ORIGINAL ARTICLE

Longitudinal changes in mandibular arch posterior space in adolescents with normal occlusion

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Introduction: The purpose of this study was to investigate the changes of available mandibular space in the posterior dental arch of teenagers from 13 to 18 years old. **Methods:** Longitudinal cephalograms of 28 adolescents (13 boys, 15 girls) with normal occlusion, selected from among 901 candidates, were taken annually from 13 to 18 years of age inclusively. Modified analyses with occlusal plane and occlusal plane perpendicular as reference planes were used to evaluate the changes of available space of the posterior mandibular arch. **Results:** From 13 to 18 years of age, significant differences of mandibular posterior space were found among ages and sexes. The total increases of available space were 5.12 mm in the girls and 5.79 mm in the boys. For girls before age 16 and boys before age 17, the increased available space was contributed mainly by resorption of bone on the anterior border of the ramus. Mesial drift of the dental arch did not occur until the eruption of the third molars. The average available spaces increased 1.22 mm in girls less than age 16 and 1.45 mm in boys less than age 17 per side per year. **Conclusions:** The prediction of available space in the posterior mandibular arch should be based on age and sex. (Am J Orthod Dentofacial Orthop 2010;137:187-93)

Total dentition space analysis is valuable for orthodontic diagnosis and design.[1] The space analysis in the posterior dental arch is of great importance and can help orthodontists to achieve a consistently high-quality result. The posterior arch area should be included in a complete orthodontic treatment. It is meaningful to predict whether there will be sufficient space for the third molars to erupt in the early permanent dentition. It is imprudent to create a posterior discrepancy while making adjustments in other areas—the midarch or the anterior arch. It is also unadvisable not to use the excess space in the posterior area to alleviate midarch and anterior space deficiencies.[1]

Contemporary treatment protocols involving molar distalizing mechanics and even arch expansion might be sound approaches for correcting some malocclusions. However, these techniques do not necessarily create space to accommodate all the teeth. Rather, they would seem to involve "borrowing" space for alignment, and, in some patients, this borrowed space might need to be paid back in other forms, such as other extractions after active treatment, less space available for the second molars, or impaction of the third molars.[2-4] The third molars account for 98% of all impacted teeth.[5]

Third molar impaction or eruption is important in clinical practice. The role of the mandibular third molars in late incisor crowding is controversial.[6-9] Some studies indicated a small, but statistically significant relationship between third molar eruption and increased crowding of anterior teeth.[10,11] Also, preservation of the third molars might be beneficial for orthodontic anchorage, prosthetic abutments, or transplants.

Factors that influence third molar eruption include skeletal growth pattern, direction of dentition eruption, dental extractions, root configurations, and maturation of the third molars.[12] However, the most important factor seems to be the space available in the retromolar region. But sometimes the third molars have not erupted, and the development of the posterior dental arch is not complete, even after active orthodontic treatment.

If it could be determined more accurately at an early age that the third molars would erupt, then orthodontic treatment and prognosis could progress on a more

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Submitted, June 2007; revised and accepted, March 2008.
0889-5406/$36.00

