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·临床研究·

Twin-Block联合上颌慢速扩弓治疗对青少年安氏Ⅱ类1分类患者牙颌横向变化的CBCT研究

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【摘要】　目的　探讨Twin-Block联合上颌慢速扩弓矫治器对青少年安氏Ⅱ类1分类患者牙颌横向相关指标的影响，为该类患者的正畸临床诊疗提供参考。**方法**　本研究为回顾性研究，已通过医院医学伦理委员会审批。纳入2021—2023年间于广西医科大学附属口腔医院正畸科使用Twin-Block联合上颌慢速扩弓矫治器行双期矫治的青少年安氏Ⅱ类1分类患者21例。第一期使用功能矫治器利用生长潜力协调上下颌骨骨性关系，二期再视情况使用固定矫治器进行牙列精细调整。于矫治前(T0)及一期矫治结束后(T1)分别行锥形束CT检查，使用Dolphin 3D Imaging软件测量治疗前后上下颌第一磨牙区的横向指标，包括磨牙颊舌向倾斜度、牙弓宽度及基骨宽度，并进行统计分析。**结果**　一期矫治结束后，上颌左侧、右侧第一磨牙颊向倾斜度分别增加5.47°±1.38°和5.35°±1.61°(均P<0.001)；上颌第一磨牙区牙弓宽度增加(2.68±1.14)mm，基骨宽度增加(1.14±1.24)mm，差异均具有统计学意义(均P<0.001)。骨性扩弓效应占比为42.86%，牙性扩弓效应占比为57.14%。下颌各项横向指标治疗前后变化差异均无统计学意义(均P>0.05)。**结论**　对于伴有上颌牙弓宽度不足的青少年安氏Ⅱ类1分类患者，采用Twin-Block联合上颌慢速扩弓矫治器治疗，可在改善上下颌骨矢状关系的同时有效扩展上颌牙弓及基骨宽度，改善上下牙颌横向不调。上颌宽度变化以牙性效应为主。

【关键词】　Twin-Block矫治器；　慢速扩弓；　安氏Ⅱ类1分类；　双期矫治；　牙弓宽度；　基骨宽度；　颊舌向倾斜度；　横向宽度；　锥形束CT

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Transverse dimensional changes following Twin-Block and slow maxillary expansion therapy in adolescents with Angle Class Ⅱ division 1 malocclusion: a cone-beam computed tomography study

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【Abstract】 **Objective** To investigate the effects of a Twin-Block appliance combined with slow maxillary expansion (SME) on transverse dental and skeletal parameters in adolescent patients with Angle Class Ⅱ division 1 malocclusion, and to provide a reference for clinical orthodontic practice. **Methods** This retrospective study was approved by the Institutional Ethics Committee. A total of 21 adolescents with Class Ⅱ division 1 malocclusion who underwent two-phase treatment with a Twin-Block appliance combined with SME at the Department of Orthodontics, College & Hospital of Stomatology, Guangxi Medical University, in 2021 to 2023 were consecutively enrolled. In the first phase, a functional appliance was used to coordinate the skeletal relationship between the maxilla and mandible by leveraging growth potential. In the second phase, a fixed appliance was employed for fine adjustments of the dental arches based on the specific condition. Cone-beam computed tomography (CBCT) scans were obtained before treatment (T0) and after the first phase of functional correction (T1). Transverse measurements at the first molar region, including molar buccolingual inclination, dental arch width, and basal bone width, were performed using Dolphin 3D Imaging software. Changes between T0 and T1 were statistically analyzed. **Results** After the first phase of treatment, the left and right maxillary first molars showed a significant increase in buccal inclination by 5.47° ± 1.38° and 5.35° ± 1.61°, respectively (P < 0.001). The arch width in the maxillary first molar region also increased by (2.68 ± 1.14) mm, and the basal bone width increased by (1.14 ± 1.24) mm (all P < 0.001). The proportion of skeletal expansion accounted for an average of 42.86%, while dental expansion accounted for 57.14%. No statistically significant changes were observed in any mandibular transverse measurements (all P > 0.05). **Conclusion** In adolescent patients with Angle Class Ⅱ division 1 malocclusion accompanied by maxillary transverse deficiency, Twin-Block appliance combined with SME can effectively expand maxillary dental arch and basal bone width while improving sagittal relationship, thereby correcting transverse discrepancy. The maxillary width changes were predominantly dental.

【Key words】 Twin-Block appliance; slow maxillary expansion; Angle Class Ⅱ division 1 malocclusion; two-phase treatment; dental arch width; basal bone width; buccolingual inclination; transverse width; cone-beam computed tomography

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【Competing interests】 The authors declare no competing interests.

