 11                |
| 6     | 21 $\leq$ Age $<$ 25 | 11              | 11                |

### 1.2 方法

1.2.1 测量方法 患者采取直立位,头部维持自然

状态,通过颏托及外耳道杆及逆行固定,确保咬合稳定于牙尖交错位。调整影像资料中头部位置,确保正中矢状面精确通过前鼻棘点 (anterior nasal spine, ANS)、后鼻棘点 (posterior nasal spine, PNS) 和鼻根点 (nasion, N)。横断面设定为经过 ANS 点与 PNS

点,且与正中矢状面保持垂直,以下称为腭平面。冠状面沿矢状向定位,以双侧腭大孔后缘连线的中点为基准,同时保持与正中矢状面及腭平面的垂直关系 (图1)。



**Note:** A. Mid-sagittal plane. B. Axial palatal plane. C. Head position in space. APP—axial palatal plane.

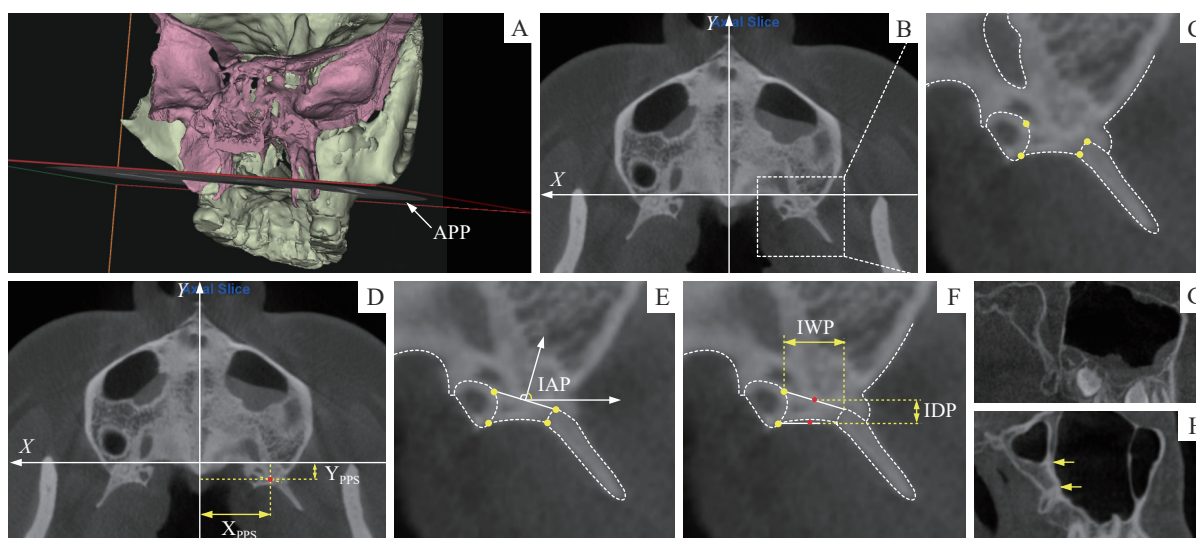
**图1** 翼腭缝宏观解剖的标准观测头位

**Fig 1** Standard observational head position of macroscopic anatomy of the pterygopalatine suture

**1.2.2 仪器** 采用KaVo OP3D Vision系统 (KaVo公司, 德国) 获取CBCT影像。扫描参数设定为管电压120 kV, 管电流5 mA, 体素层厚0.3 mm, 总扫描时间8.9 s, 其扫描视野直径为23 cm, 高度为17 cm。对于CBCT DICOM数据的三维重建、头位调整及标志点定位, 则通过Dolphin Imaging软件 (版本11.9, 美国) 实现。所有参数的计算处理均基于Windows系统, 通过PyCharm集成的Python环境 (版本3.8.12)

完成。

**1.2.3 观察指标** 腭平面与上颌扩弓及前牵引治疗之间存在密切的关联性, 该平面成为本研究的关键观测基准。在此研究中, PPS被腭平面划分为内外2个部分, 腭骨锥突嵌入蝶骨翼切迹的结构简称为“锥突嵌体”。对于每侧PPS区域, 本研究标定了4个特定的标志点, 分别为锥突嵌体的最外侧后点、最外侧前点、最内侧后点、最内侧前点, 见图2A~C。



**Note:** A. Positional relationship between the axial palatal plane and pterygopalatine sutures. Pink block represents the sphenoid bone, and green block represents the rest. B. Axial palatal plane. C. Landmarks of the pterygopalatine suture. D. Transverse and sagittal position of the PPS ( $X_{PPS}$  and  $Y_{PPS}$ ). E. Insertion angle of the pyramidal process (IAP). F. Insertion width and depth of the pyramidal process (IWP and IDP). G. Pterygomaxillary junction-noncontacted (PMJ-N). H. Pterygomaxillary junction-contacted (PMJ-C); the segment between yellow arrows represents the contacting segment.