doi:10.1016/j.ajodo.2008.03.021

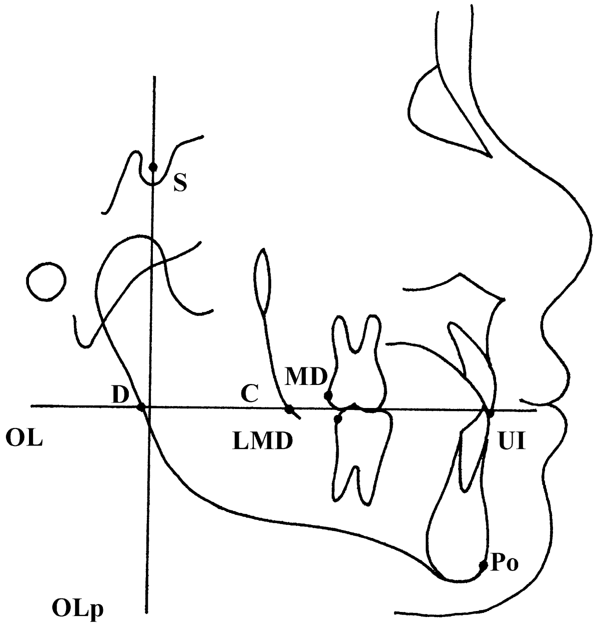

Fig 1. Measuring points and reference lines used in the cephalometric analysis: *S,* the center of sella turcica; *UI,* the incisal tip of the most prominent maxillary central incisor; *MD,* the distobuccal cusp of the maxillary permanent first molar; *Po,* the most anterior point on the bony chin; *LMD,* the distal contact point of the mandibular permanent first molar; *OL*, occlusal line, a line through UI and MD; *OLp,* occlusal line perpendicular, a line perpendicular to OL through S; *C,* the intersection of the occlusal plane with the anterior border of the ramus; *D,* the intersection of the occlusal plane with the posterior border of the ramus.

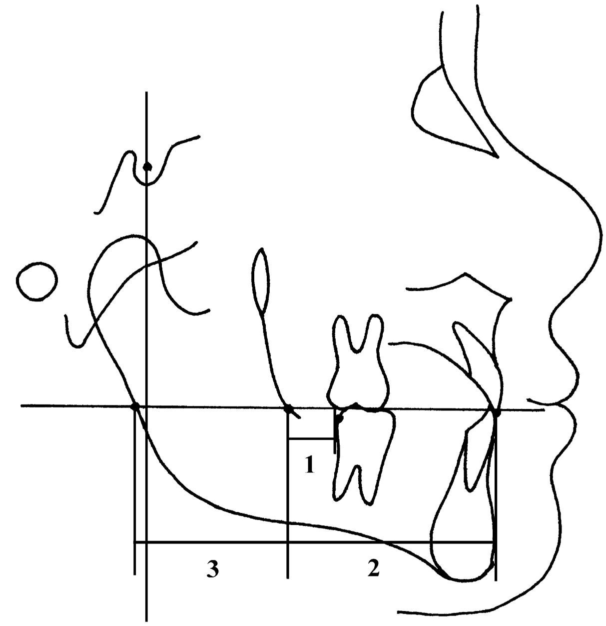

Fig 2. Linear measurements used in the cephalometric analysis. All variables were parallel to OL and vertical to OLp. The measurements included: *1,* C-LMD, indicating the posterior available space in the mandibular dental arch; *2,* C-Po, the change of C-Po indicating the resorption of bone from the anterior border of the ramus; *3,* C-D, indicating the width of the ramus.

positive basis, and the orthodontist would not need to be concerned with checkups of the patient until ages 20 to 22 years.

The aim of this study was to investigate the changes of posterior available space (distance between the distal contact point of the mandibular permanent first molar and the intersection of the occlusal plane with the anterior border of the ramus) in the mandible of adolescents from 13 to 18 years of age. This would provide important information for orthodontic clinicians.

MATERIAL AND METHODS

We selected 75 subjects from 901 high school students. The selection criteria were (1) complete permanent dentition; (2) normal occlusion and normodivergent skeletal pattern with Class I canine and molar relationship (less than 3 mm of crowding in the anterior and midarch, less than 3 mm overjet, and overbite with less than one-third coverage of the mandibular incisor); (3) harmonious facial profile and competent lips at rest; and (4) no orthodontic treatment or dental extractions. These 75 adolescents agreed to participate in our research project, with cephalograms taken annually from 13 to 18 years of age inclusively. The study protocol was reviewed and approved by the institutional review board of Peking University. Because of the longitudinal nature and the aim of this investigation, subjects with less than 6 consecutive cephalometric observations were excluded. Thus, the investigation included 28 subjects (13 boys, 15 girls).

All cephalometric radiographs were taken with the same x-ray machine. Cephalometric landmarks were identified by 1 observer (L.-L.C.) under optimal conditions and then digitized with custom cephalometric analysis software.

When double projection caused 2 points or the right and left sides did not superimpose, the midpoint was used. The analysis of Bock and Pancherz[13] with occlusal plane and occlusal plane perpendiculars as reference grids was used. The measuring points and reference lines used are shown in Figures 1 and 2 and defined in their legends.