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安氏Ⅱ类1分类错𬌗畸形是正畸临床上常见病例，多表现为下颌骨发育不足所致的上下颌骨矢状向不调，并常伴有上牙弓宽度不足等三维方向上的异常，严重影响患者口颌功能与面部美观[1]。对于处于生长发育高峰期的青少年，双期矫治是常用的治疗策略，即第一期使用功能性矫治器利用生长潜力协调上下颌骨骨性关系，二期再视情况使用固定矫治器进行牙列精细调整，可以达到良好疗效[2-3]。双板矫治器（Twin-Block）作为一种改良型肌激动器，因其佩戴舒适、疗效明确，被广泛应用于此类患者的治疗[4]。其作用机制为通过咬合斜面前导下颌，并充分利用咀嚼等口腔功能运动刺激下颌骨矢状向生长[5]。临床上，为解决上颌牙弓狭窄问题，常将Twin-Block矫治器与上颌慢速扩弓装置联合使用，以期在矫正矢状关系的同时改善横向不调。然而，目前关于Twin-Block矫治器的研究多聚焦在矢状向与垂直向的变化[4,6]，其对牙弓横向维度的影响，尤其在联合扩弓治疗时牙弓及基骨宽度的变化规律，尚缺乏基于三维影像的深入分析。

本研究利用锥形束CT（cone-beam computed tomography，CBCT），对接受Twin-Block联合上颌慢速扩弓治疗的青少年安氏Ⅱ类1分类患者进行测量分析，量化评估治疗前后上下第一磨牙区磨牙颊舌向倾斜度、牙弓宽度及基骨宽度的变化，探讨该联合治疗对牙弓横向关系的疗效，为临床矫治提供参考。

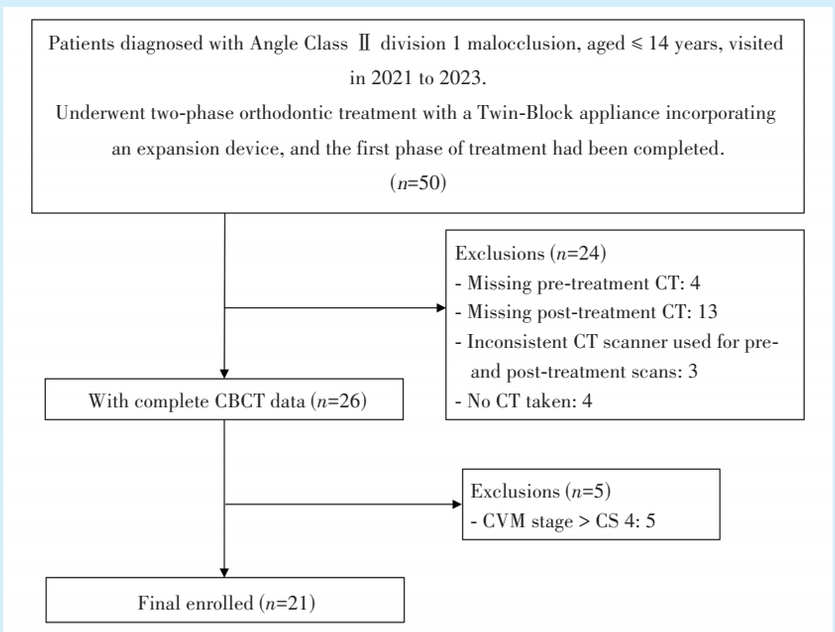
1　资料和方法

1.1　研究对象

本研究方案经广西医科大学附属口腔医院伦理委员会审核批准（审批号：2024050）并获得患者书面知情同意，依照《赫尔辛基宣言》制定的伦理

准则进行研究。选取2021—2023年期间于本院正畸科就诊进行双期矫治的青少年安氏Ⅱ类1分类患者为研究对象，所有患者一期均采用上颌联合螺旋扩弓器或菱形分裂簧的Twin-Block矫治器进行治疗，并于功能矫治结束时达到后牙中性咬合及前牙正常覆𬌗覆盖关系。

根据预实验结果，治疗前后上颌基骨宽度差值的均值为1.11 mm，标准差为1.38 mm。通过G*Power 3.1软件进行样本量估算，选择双尾配对t检验，设定α=0.05、检验效能(1-β)=0.90，计算得到所需最小样本量为15例。研究对象的筛选流程及结果如图1所示，根据纳入与排除标准连续筛选后，最终纳入21例患者，其中男10例，女11例，满足样本量估算要求。纳入标准：①矫治开始年龄≤14周岁，且处于生长发育高峰期前或高峰期(颈椎骨龄处于CS 2~CS 4阶段，Baccetti颈椎成熟法)；②磨牙远中关系；③ANB>4°，SNB<78°，SNA=83°±4°，前牙覆盖>4 mm；④有完整清晰的治疗前(T0)及功能矫治结束时(T1)的CBCT影像资料；⑤此前未接受过任何正畸治疗或其他影响面部发育的治疗。排除标准：①患有影响颅面部生长或建𬌗的疾病者；②有颞下颌关节病者；③牙型与骨型不符者；④第一恒磨牙缺失、大面积缺损、存在充填体或修复体影响CBCT测量者；⑤一期功能矫治未完成者。



CVM: cervical vertebral maturation; CS 4: cervical stage 4 (deceleration phase)

Figure 1　Flowchart of the inclusion and exclusion process for the study participants