**图2** 翼腭缝宏观解剖结构的标志点与观测指标

**Fig 2** Landmarks and observation indexes of the macroscopic anatomical structure of pterygopalatine suture



本研究综合分析6项评价指标(图2),其中5项为定量指标,其参数值基于腭平面上的系列PPS标志点进行三维坐标测量而确定;另1项为定性指标,通过多平面空间观察予以判定,计算方法见表2。

定量指标如下。①PPS 横向位置(transverse position of PPS,  $X_{\text{PPS}}$ )即锥突嵌体前缘中点至ANS-PNS连线的水平距离。②PPS 矢状向位置(sagittal position of PPS,  $Y_{\text{PPS}}$ )即锥突嵌体前缘中点至腭大孔后缘( $X$ 轴)的矢状向距离。③锥突嵌入角(insertion angle of pyramidal process, IAP)定义为锥突嵌体前缘的前向垂线与水平外侧线之间的夹角。④锥突嵌入宽度(insertion width of pyramidal process, IWP)指锥突嵌体前缘的横向延伸宽度。⑤锥突嵌入深度(insertion depth of pyramidal process, IDP)即锥突嵌体前缘中点至后缘中点的矢状向距离。⑥翼上颌联合类型:非连接型(pterygomaxillary junction-noncontact type, PMJ-N),即上颌骨后壁未与蝶骨翼突直接相连;连接型(pterygomaxillary junction-contact type, PMJ-C),即上颌骨后壁与蝶骨翼突直接连接。

表2 参数计算方法

Tab 2 Calculation of parameters

| Measurement      | Calculation                   |
|------------------|-------------------------------|
| $X_{\text{PPS}}$ | $ X_b + X_d /2$               |
| $Y_{\text{PPS}}$ | $(Y_b + Y_d)/2$               |
| IAP              | $\cos^{-1}[(Y_b - Y_d)/ bd ]$ |
| IWP              | $ X_d - X_b /2$               |
| IDP              | $(Y_b + Y_d - Y_a - Y_c)/2$   |
| PMJ              | Noncontact/contact (N/C)      |

### 1.3 统计学方法

由单一研究者对所有影像资料进行头位校正、标志点标定及翼上颌联合情况的判定。2周后,随机抽取20%的样本,由2名研究者独立并行地重复相同流程。组内相关系数(intraclass correlation coefficient, ICC)及Kappa系数用于评价组间及组内的一致性。

使用PASS 15软件进行样本量估算,确定每组所需的最小样本量为21人,本研究的样本量符合标准。使用SPSS 26.0软件进行统计学分析。PMJ-N被指定

为0, PMJ-C被指定为1。通过逐步线性回归分析及二元逻辑回归,探究定量和定性参数与年龄、性别的整体相关性。进一步开展多重比较分析,以确定这些参数快速变化和稳定的年龄段。定量参数的双侧差异采用配对 $t$ 检验进行分析,定性参数的双侧差异则采用配对 $\chi^2$ 检验。 $P < 0.05$ 表示差异具有统计学意义。

## 2 结果

5项定量参数的组内ICC值为0.830~0.934,组间ICC值为0.822~0.920,表明观测结果可信度高。翼上颌联合类型判定的组内及组间Kappa系数分别为0.982和0.957,表明结果高度一致。

### 2.1 观察指标与年龄及性别的相关性

观察指标与年龄及性别的相关性分析结果见表3。 $X_{\text{PPS}}$ 与年龄呈正相关,且男性的测量值显著高于女性; $Y_{\text{PPS}}$ 与年龄、性别均未显示出显著的相关性。就内部嵌合形态而言,IAP及IWP与年龄增长呈正相关,与性别无显著相关性;IDP与年龄和性别均无显著相关性。此外,翼上颌连接型的形成与年龄的增加呈现显著相关性。

表3 翼腭缝位置及形态与年龄及性别的相关性( $N=268$ )

Tab 3 Correlation between pterygopalatine suture position/morphology and age/gender ( $N=268$ )

| Measurement      | Age    |        | Gender |       |
|------------------|--------|--------|--------|-------|
|                  | $r$    | $P$    | $r$    | $P$   |
| $X_{\text{PPS}}$ | 0.098  | <0.001 | 0.560  | 0.008 |
| $Y_{\text{PPS}}$ | 0.011  | 0.565  | 0.054  | 0.181 |
| IAP              | 0.835  | <0.001 | 1.098  | 0.517 |
| IWP              | 0.079  | 0.001  | 0.371  | 0.133 |
| IDP              | -0.009 | 0.218  | 0.078  | 0.309 |
| PMJ(N/C)         | 0.304  | <0.001 | -0.653 | 0.060 |