Table I. Variables from 13 to 18 years of age (mm, means ± SD)

	C-LMD		C-Po		C-D	
Age (y)	*Boys*	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
13	13.57 ± 0.61	14.95 ± 0.34	48.29 ± 0.56	49.25 ± 0.47	34.23 ± 0.38	34.13 ± 0.31
14	15.79 ± 0.62	16.15 ± 0.34	50.44 ± 0.50	50.55 ± 0.57	34.34 ± 0.39	34.34 ± 0.31
15	16.82 ± 0.64	17.38 ± 0.35	51.49 ± 0.52	51.60 ± 0.57	34.46 ± 0.40	34.26 ± 0.32
16	18.03 ± 0.66	18.60 ± 0.35	52.80 ± 0.63	52.91 ± 0.47	34.36 ± 0.41	34.10 ± 0.32
17	19.23 ± 0.65	18.75 ± 0.59	54.07 ± 0.63	53.02 ± 0.49	34.26 ± 0.42	34.22 ± 0.30
18	19.36 ± 0.64	20.07 ± 0.59	54.06 ± 0.60	53.01 ± 0.47	34.31 ± 0.38	34.11 ± 0.29

Table II. Annual growth changes from 13 to 18 years of age (mm, mean ± SD)

	C-LMD		C-Po		C-D	
Age (y)	*Boys*	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
13-14	2.22 ± 0.02*	1.20 ± 0.02*†	2.15 ± 0.03*	1.30 ± 0.02*†	0.11 ± 0.03	0.21 ± 0.02
14-15	1.03 ± 0.05*	1.23 ± 0.03*	1.05 ± 0.03*	1.05 ± 0.03*	0.12 ± 0.05	−0.08 ± 0.02
15-16	1.21 ± 0.02*	1.22 ± 0.03*	1.31 ± 0.02*	1.31 ± 0.02*	−0.10 ± 0.03	−0.16 ± 0.33
16-17	1.20 ± 0.02*	0.15 ± 0.48†	1.27 ± 0.04*	0.11 ± 0.05†	−0.10 ± 0.03	0.12 ± 0.05
17-18	0.13 ± 0.04	1.32 ± 0.04*†	−0.01 ± 0.09	−0.01 ± 0.02	0.05 ± 0.08	−0.11 ± 0.03
13-18	5.79 ± 0.04*	5.12 ± 0.04*†	5.77 ± 0.09*	3.76 ± 0.09*†	0.08 ± 0.08	−0.02 ± 0.06

Statistical method was ANOVA.
*P <0.01, significant difference between annual growth changes; †P <0.01, significant difference between boys and girls.

Statistical analysis

The statistical analysis was performed with SPSS software (version 13.0, SPSS for Windows, SPSS, Chicago, Ill). The arithmetic mean and standard deviation were calculated for each variable. Analysis of variance (ANOVA) and paired *t* tests were performed. The level of significance was $P > 0.05$.

Intraobserver reliability and reproducibility of the digitizer were checked on 20 randomly selected cephalometric radiographs that were retraced and redigitized 2 weeks later. The method error, *S*, was calculated as follows:

$$S_x = \sqrt{\frac{\sum D^2}{2N}}$$

D was the difference between duplicate measurements, and *N* was the number of double measurements. The errors did not exceed 0.2 mm for any linear variable.

RESULTS

There were changes of available space in the mandibular posterior dental arch (C-LMD). The total increases of available space from 13 to 18 years of age were 5.12 mm in girls and 5.79 mm in boys (Tables I and II). Significant differences were found between ages and sexes. Although the mean values of C-LMD in boys were consistently smaller than those in girls during the observation period (Table I), the annual increase of C-LMD was greater in boys than in girls (Table II), with the exception of age 17 to 18, when a sudden increase of about 1.32 mm was noticed in the girls.

The completion of resorption of bone in the anterior border of the ramus (C-Po) in the boys was about 1 year behind the girls. No significant resorption was found in girls beyond 16 years of age and boys beyond 17 years. From ages 13 to 18, the changes of C-Po were 5.77 mm in girls and 3.76 mm in boys (Table II). The average available space increased 1.22 mm in girls less than 16 years and 1.45 mm in boys less than 17 years per side per year. Little if any variation of ramus width (C-D) was found from 13 to 18 years of age.

The total increase of available space from 13 to 18 years of age was 5.79 mm in the boys. Resorption of bone in the anterior border of the ramus was 5.77 mm, which contributed 99.66% to the whole increase; the mesial movement of the first molar was 0.02 mm; this contributed 0.34% to the whole increase (Table III).