图1　本研究的纳入及排除研究资料的流程图

1.2　影像数据采集

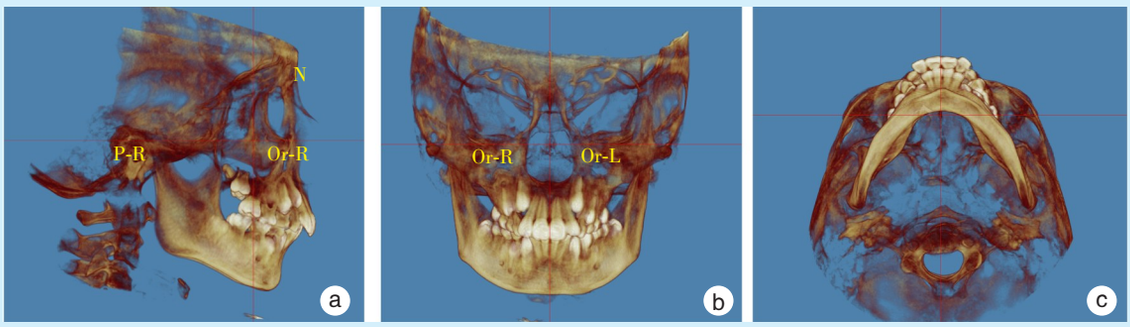
所有CBCT影像数据均采用同一台扫描设备(i-CAT 17-19，Kavo，美国)进行采集。扫描参数设定如下：管电压120 kV，管电流7 mA，轴向层厚0.25 mm。拍摄时患者取自然坐位，眶耳平面与地面平行，光标定位于面中部，上下牙列轻咬于最大牙尖交错位，保持静息状态，无咀嚼或吞咽动作。所有影像数据以DICOM格式导出，并使用Dolphin 3D Imaging软件(版本11.0)进行后续处理与分析。

1.3　确定测量平面

对CBCT数据进行三维重建及头位校正[7]：基准平面定义为眶耳平面(frankfort horizontal plane，FH Plane)，过双侧眶下点和右侧耳点所构成；矢状面为经过颅底点和鼻根点做垂直于基准平面的平面；冠状面为过一侧第一磨牙阻抗中心且同时垂直于基准平面与正中矢状面的平面(图2)。

1.4　测量项目与测量方法

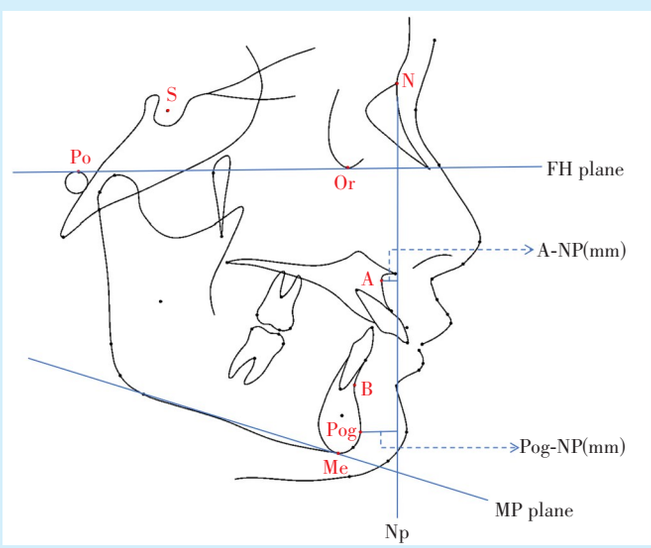
1.4.1　矢状向及垂直向指标的测量　将三维重建及头位校准后的CBCT数据生成头颅侧位片，进行定点测量，测量指标包括SNA角、SNB角、ANB角、FMA角、A-NP距和pog-NP距(图3)。在石膏模型上用游标卡尺测量前牙覆盖。



a: right view, head orientation is adjusted so that the axial plane passes through the bilateral infraorbital points (Or-L, Or-R) and the right porion (P-R); the plane defined by these three points is the frankfort horizontal (FH) plane, serving as the horizontal reference. The coronal plane is defined as passing through the center of resistance of a first molar and perpendicular to both the FH plane and the midsagittal plane. b: front view, the FH plane is used as the horizontal reference; the midsagittal plane is defined as passing through the nasion (N) and perpendicular to the FH plane. c: bottom (facing up) view, demonstrating the perpendicular relationship between the midsagittal plane and the FH plane

Figure 2　Head orientation and reference plane establishment

图2　头位校正与基准平面建立



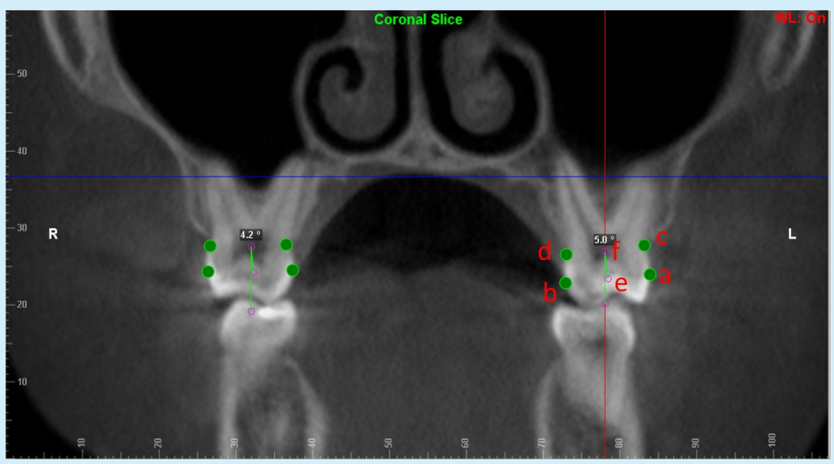
N: nasion; Po: porion; Or: orbital; A: subspinal point A; B: supramental point B; Pog: pogonion; Me: menton. FH plane: the plane defined by the Or and the Po, serving as the horizontal reference for cephalometric analysis. MP plane: a tangent line drawn through Me along the lower border of the mandible. Np line: a line drawn through point N perpendicular to the FH plane. SNA angle: the angle formed by the points S, N, and A. SNB angle: the angle formed by the points S, N, and B. ANB angle: the angle formed by the points A, N and B. FMA: the angle formed by the intersection of the MP and FH planes. A-Np distance: the perpendicular distance from point A to the Np line. The value is positive when point A lies anterior to the Np line, and negative when it lies posterior. Pog-Np distance: the perpendicular distance from the point Pog to the line Np. The value is positive when Pog lies anterior to the Np line, and negative when it lies posterior

