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Dental Arch Development of Chinese Adolescents: A Retrospective Cross-Sectional Study

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ABSTRACT

Introduction and aims: Understanding the patterns of dental arch development is crucial for precise diagnosis and management of malocclusion in adolescents. However, large-scale, region-specific analyses based on big data are scarce.This study aimed to identify the dental arch growth patterns of Chinese adolescents to refine early orthodontic treatment strategies.

Methods: A retrospective cross-sectional analysis was conducted using 3D digital impressions from 5951 Chinese adolescents, collected between July 2020 and June 2021. AI-assisted measurements delineated dental arch dimensions, which were analyzed using locally weighted regression to chart developmental trends and Lasso regression to explore influencing factors, with a particular focus on geographical variances.

Results: Significant differences in dental arch dimensions were observed between genders and across different latitudes. Males generally displayed larger arch dimensions than females of the same age. The dental arches experienced rapid growth before age 13.7 in males and 13.1 in females, with limited growth potential in later years, with regional disparities evident in the magnitude of dental arch dimensions. These variations were prominently associated with geographical latitude, underscoring the influence of environmental factors on dental arch development.

Conclusion: This comprehensive study provides valuable regional insights into the dental arch development of Chinese adolescents, facilitated by advanced AI methodologies. The fitted curves of age-specific dental arch offer valuable insights for optimizing early orthodontic treatment strategies. The findings advocate for region-tailored orthodontic planning and highlight the potential of AI in enhancing the precision of orthodontic treatment.

Clinical Relevance: Our study of 5951 3D dental models reveals gender and geographical differences in arch growth, highlighting pre-teen rapid growth and later limitations, informing treatment planning.

Abbreviations: AI, artificial intelligence; CNNs, convolutional neural networks; LASSO, least absolute shrinkage and selection operator; 3D, three dimension; SD, standard deviation; CV, cross-validation; MSE, mean squared error; UDL, upper dental arch length; LDL, lower dental arch length; UDW, upper dental arch width; LDW, lower dental arch width; UCL, upper dental arch circumference length; LCL, lower dental arch circumference length; CW, crown width

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Introduction

The development of dental arches plays a pivotal role in the overall craniomaxillofacial growth of adolescents.[1] Misalignment in the upper and lower dental arches can lead to malocclusion, which has been recognized by the World Health Organization as one of the most prevalent oral diseases.[2] Malocclusion not only impairs dental-oral function and aesthetics, but also impacts the overall well-being of school-age children.[3,4] Globally, malocclusion affects 56% of individuals during mixed and early permanent dentition, with a slightly lower prevalence of 48% in Asia.[5] The high prevalence of malocclusion imposes a heavy burden on both patients and the healthcare system.[6,7]

Due to the progress of the growth and development, the correction of malocclusions in adolescents has special issues. For example, the purpose of orthodontic treatment is to correct malocclusions that are not conducive to the development of the jawbones and dental arch, such as dental arch stenosis, development defects of jawbones, occlusal interference, et al.[8-10] The refinement of diet, the degeneration of the jawbone and upper airway pathologies and other confounding factors have led to a high incidence of dental arch stenosis approximately 8% to 23.3%.[11,12] The correct development of dental arches during the mixed and early permanent dentition phases are paramount to the oral health of adolescents.[13] In this respect, early orthodontic interventions especially the management of dental arches size and shape are crucial in the process. However, there has not been an accurate reference for the goals and limits of dental arch expansion, as well as the growth rate of pantients' own dental arch that needs to be tested. Therefore, understanding the development patterns of dental arches and their impact on malocclusion is essential for advancing precision medicine, reducing healthcare demands, and improving the effectiveness and accuracy of early orthodontic interventions.[14,15]

The development patterns of dental arches and their influencing factors such as age, gender and the three-dimensional (3D) relationship between the maxilla and mandible (sagittal, horizontal, and vertical), are critical considerations in the precision of early orthodontic treatment planning for optimal occlusion and facial aesthetics.[16-19] However, current orthodontic practices predominantly rely on measurements derived from adult populations,[17,20,21] potentially limiting treatment efficacy in adolescents whose dental arches continue to develop until adulthood stability is reached. Therefore, accurate developmental patterns of dental arches in adolescents, accounting for their growth patterns, are essential for enhancing treatment outcomes. Current evidence on dental arch development in Chinese adolescents is hindered by small sample sizes that inadequately represent the national population(22, 23). A significant contributing factor to these limitations is the reliance on physical dental impressions, which are labor-intensive, time-consuming, and prone to measurement biases.[22-24] In contrast, digital impression techniques coupled with artificial intelligence (AI), particularly deep Convolutional Neural Networks (CNNs),[25] offer a faster and more precise alternative. This approach enables the rapid collection of extensive datasets on adolescents' dental arches, significantly reducing measurement errors[26] and resource costs.[27-29]