The total increase of available space from 13 to 18 years of age was 5.12 mm in the girls. Resorption of bone in the anterior border of the ramus was 3.76 mm, which contributed 73.43% to the whole increase. The mesial movement of the first molar was 1.36 mm, which contributed 26.57% to the whole increase (Table III).

Table III. Difference of annual growth changes of C-LMD and C-Po (mm, mean ± SD)

	Girls				*Boys*			
Age (y)	*C-LMD*	*C-Po*	*Diff*	P	*C-LMD*	*C-Po*	*Diff*	P
13-14	1.20 ± 0.03	1.30 ± 0.09	−0.10 ± 0.07	4.0061	2.22 ± 0.02	2.15 ± 0.03	0.07 ± 0.03	7.5943
14-15	1.23 ± 0.04	1.05 ± 0.06	0.18 ± 0.06	1.0046	1.03 ± 0.05	1.05 ± 0.03	−0.02 ± 0.04	15.4359
15-16	1.22 ± 0.05	1.31 ± 0.05	−0.09 ± 0.05	8.5833	1.21 ± 0.02	1.31 ± 0.02	−0.10 ± 0.02	1.6893
16-17	0.15 ± 0.45	0.11 ± 0.05	0.04 ± 0.05	10.0859	1.20 ± 0.02	1.27 ± 0.04	−0.07 ± 0.04	7.6342
17-18	1.32 ± 0.04	−0.01 ± 0.05	1.33 ± 0.05	0.0001*	0.13 ± 0.04	−0.01 ± 0.09	0.14 ± 0.06	0.9468
13-18	5.12 ± 0.04	3.76 ± 0.09	1.36 ± 0.07	0.0001*	5.79 ± 0.04	5.77 ± 0.09	0.02 ± 0.05	16.1352

Diff, Difference.
*$P < 0.01$ (paired t test).

DISCUSSION

It is wise to balance tooth mass most advantageously with present and future space available. All 32 teeth must be considered, including those in the anterior, midarch, and posterior dental arch. The space analysis in the posterior area is of great importance when the orthodontist wants a high-quality and stable result. Posterior space must be carefully measured and predicted so that we can be more accurate in decisions about whether, when, and which teeth should be extracted for proper space management.

The rotational tomogram (RT) was chosen by many authors to evaluate the available space, especially the space-width ratio.[14,15] Ganss et al[16] compared the RT and the lateral cephalometric radiograph (LCR) to find a threshold value for third molar eruption, and found a strong correlation between RT and LCR measurements.

In our opinion, because the projection angles of these techniques vary considerably, LCR might have been expected to perform better than RT with less distortion and magnification. Because of greater distortion and unequal magnification, especially in the molar and retromolar regions, it was impossible to make the linear measurements on the RT even though this is accurate for angular and ratio measurements. Meanwhile, comparability and validity of RT for longitudinal data are poor.

The most frequently mentioned shortcoming of LCR is the difficulty in landmark location, especially the overlap of radiopaque bilateral dental structures, making the cusp tips difficult to locate. In this study, all cephalometric radiographs were taken with the same cephalostat by the same technician; thus, we had radiograms of better quality and definition. Cephalometric landmarks were located by 1 observer under optimal conditions. When double projection caused 2 points or the right and left sides did not superimpose, the midpoint was used. We discarded some obscure measuring points and chose points that were clear and easy to locate to achieve a considerably more accurate result.

A number of cephalometric planes and lines of reference have been used to study growth changes of posterior available space.[16-19] Sable and Woods,[17] Schulhof,[18] and Kim et al[19] evaluated available space using the LCR of the Ricketts analysis described by Schulhof.[18] Space changes distal to the mandibular first molar were measured along Ricketts' corpus axis by drawing a tangent line from the distal convexity of the tooth perpendicular to the corpus axis and measuring the distance between the Xi point and the tangent line. In our opinion, the available space along the occlusal plane is important for predicting the probability of third molar eruption. An angle between the corpus axis and the occlusal plane limits its predictive use in clinical practice.