Figure 3　Landmarks and measurements used in cephalometric analysis

图3　头影测量标志点及测量示意图

1.4.2　横向指标的测量　在冠状面分别对上颌(maxillary, Mx)和下颌(mandibular, Md)的左侧第一磨牙(left first molar, L6)及右侧第一磨牙(right first molar, R6)区域进行测量[8-9]。测量项目包括：①颊舌向倾斜度(buccolingual inclination, BI)：测量第一磨牙牙长轴与垂直于眶耳平面的直线所成的角度。牙长轴定义为冠状面上连接牙冠颊舌向最凸点连线中点及牙颈部颊舌向连线中点的直线。角度值为正表示牙齿颊向倾斜，为负表示牙齿舌向倾斜(图4)；②牙弓宽度(dental arch width, DAW)：同颌左右两侧第一磨牙中央窝连线的距离(图5)；③基骨宽度(basal bone width, BBW)：同颌

左右两侧第一磨牙根尖点连线与颌骨外表面的交点的距离(图5)。所有测量均由同一观察者集中完成,每间隔2周后再次测量,共测3次。经组内相关系数(intraclass correlation coefficient,ICC)检验显示测量结果一致性良好($ICC > 0.8$),取3次测量的均值作为最终测量结果,用于后续统计分析。



Points a and b represent the most prominent points on the buccal and lingual surfaces of the first molar crown, respectively, with e being the midpoint of the line connecting a and b. Points c and d represent the buccal and lingual cervical points, respectively, with f being the midpoint of the line connecting c and d. The line connecting e and f is defined as the long axis of the tooth. The angle between the long axis and the line perpendicular to the Frankfort horizontal plane is defined as the buccolingual inclination (BI), with buccal inclination assigned as positive and lingual inclination as negative

Figure 4　Measurement of first molar buccolingual inclination

图4　第一磨牙颊舌向倾斜度的测量

1.5　统计学分析

采用SPSS 22.0软件进行统计分析。计数资料以频数[百分数(%)]表示。采用Shapiro-Wilk检验对连续变量进行正态性检验,符合正态分布的计量资料以均数±标准差($\bar{x}\pm s$)表示,组内前后比较采用配对样本t检验;非正态分布的计量资料以中位数(四分位数间距)[$M(P_{25},P_{75})$]表示,组内前后比较采用Wilcoxon符号秩检验。正态分布的资料采用Pearson相关分析,非正态分布的资料采用Spearman秩相关分析。双侧检验,以P<0.05为差异有统计学意义。

2　结　果

2.1　纳入对象的一般情况

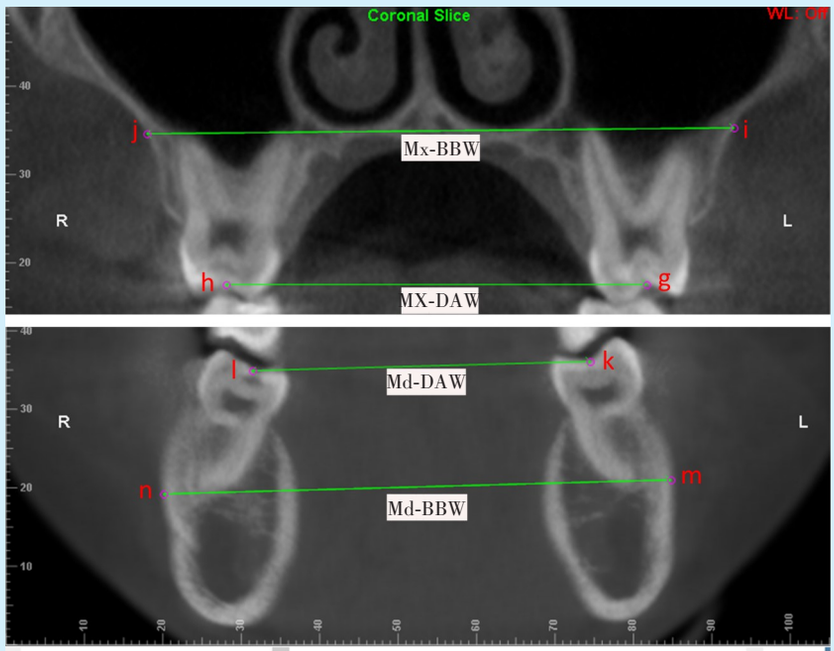
本研究共纳入21例患者,其中男性10例,女性11例,平均年龄(11.71±1.41)岁。骨龄分期分布在CS2~CS4,符合生长发育高峰期及高峰前期特征。其中6例患者(28.6%)处于替牙列期,5例(23.8%)处于恒牙列早期,10例(47.6%)处于恒牙列期。所有患者均完成一期功能矫治,平均疗程(1.0±0.12)年。见表1。