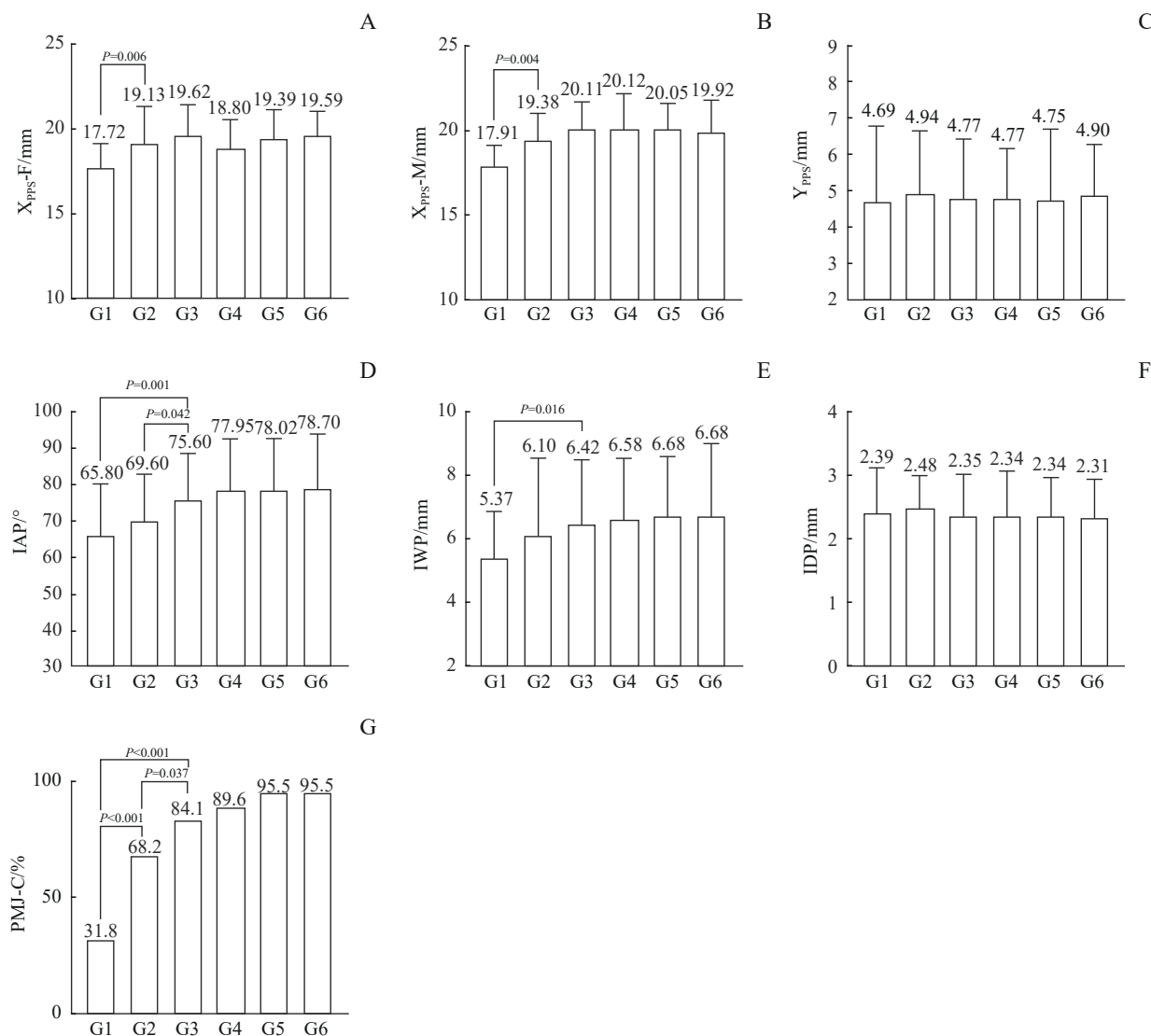
**Note:** Multifactorial linear or binary Logistic regression was performed. Female was recorded as 0, and male as 1.