This retrospective cross-sectional study employed AI-assisted 3D digital dental impressions measurements to establish a robust dataset of dental arch measurements in 5951 Chinese adolescents aged 7-18. Through the CNN model, we achieved precise segmentation and localization of the teeth. Then, we measured the dental arch and tooth parameters and constructed a model that includes all these measurement parameters. We analyzed the development patterns by sex and age, identified influencing factors in dental arch measurements relevant to clinical practice, and explored correlations between these measurements and geographical distribution using a comprehensive national dataset. These findings aim to provide valuable insights for precision orthodontic treatment planning in adolescents(Figure 1).

Material and methods

Study design and data source

This retrospective cross-sectional study continuously collected digital dental impressions collected between 1st July 2020 and 30th June 2021 from 20,3198 cases across 31 regional areas (i.e. provinces) in China (Supplemental Figure 1) from Angelalign Research Institute. The inclusion criteria required subjects to be aged between 7 and 18 years old, with available digital dental impressions. Cases with incomplete data on age, gender, region, or dental scan data were excluded from the study. A random sampling at a rate of 3% was applied to all eligible patients to form the study cohort with a minimized sample size ensuring statistical power was not compromised. The samples were segregated by gender to form the two primary study cohorts (male and female), as dental arch development significantly varies between genders. A total of 5951 cases (mean age: 13.6 ± 3.0) were included in the study cohort for final analysis (Supplemental Figure 2) including 3690 females and 2261 males, with a female to male ratio of was 1.63:1. The digital dental impressions, gender, age, and geographic information of all included cases were collected. In order to verify the validity and accuracy of the proposed method for automatic segmentation and the following analysis, all the 3D digital dental impressions were obtained by high-resolution laser scanner(such as 3Shape D700) and were represented as STL format.[30]

This study was approved by the Ethics Committee of Shanghai Ninth People's Hospital (No. SH9H-2021-T197-1) and registered in the Chinese Clinical Trial Registry

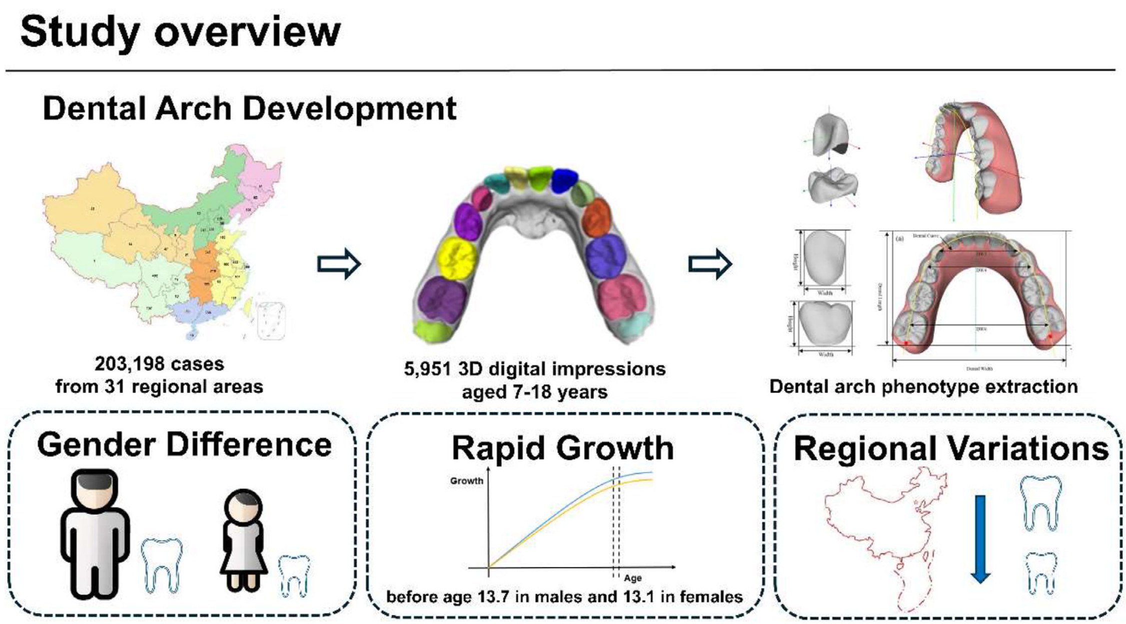

Figure 1 – Study overview.

Notes: AI-assisted retrospective study analyzed 3D dental arch data from 5951 Chinese adolescents aged 7-18. The CNN model segmented teeth, measured dental arch and tooth parameters. Dental arch growth trends by age have been revealed. Northern and southern dental arches have been comared to highlight geographical importance in treatment planning.