2.2　一期功能矫治前后矢状向及垂直向测量结果分析

矫治前后矢状向及垂直向各项指标的测量结果详见表2。矫治前,患者表现为典型以下颌后缩为特征的骨性Ⅱ类错𬌗畸形,上颌无明显骨性前突。一期功能矫治结束后,患者上下颌骨矢状向关系改善,SNB角平均增大1.38°(P = 0.001),ANB角平均减小1.13°(P = 0.001),前牙覆盖由(6.90±2.19)mm减小至(2.23±1.76)mm(P < 0.001),颏部骨性突度距离(pog-NP距离)由(−8.08±5.59)mm至(−6.01±6.64)mm(P = 0.001),上颌骨指标(SNA角、A-NP距离)治疗前后差异无统计学意义。以上结果说明经过Twin-Block矫治后,下颌骨获得有效前导。

2.3　一期功能矫治前后横向宽度CBCT测量结果分析

①第一磨牙颊舌向倾斜度改变:一期功能矫治后,Mx-L6 BI平均增加5.47°±1.38°,Mx-R6 BI平均增加5.35°±1.61°,矫治前后差异有统计学意义(P<0.001);Md-L6 BI增加0.26°±0.58°,Md-R6 BI平均增加0.40°,差异无统计学意义(P>0.05)。②第



Measurements were performed on coronal slices. Points g and h represent the central fossae of the maxillary left and right first molars, respectively; points k and l represent the central fossae of the mandibular left and right first molars, respectively. The distances g-h and k-l are defined as the dental arch width (DAW) at the first molars. Points i and j are the intersections of the lines connecting the apices of the maxillary left and right first molars with the buccal cortical plate, respectively; points m and n are the intersections of the lines connecting the apices of the mandibular left and right first molars with the buccal cortical plate, respectively. The distances i-j and m-n are defined as the basal bone width (BBW) at the first molars. Mx: maxillary; Md: mandibular

Figure 5　Measurement of dental arch width and basal bone width

图5　牙弓宽度与基骨宽度的测量

表1　纳入患者的基本情况

Table 1　Baseline characteristics　*n*=21

Parameter	Value
Sex, *n* (%)	
Male	10 (47.6)
Female	11 (52.4)
Age / years, $\bar{x}\pm s$	11.71 ± 1.41
CVM stage, *n* (%)	
CS 2	9 (42.9)
CS 3	5 (24.8)
CS 4	7 (33.3)
Dentition status, *n* (%)	
Mixed dentition	6 (28.6)
Early permanent dentition	5 (23.8)
Permanent dentition	10 (47.6)
Duration/ years, $\bar{x}\pm s$	1.0 ± 0.12

CVM: cervical vertebral maturation (assessed by the Baccetti method); CS 2: cervical stage 2 (pre-peak phase of mandibular growth); CS 3: cervical stage 3 (peak acceleration phase); CS 4: cervical stage 4 (deceleration phase). Early permanent dentition: no deciduous teeth, second molars not fully erupted; Duration: duration of the first phase of functional treatment

一磨牙区牙弓宽度改变：一期功能矫治后，Mx-DAW平均增加(2.68±1.14)mm，差异有统计学意义(P<0.001)；Md-DAW平均增加(0.21±0.65)mm，差异无统计学意义(P=0.162)。③第一磨牙区基骨宽度改变：一期功能矫治后，Mx-BBW矫治后平均增加(1.14±1.24)mm，其差异具有统计学意义(P<0.001)；Md-BBW平均增加(0.13±0.62)mm，差异无统计学意义(P=0.334)。④上下颌第一磨牙区牙弓及基骨宽度差值改变：一期功能矫治后，上下颌第一磨牙区牙弓宽度差值由治疗前的(2.46±0.85)mm变化至治疗后的(4.93±1.57)mm，差异具有统计学意义(P<0.001)；上下颌第一磨牙区基骨宽度差值由治疗前的(4.04±1.00)mm变化至治疗后的(5.05±0.97)mm，差异具有统计学意义(P=0.001)。见表3。

2.4　一期功能矫治前后上颌扩弓效应量分析

上颌扩弓骨性与牙性效应的占比分析结果显示，骨性扩弓效应约占42.86%，牙性代偿占比平均为57.14%。见表4。

表2　Twin-Block联合上颌慢速扩弓治疗青少年安氏Ⅱ类1分类患者一期功能矫治前后的矢状向及垂直向CBCT测量结果

Table 2　The results of CBCT measurement of sagittal and vertical variables before and after primary functional correction in adolescent patients with Angle Class Ⅱ division 1 malocclusion treated with Twin-Block appliance combined with slow maxillary expansion

$\bar{x} \pm s$, n=21

Parameter	T0	T1	T1−T0	t / Z	P
SNA / °	81.48 ± 1.42	81.65 ± 1.43	0.17 ± 0.60	1.283	0.214
SNB / °, $M(P_{25}, P_{75})$	76.89(74.94, 77.42)	77.95(76.49, 79.14)	1.38(0.41, 1.92)	−3.389 [a]	0.001
ANB / °	5.70 ± 1.68	4.57 ± 2.48	−1.13 ± 1.36	−3.825	0.001
FMA / °	24.91 ± 5.76	25.64 ± 5.58	0.73 ± 2.07	1.617	0.122
A-NP / mm, $M(P_{25}, P_{75})$	1.44(0.19, 2.29)	1.30(−0.44, 2.13)	−0.09(−0.97, 0.59)	−0.800[a]	0.424
pog-NP / mm	−8.08 ± 5.59	−6.01 ± 6.64	2.08 ± 2.34	4.064	0.001
OJ / mm	6.90 ± 2.19	2.23 ± 1.76	−4.66 ± 2.42	−8.817	< 0.001