### 2.2 发育节点比较

为了确定发育节点,本研究在样本按年龄分组的基础上进行了进一步分析。多重比较的结果如图3所

示,在翼腭缝的横向位置上,第1组和第2组之间均显示出统计学差异(女性,  $P=0.006$ ; 男性,  $P=0.004$ ),而其余相邻组间的差异不显著。其余相邻组间的差异无统计学意义。IAP(锥突嵌入角)在组2和组3之间的比较显示出统计学差异( $P=0.042$ ),其他相邻组间的差异不显著。IAP的数值范围为 $3.6^{\circ}\sim 167.2^{\circ}$ ,但各年龄组多数个体的IAP均处于 $4^{\circ}\sim 90^{\circ}$ 范围内(图4)。IWP(锥突嵌入宽度)在组1和组3之

间的比较显示出统计学差异( $P=0.016$ ),相邻组间的差异不显著。翼上颌联合类型在第1组和第2组之间( $P<0.001$ )、组2和组3之间( $P=0.037$ )的分布显示出统计学差异,其他相邻组间的差异不显著。在本研究纳入的样本中,翼上颌连接型的比例为77.6%(208/268),而在纳入的成年样本中,该比例为95.5%(84/88)。



**Note:** A. Transverse position of PPS-Female ( $X_{PPS-F}$ ). B. Transverse position of PPS-Male ( $X_{PPS-M}$ ). C. Sagittal position of PPS ( $Y_{PPS}$ ). D. Insertion angle of the pyramidal process (IAP). E. Insertion width of the pyramidal process (IWP). F. Insertion depth of the pyramidal process (IDP). G. The proportion of pterygomaxillary junction-Contact (PMJ-C). G1-6 represent Group 1-6.

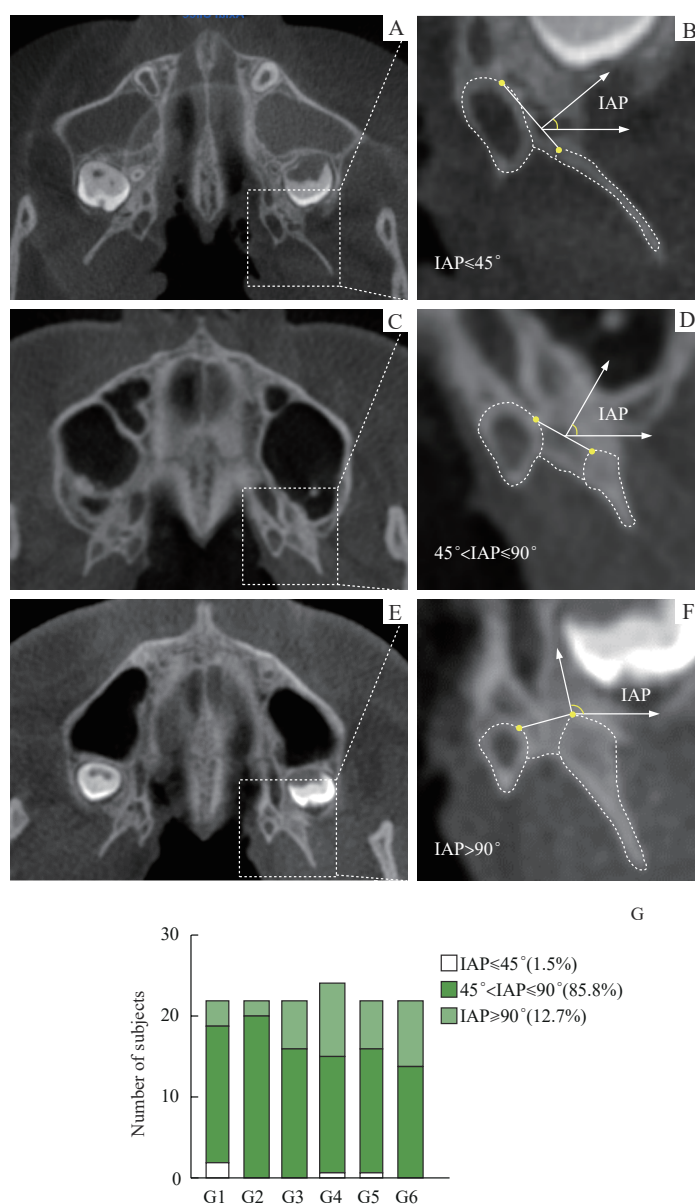
图3 翼腭缝位置及形态参数的年龄组间比较

Fig 3 Comparison of the parameters of pterygopalatine suture morphology and position between age groups

### 2.3 双侧结构对称性比较

样本间双侧PPS横向及矢状向位置,锥突嵌入

角、嵌入宽度、嵌入深度、翼上颌连接情况的差异均无统计学意义( $P>0.05$ )。



**Note:** A/B. Insertion angle of the pyramidal process (IAP) less than  $45^\circ$ . C/D. IAP larger than  $45^\circ$  and less than  $90^\circ$ . E/F. IAP larger than  $90^\circ$ . G. Proportion of 3 types of IAP in each age group.