The analysis of Bock and Pancherz[13] with occlusal plane and occlusal plane perpendiculars as reference grids was used in this study. Some researchers thought that the occlusal plane would tilt during development. We measured this carefully and found little change of the occlusal plane from 13 to 18 years of age in adolescents with normal occlusion ($P > 0.05$). Vertical growth of the ramus, eruption of the teeth, and rotation of the mandible can occur and have some influence on vertical direction. But all measurements in our study were made in the anteroposterior direction, which would have less influence. The reference system for linear measurements of sagittal changes used in this investigation was chosen mainly for 3 reasons: (1) it was close to the problem area; (2) all variables were parallel to the occlusal plane and vertical to occusal line perpendicular, making it possible to evaluate the interrelationship between skeletal and dental changes in the mandible; and (3) the available space we evaluated was along the occlusal plane, which was useful in predicting the probability of third molar eruption.

Significant differences of available space were found between the sexes. The total increases from 13 to 18 years of age were 5.12 mm in girls and 5.79 mm in boys (Table II). It was obvious that the sexes should

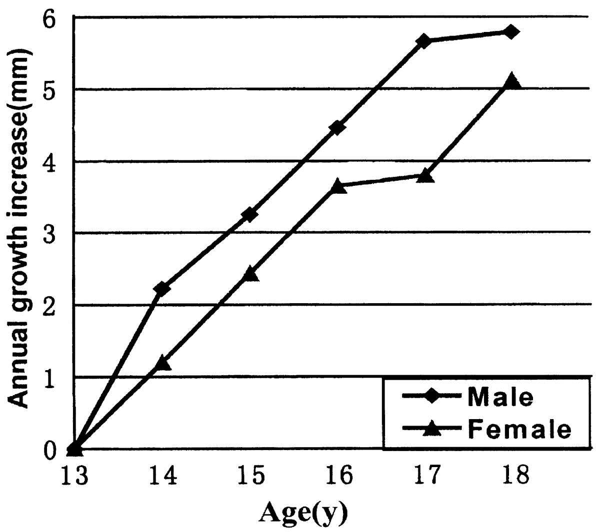

Fig 3. Curve of the increase of C-LMD from 13 to 18 years of age in boys and girls.

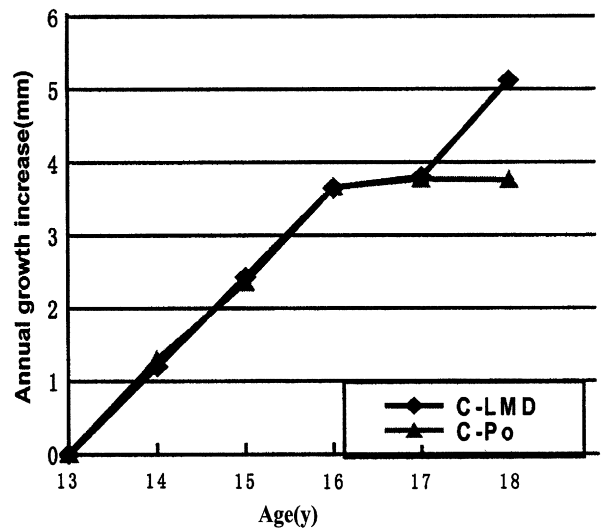

Fig 4. Curve of growth changes of C-LMD and C-Po in girls from 13 to 18 years of age.

be separated for predicting the increase of available space from 13 to 18 years of age.

The difference between sexes was complicated. The value of C-LMD in boys was smaller than in girls until age 17, but the increase of C-LMD in boys before 17 was larger than that in girls (Fig 3). It might be expected because boys of this age normally have more remaining growth than girls of the same age. It was well accepted that, on average, girls had their pubertal spurt and reached maturity approximately 1 or 2 years before boys. There was a sudden increase of available space of about 1.32 mm at age 17 to 18 years in girls (Fig 3); this probably resulted from the eruption of the third molars.

There was little if any variation of C-D from 13 to 18 years of age. This agreed with the findings of Ledyard and Calif.[20] They pointed out that there was little variation of C-D after 8 years of age; it was maintained as growth continued. We found that the width of the ramus had been attained before the age of 13. However, little variation of C-D after the age of 13 does not mean that resorption of bone from the anterior border of the ramus stopped. Point C would move forward along with mandible movement. Very little variation of C-D meant that the value of the backward resorption of the ramus and the forward movement of the mandible were almost the same.

Richardson[21] concluded that molar space increased by an average of 4 mm from 13 to 18 years of age. The resorption of the ramus averaged about 2 mm, and the mandibular first molar moved forward by about 2 mm.