SNA: angle between the sella, nasion, and subspinal point A; SNB: angle between the sella, nasion, and supramental point B; ANB: angle between subspinal point A and supramental point B; FMA: Frankfort-mandibular plane angle (angle between the Frankfort horizontal plane and mandibular plane); A-NP: distance from point A to nasion perpendicular; pog-NP: distance from the pogonion to nasion perpendicular; OJ: overjet (horizontal distance between the incisal edges of maxillary and mandibular central incisors); T0: before treatment; T1: after the first phase of functional correction. [a] The Z value is from the Wilcoxon signed-rank test (non-normal distribution)

表3　Twin-Block联合上颌慢速扩弓治疗青少年安氏Ⅱ类1分类患者一期功能矫治前后的横向宽度CBCT测量结果

Table 3　The results of CBCT measurement of transverse variables before and after primary functional correction in adolescent patients with Angle Class Ⅱ division 1 malocclusion treated with Twin-Block appliance combined with slow maxillary expansion　n=21

Parameter	T0	T1	T1 − T0	t / Z	P
Mx-L6 BI / °	−2.95 ± 1.28	2.52 ± 2.20	5.47 ± 1.38	18.233	< 0.001
Mx-R6 BI / °	−3.34 ± 1.52	2.01 ± 2.09	5.35 ± 1.61	15.028	< 0.001
Md-L6 BI / °	−13.48 ± 1.37	−13.22 ± 1.37	0.26 ± 0.58	2.028	0.056
Md-R6 BI / °, $M(P_{25}, P_{75})$	−14.50(−16.00, −12.95)	−14.30(−15.5, −12.45)	0.40(−0.30, 0.70)	−1.707 [c]	0.088
Mx-DAW / mm	47.89 ± 1.28	50.56 ± 1.24	2.68 ± 1.14	10.724	< 0.001
Md-DAW / mm	45.42 ± 1.55	45.62 ± 1.67	0.21 ± 0.65	1.451	0.162
Mx-BBW / mm	65.83 ± 1.46	66.97 ± 1.13	1.14 ± 1.24	4.197	< 0.001
Md-BBW / mm	61.79 ± 1.11	61.92 ± 1.23	0.13 ± 0.62	0.989	0.334
Interdental width difference / mm[a]	2.46 ± 0.85	4.93 ± 1.57	2.57 ± 1.09	10.395	< 0.001
Interbasal width difference / mm[b]	4.04 ± 1.00	5.05 ± 0.97	1.00 ± 1.18	3.899	0.001

Mx: maxillary; Md: mandibular; L6: left first molar; R6: right first molar; BI: buccolingual inclination (angle between the tooth long axis and a line perpendicular to the Frankfort horizontal plane); DAW: dental arch width (distance between the central fossae of contralateral first molars); BBW: basal bone width (distance between the most lateral points on the external cortical bone surfaces at the level connecting the apices of the contralateral first molars); T0: before treatment; T1: after the first phase of functional correction. [a] Interdental width difference = Mx-DAW − Md-DAW. [b] Interbasal width difference = Mx-BBW − Md-BBW. [c] The Z value is from the Wilcoxon signed-rank test (non-normal distribution)

表4　Twin-Block联合上颌慢速扩弓治疗青少年安氏Ⅱ类1分类患者一期功能矫治前后的上颌扩弓效应分析

Table 4　Decomposition analysis of maxillary expansion efficacy in adolescent patients with Angle Class Ⅱ division 1 malocclusion treated with Twin-Block combined with slow maxillary expansion　n=21

Parameter	T1−T0 / mm	Proportion of total expansion (%)[a]	P^b
TE (d Mx-DAW)	2.68 ± 1.14	100	< 0.001**
SE (d Mx-BBW)	1.14 ± 1.24	42.86 (22.04, 73.77)	< 0.001**
Dental compensation (TE-SE)[c]	1.54 ± 1.63	57.14 (26.23, 77.96)	−

d: change (T1 − T0); TE: total expansion (represented by change in dental arch width); SE: skeletal expansion (represented by change in basal bone width); Mx: maxillary; DAW: dental arch width; BBW: basal bone width. [a] Proportions were calculated on a per-subject basis and are presented as $M(P_{25}, P_{75})$. [b] P values refer to the significance of changes from T0 to T1 (detailed in Table 3). [c] Dental compensation = change in maxillary dental arch width − change in maxillary basal bone width

2.5　一期功能矫治前后上下颌牙弓宽度与基骨宽度增量的相关性分析

上颌DAW、BBW增量与下颌DAW、BBW增量之间的Pearson相关性分析结果见表5。总体来看，各变量组合间均呈正相关趋势，相关系数r值为0.112～0.364，属弱相关范围（$P > 0.05$）。

表5　Twin-Block联合上颌慢速扩弓治疗青少年安氏Ⅱ类1分类患者上颌与下颌牙弓宽度及基骨宽度变化量的相关性分析

Table 5　Correlation analysis of changes in maxillary and mandibular dental arch width and basal bone width in adolescent patients with Angle Class Ⅱ division 1 malocclusion treated with Twin-Block combined with slow maxillary expansion　n= 21

Parameter	Mx-DAW		Mx-BBW	
	r	P	r	P
d Md-DAW	0.364	0.104	0.268	0.239
d Md-BBW	0.112	0.630	0.346	0.124

d: change (T1 − T0); Mx: maxillary; Md: mandibular; DAW: dental arch width; BBW: basal bone width. Pearson correlation analysis was performed with two-tailed test. The correlation coefficient r indicates the strength and direction of the linear relationship: positive values indicate positive correlation; negative values indicate negative correlation. The absolute value of r reflects the strength of correlation ($|r| \geq 0.6$ = strong, $0.4 \leq |r| < 0.6$ = moderate, $|r| < 0.4$ = weak). $P < 0.05$ was considered statistically significant