图4 不同角度范围的IAP

Fig 4 IAP for different angular ranges

### 3 讨论

上颌矢状向及横向发育不足的正畸矫治与骨缝的密切相关性已得到广泛认可<sup>[3, 6-8]</sup>。作为上颌复合体矢状向生长的关键骨缝,翼腭缝分离过程在上颌生长改良及骨性矫正中发挥着重要作用<sup>[9]</sup>。在上颌扩弓治疗中,腭后段骨性扩展难度大,而翼腭缝分离已被证实是提升腭后段扩弓量的关键因素<sup>[9]</sup>。此外,在生长发育期,上颌前徙主要依赖于前牵引力对翼腭缝等骨缝处骨沉积的刺激,而成熟期患者则主要依赖于翼腭缝等骨缝分裂后在前牵引力作用下的类牵引成骨效应实

现上颌前徙<sup>[10]</sup>。

6岁以后的成长期间,翼腭缝相对于腭大孔的矢状向位置稳定。但随着上颌第二(第三)磨牙的萌出,上颌结节区域的骨沉积持续向后推进,使得上颌结节与蝶骨翼突的间距逐渐缩短<sup>[2]</sup>,并倾向于在翼腭缝的上方外侧形成翼上颌联合结构。成人人群中,翼上颌联合的发生率高于90%。此联合的形成及其连接面积的增加,可能会引起翼颌区域骨性阻力的增强。此外,在翼腭缝的嵌合形态方面,IAP在发育过程中逐步扩大,其嵌入方向亦逐步趋向矢状向。

尽管普遍观点认为,腭中缝与上颌周缘骨缝的骨

化闭合是导致随着年龄增长, 上颌扩弓及前牵引治疗难度增加的关键因素<sup>[2,11]</sup>, 然而, 本研究的结果提示, 翼上颌联合融合程度的增长及其翼腭缝锥突在矢状向上的偏转, 亦可能是促成这一现象的潜在因素之一。

翼腭缝分离在提升扩弓及治疗效果中扮演着关键角色<sup>[9-10,12]</sup>。相较于横向, 翼腭缝嵌入方向普遍更靠近矢状向 (即  $IAP \geq 45^\circ$ )。这提示在扩弓过程中, 翼腭缝的锁结机制可能会形成较大的结构性阻力。然而, 通过施加前牵引力, 可促使锥突沿着其嵌入方向自翼切迹脱出, 进而导致翼腭缝分离, 有效解除上颌复合体后方的骨性障碍。

因此, 除了业界广泛接受的扩弓治疗通过松解上颌周缘骨缝以增强前牵引疗效的作用机制外<sup>[6]</sup>, 上颌前牵引治疗具备通过促进翼腭缝分离以进一步增强扩弓效果的可能性。因此针对上颌横向生长不足的骨性Ⅲ类错殆患者, 交替运用前牵引力与扩弓力的治疗方案, 较之传统的联合治疗方法, 在促进疗效互惠性方面可能具备更明显的优势。

本研究创新性地应用CBCT技术对中国人群的翼腭缝宏观形态进行了探讨, 但仍存在一定局限性。首先, 对翼腭缝形态的分析仅限于腭平面, 尚未涵盖立体三维空间的全面评估。此外, 本研究采用回顾性横断面设计, 且样本量相对有限, 只是翼腭缝宏观解剖的初步探索, 未来将开展基于更大数据样

本的纵向研究。

#### 利益冲突声明/Conflict of Interests

所有作者声明不存在利益冲突。

All authors disclose no relevant conflict of interests.

#### 伦理批准和知情同意/Ethics Approval and Patient Consent

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The study was approved by the Medical Ethics Committee of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine (Approval No.SH9H-2023-T309-1), and informed consents were waived.

#### 作者贡献/Authors' Contributions

章文益负责研究方案设计、资料收集、数据分析及初稿撰写; 郑美里参与研究方案设计、资料收集、论文撰写及修改; 谢羽番参与资料收集及数据分析; 江凌勇负责研究指导及最终审核。所有作者均阅读并同意了最终稿件的提交。

ZHANG Wenyi was responsible for the research protocol design, data collection, statistical analysis, and writing original draft. CHUNG Miri contributed to the research protocol design, data collection, writing review and editing. XIE Yufan contributed to the data collection and statistical analysis. JIANG Lingyong contributed to the research supervision and final review. All authors have read the final manuscript and approved for submission.

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