(No. ChiCTR2100051700, Registration date: 01/10/2021). The data has been processed and the information is unidentifiable, and approval has been obtained for exemption from informed consent. and was conducted by the Declaration of Helsinki and Ethics and governance of artificial intelligence for health under WHO guidance.

AI-assisted 3D digital dental impressions measurement

The 3D digital dental impressions were optimized using a CNN architecture, which included convolution, pooling, and fully connected layers, and relied on the gradient descent method to optimize network parameters, as previously reported in the literature.[31,32] We measured parameters that represented generated individual-level dental data including the width of teeth crowns, the length, width and circumference length of dental arches (Figure 2). To enhance accuracy, a graph cut method was applied to refine the sometimes imprecise tooth boundaries produced by the CNNs. This process involved repairing the contact area of each tooth and outputting a labelled mesh model.[32] The 3D dental impressions were captured during consultations and processed using a CNN model at the Angelalign Research Institute. A dynamic graph CNN model was trained to segment tooth types within the 3D dental impressions, followed by a graph cut method to refine the crown boundaries (Figure 2 A). The AI model training process utilized 4000 intra-oral scanners (IOS) upper and lower mesh datasets, which were manually labeled by human experts from 2000 patients. For evaluation, a separate hold-out test set of 200 datasets was employed. To enhance model performance, techniques such as data augmentation, dropout, and learning rate decay were applied during training.

The CNN model architecture featured 4 Edge-Conv layers, designed specifically to capture and aggregate local semantic geometric information. By stacking the outputs of multiple Edge-Conv layers, the model effectively extracted global features. The training parameters were configured as follows: a learning rate of 0.01, a batch size of 8, and 100 epochs. Under these settings, the AI model, combined with graph cut optimization, demonstrated outstanding segmentation performance. Key metrics included an average mean Intersection over Union (IoU) of 93.92%, a pre-face accuracy of 96.94%, an average-area accuracy of 98.26%, and an Area Under the Receiver Operating Characteristic Curve (AUC-ROC) of 0.9991.[31]

Subsequently, we constructed a comprehensive model that included all measured parameters for subsequent statistical analyses. In this model, we defined the local Z-axis as the long axis of the tooth and the local X-axis as the mesial direction and computed the local Y-axis using the right-hand rule (Figure 2 B). The dental arch was located on the dental arch plane (indicated by the yellow curve in Figure 2 C), and relevant measures were presented as global parameters in the model. The global Z-axis was defined as the normal vector of the fitting plane of all occlusal surfaces in the dental arch. The global Y-axis was defined as the direction of the fitting symmetric line of the arch, while the global X-axis direction was from left to right (Figure 2 C). Other parameters derived from the CNNs model included the width of tooth crown (Figure 2 D); width, length, and circumference length of the dental arch (Figure 2 E).

Descriptive statistics

Descriptive statistics were employed to report cases demographics and dental impression outcomes. Categorical

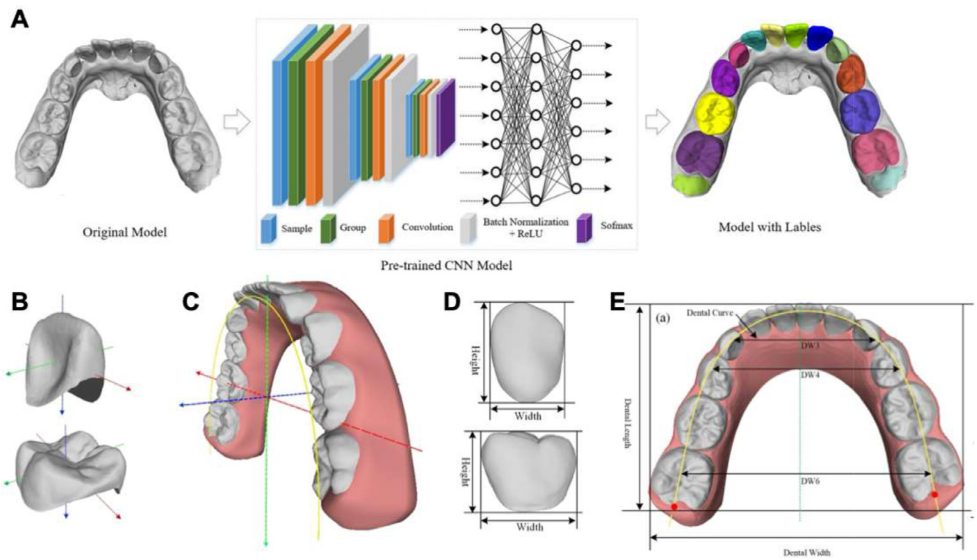

Figure 2 – Demonstration of the AI-assisted 3D dental arch measurements.