2.6　Twin-Block联合上颌慢速扩弓矫治器行双期矫治的青少年安氏Ⅱ类1分类典型病例

患者，男，12岁。主诉：上前牙前突伴牙不齐。口外检查：侧貌为凸面型，下颌后缩，均角型。口内检查：恒牙列，左侧磨牙远中关系，尖牙远中关系；右侧磨牙中性关系，尖牙中性关系。上前牙唇倾，前牙Ⅱ度深覆盖，Ⅱ度深覆𬌗，上下牙列轻度拥挤。开口度、开口型正常，双侧颞下颌关节未见明显异常。颈椎骨龄CS 2期。诊断：安氏Ⅱ类1分类错𬌗畸形。治疗方案：双期矫治。一期矫治采用带菱形分裂簧的Twin-Block功能矫治器对患者进行下颌前导联合慢性扩弓治疗，疗程13个月，一期治疗结束时，前牙覆𬌗覆盖正常，磨牙中性关系，上下牙弓形态较之前协调，上颌牙弓扩宽扩圆。随后进行为期8个月的二期固定矫治精细调整咬合关系，达到满意疗效。33个月随访疗效稳定（图6）。

3　讨　论

早期横向测量多依赖于石膏模型，存在无法获取牙根信息、模型制取误差较大等局限，影响测量精确度[10-11]。CBCT具有扫描时间短、辐射剂量低、分辨率高等优势，可实现颅颌骨及牙齿的三维重建，进行多维度精准测量[12]，其数据更接近于实体解剖[13]。因此，本研究选择CBCT进行测量分析。

安氏Ⅱ类1分类错𬌗畸形是临床常见错𬌗畸形[14-15]，涉及上下颌骨及牙弓矢状、垂直及横向三维的不协调。与易通过头影测量识别的矢状向和垂直向异常相比，横向关系不调因牙齿代偿或被更显著的矢状向问题掩盖而易于被忽视[16]。McNamara[17]指出多数混合牙列期的Ⅱ类错颌与上颌狭窄有关，后续研究证实此类患者多伴上牙弓和上颌基骨宽度不足[18-19]，且狭窄程度与面高呈正相关[20]，其成因包括骨性发育不足及上颌磨牙为适应下颌后缩而发生的代偿性腭倾[21-22]。

准确判断横向不足是制订治疗方案的关键。临床常以理想矢状向与垂直向关系下横向宽度是否匹配作为诊断标准[23]。Andrews要素Ⅲ[24]及宾夕法尼亚大学横向分析法[25]认为理想的上下颌横向宽度差值（牙弓或基骨）约为5 mm；Shen等[16]建议上下颌横向宽度差值小于4 mm即可诊断为上颌横向不足。本研究治疗前上下颌牙弓宽度差值远低于上述理想标准，基骨宽度差值亦处于临界范围，表明本组患者存在明显的横向不协调，符合扩弓治疗适应证。

在颅颌面生长发育过程中，横向维度发育是最早发生且最早完成的[26]，上颌优先于下颌[27]。因此，上颌宽度不足不仅可能限制下颌宽度发育，甚至可能加剧矢状向与垂直向不调[17, 28]。研究表明，生长发育高峰期进行上颌扩弓可诱导下颌牙弓适应性增宽[29-30]。基于此，本研究选择处于生长发育高峰期或高峰前期的患者作为研究对象，此时腭中缝尚未完全骨性融合[31]，对慢速扩弓产生的生理性矫治力反应最佳，可充分利用剩余生长潜力实现牙性与骨性双重扩弓，同步改善矢状向与横向不调，促进牙颌面的整体协调发育。同时，该阶段患儿的心理成熟度与配合度也足够满足Twin-Block矫治器需长时间佩戴的治疗需求[32]，有利于充分发挥其功能适应性改建的诱导作用[33]。本研究中Twin-Block矫治器有效诱导了下颌前移，同时下颌平面角保持稳定，为后续矫治建立了良好的矢状向基础。

横向维度上，上颌第一磨牙区牙弓宽度增加



Intraoral photos, lateral facial photo and lateral cephalogram radiograph of Twin-Block combined with slow maxillary expansion therapy in adolescents with Angle Class II division 1 malocclusion through out the treatment. Patient's lateral cephalogram radiograph was unavailable during phase Ⅰ treatment and 33-month follow-up period. a: pre-treatment, distal relationship of left molars and canines, tapered maxillary arch with transverse deficiency, proclined maxillary incisors, Ⅱ° deep overjet and overbite, cervical vertebral maturation stage CS 2, convex profile with mandibular retrusion and normodivergent vertical skeletal pattern; b: wearing Twin-Block appliance with rhomboid expansion spring during the first phase of orthodontic treatment; c: after the first phase of functional orthodontic treatment, bilateral Class I molar and canine relationships, improved maxillary arch morphology with widening and rounding, coordinated upper and lower arch forms, normal overjet and overbite, enhanced mandibular advancement and reduced profile convexity; d: after the second phase of fixed orthodontic treatment, satisfactory dental alignment which is more orderly than that after post-phase I, widened and rounded upper and lower dental arches with coordinated forms, normal overjet and overbite, bilateral Class I molar and canine relationships; e: 33-month follow-up, showing long-term stability of treatment outcomes, with maintained upper and lower dental arch width and coordinated forms