Our result did not agree with Richardson's. We found little variation of C-D from 13 to 18 years of age, no matter what sex, but the increases of C-Po were obvious: 5.77 mm in boys and 3.76 mm in girls. The whole increase of available space (5.79 mm) was almost the same as that of C-Po (5.77 mm) ($P > 0.05$) in boys (Table III). This meant that, in boys in this period, the mandibular molars moved forward along with the mandible without their own mesial drift. The increase of available space mainly resulted from resorption of bone in the anterior border of the ramus; this made up 99.66% of the whole increase. A similar trend was also found in girls before 17 years of age. Girls then had a sudden increase of C-LMD between 17 and 18 years (Fig 4), so that the total increase of available space (5.12 mm) was more than that of C-Po (3.76 mm) ($P < 0.01$) (Table III). Mesial drift of the mandibular molars might be the major contributing factor to the sudden increase because the change of C-Po was nearly completed at this time. Resorption of the ramus accounted for 73.43% of the total increase, and mesial drift of the molars accounted for 26.57% of the total increase.

We saw, on the LCRs of the 28 subjects, that the mandibular third molars were erupting in 4 girls, but not in the boys. This was in accord with the phenomenon that eruption of girls' third molars occurred earlier than in boys. It was estimated that the mesial drift of the dentition in girls was due to the mesial pressure of the erupting third molars. This meant that, to obtain a consistently high-quality and stable orthodontic result, the influence of the third molars' eruption on the mesial drift of the dentition should be considered in both extraction and nonextraction patients. Moveover, when we estimated whether there was a deficit of space

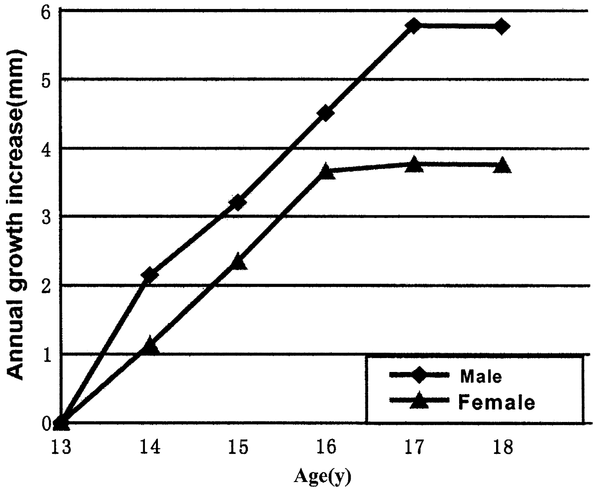

Fig 5. Curve of resorption of the ramus (C-Po) from 13 to 18 years of age in boys and girls.

for the third molars, the extra space in response to the eruption of the third molars should be considered. The time span of this study was 13 to 18 years of age, and boys' third molars had not started to erupt. But we could predict that, when third molars erupt in boys, there also would be an increase in space.

There are significant differences between the sexes from 13 to 18 years of age, not only in the magnitude of the change of available space, but also in the mechanics of the change.

The investigation of Bjork[22] led to the conclusion that 3 mm of increase in the posterior dental arch occurred per year until ages 14 for girls and 16 for boys. There was a 1.5-mm increase on each side per year. This result had great clinical importance in the prediction of available space.

In this study, we found that, before eruption of the third molars, the increase of available space was mainly because of resorption of bone on the anterior border of the ramus. The completion of ramus resorption in boys lagged behind girls by about 1 year. No significant resorption was found in girls after 16 years of age and in boys after 17 years (Fig 5); this was later than the result found by Bjork.[22] The average available spaces increased 1.22 mm in girls before 16 years of age and 1.45 mm in boys before 17 years per side per year. It was obvious that the sexes should be separated for predicting increased available space from 13 to 18 years of age.

CONCLUSIONS

1. From 13 to 18 years of age, significant differences of mandibular posterior available space were found between ages and sexes.
2. For girls before 16 years of age and boys before 17 years of age, the increased available space was contributed mainly by resorption of bone on the anterior border of the ramus. Mesial drift of the dental arch does not occur until the third molars erupt.
3. On average, the available space increased 1.22 mm in girls below 16 years of age and 1.45 mm in boys below 17 years per side per year.

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