Figure 6　Twin-Block combined with slow maxillary expansion therapy in adolescents with Angle Class Ⅱ division 1 malocclusion: a representative case

图6　Twin-Block联合上颌慢速扩弓矫治器行双期矫治的青少年安氏Ⅱ类1分类典型病例

2.68 mm，基骨宽度增加1.14 mm。为评估扩弓效应的临床意义，本研究将结果与历史对照自然生理增量进行比较。Bishara等[34]报道8~13岁人群上颌第一磨牙区牙弓宽度生理增量平均为2.2 mm / 5年，Seubert等[35]报道该年龄段上颌基骨宽度年均自然增量约0.5 mm。本研究中，平均1年期的功能矫治后上颌牙弓宽度和基骨宽度均超过上述自然生理增长范围，证实慢速扩弓装置在矢状向功能矫治的基础上确能产生有效的扩弓效应。

本研究上颌扩弓效应构成分析显示骨性与牙性扩弓并存，总体以牙性效应略占主导。骨性扩弓占比42.86%与Yacout等[36]报道的慢速扩弓骨性占比47.35%相近，提示上颌慢速扩弓在一定程度上可打开腭中缝、促进基骨改建。包括动物实验在内的多项研究指出，与快速扩弓相比，慢速扩弓虽骨性扩开程度较低，但其组织反应更接近生理性改建过程，具有良好的组织适应性和远期稳定性[37-38]。本研究牙性扩弓占比较高，表现为上颌第一磨牙颊倾度明显增加，提示慢速扩弓装置施加的颊向力有效解除了上颌后牙的代偿性腭倾[39-40]。临床需关注磨牙颊倾程度，避免过度颊倾导致颊侧牙槽骨变薄进而增加牙周骨开窗、骨开裂的潜

在风险。此外，若牙性扩弓效应过大而骨性支撑不足，复发风险将相应增高[41]，一期矫治结束后应设计合理的保持方案，并在二期固定矫治中注意转矩控制。

从上下颌横向协调性来看，一期矫治后上下颌牙弓宽度及基骨宽度差值均接近理想正常值（约5 mm）。这表明上颌扩弓不仅有效增加了自身宽度，还使上下颌横向关系趋向协调，为建立稳定的咬合关系和后续矫治奠定了基础。与此同时，下颌各项横向指标差异虽无统计学意义，但均表现出磨牙趋于直立、牙弓及基骨轻微增宽的趋势，且与上颌基骨宽度增量呈正相关。

上颌扩弓对下颌横向维度的影响一直是正畸领域关注的问题。Lanteri等[42]报道上颌慢速扩弓治疗后下颌可发生约1.7 mm扩宽（快扩组约4 mm）；而Godoy等[43]的研究结果与本研究相似，采用四眼圈簧慢速扩弓仅能产生不足0.5 mm的下颌扩宽效应，慢速螺旋扩弓组则未观察到下颌扩宽。研究结果的差异可能与扩弓装置所产生的矫治力大小有关，扩弓强度不足可能难以触发下颌的适应性改变，本研究所施加的矫治力相对轻柔。此外，下颌对上颌扩弓的适应性反应通常滞后于上颌骨性改建，即使在快速扩弓中，显著变化也需6个月以上才能观察到[44]；而本研究观察期仅至治疗结束阶段，难以捕捉其完整变化。Moss功能基质假说认为，上颌扩弓后口腔前庭形态及舌-颊动力平衡的改变[45]，为下颌牙弓的适应性改建提供了功能环境基础[46]，这可能解释了下颌以牙性适应为主、变化轻微的特征。未来研究需延长观察周期，进一步探讨上颌慢速扩弓诱导下颌适应性改变的远期效应。

本研究尚存在以下局限性。首先，未设置单纯Twin-Block矫治器对照组，难以完全分离出扩弓装置在整体疗效中的独立贡献。其次，样本量相对有限，且缺乏长期随访，远期稳定性有待进一步追踪。因此，本研究结论主要适用于评估该联合方案的短期、综合性疗效。

综上所述，在生长发育高峰期及高峰前期使用Twin-Block联合慢速扩弓治疗，可有效纠正上后牙代偿性腭倾，扩大上颌牙弓并促进一定程度的骨性扩展，从而协调安氏Ⅱ类1分类患者的横向关系不调，为矢状向改善及颌面正常发育创造条件。临床中对于有生长潜力的青少年安氏Ⅱ类错𬌗畸形患者，在纠正矢状向不调的同时应尽早采取措施干预上颌宽度不足，充分利用其生长发育的潜力促进颌骨协调发育。但慢速扩弓仍以牙性扩弓效应为主，治疗后上颌后牙可能出现一定程度的颊倾，治疗中应当关注牙周健康，一期矫治结束后注意保持，二期固定矫治时需注意有效控制后牙转矩。

【Author contributions】 Pan YT designed the study, collected and analyzed the data, and wrote the article. Qin CT conceived and designed the study, performed the measurements, interpreted the data, and revised the article. Zheng Y, Guo AJ and Sun X collected the data, analyzed or interpreted the data, and critically reviewed the intellectual content. Chen ZX and Mo SX designed the study, critically reviewed the article, and revised the manuscript. All authors read and approved the final manuscript as submitted.

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