Notes: A The generation process of the 3D dental scan model. B Local coordinate for maxillary incisor and maxillary molar. C Global coordinate for upper dental arch. D Crown width for maxillary canine and molar in labial aspect. E Dental Arch Calculation for Normal Dentition.

variables were presented as counts and proportions. Continuous variables were presented as mean ± standard deviation (SD). Differences between the two cohorts were tested using Welch's two-sample t-test, with a two-tailed p-value of less than 0.05 considered statistically significant.

Dental arch development pattern curves fitting and inflection points identification

We generated the dental arch development curves separately for upper and lower dental arch length, width and circumference in males and females. These curves were derived by fitting dental arch measurements within each age group using the locally weighted regression (loess), revealing patterns of occlusal development in early orthodontic treatment. Linear regressions were performed before and after each age point, incremented by 0.01 from 7 to 18 years. By comparing the differences in slopes, which represented growth rates, we identified the age point with the biggest difference as the inflection point. Participants younger than 10 years old were excluded from inflection point identification due to their unbalanced distribution.

Correlation analysis between dental arch measurement and variables

Firstly, we served each dental arch measurement as a dependent variable in linear regression models for univariate correlation analysis. The uni-independent variables included age, geneder, width of individual teeth crown, longitude and latitude of the province where the sample was located. To the six dental arch measurements, P-values that passed the threshold corrected by multiple testing using Bonferroni adjustment were considered statistically significant ($P < 0.008$).

Furtherly, we conducted a Least Absolute Shrinkage and Selection Operator (LASSO) regression for multivariate analysis in each dental arch measurements. We performed 10-fold cross-validation (CV) and chose the largest penalty value within 1 standard error of the lowest CV mean squared error (MSE). These models used tooth-level dental measurements, including variables of age, gender, longitude and latitude, as well as width of individual teeth crown. All independent variables included in the model are continuous except for gender. We used the glmnet package to estimate the LASSO coefficients and all analyses were performed using R statistical software (v. 4.1.0).

Results

Cohort characteristics

203,198 cases aged 7 to 18-year-old who had complete digital dental impressions were included during the study. 79 cases without age were excluded. Sampling was conducted according to each age group and sex, with a sampling ratio of 0.1. 97 cases with incomplete data were removed. Finally, 5951 participants(mean age 13.6 ± 3.0; female 3690 [62.0%]) were involved in this study (Figure 3).

Dental arch parameters and development pattern between genders

Comprehensive dental arch measurements, including upper dental arch length (UDL), upper dental arch width (UDW), upper dental arch circumference (UCL), lower dental arch length (LDL), lower dental arch width (LDW) and lower dental arch circumference (LCL), were reported across various age groups (Table). Notably, dental arch dimensions consistently

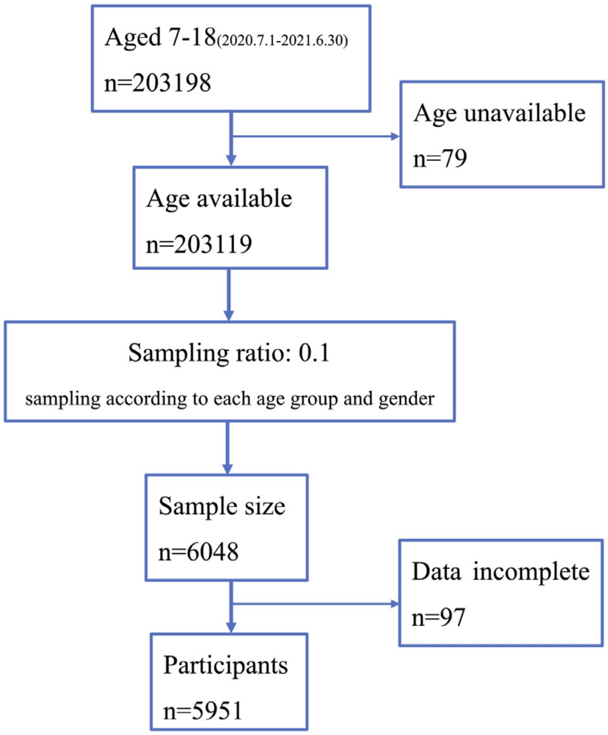

Figure 3 – Cohort construction flow.

exhibited statistically significant differences between males and females across all age groups from 7 to 18 years, with males showing larger measurements compared to females.

The six dental arch development curves showed the association between age and the dental arch measures in male and female adolescents (Figure 3). The growth rates of dental arch measures, indicated by the slope of the tangent of the development curves, showed a tendency to decrease with age after a certain point (Figure 4). We identified the inflection points of age to be around 13.7 years in males and approximately 13.1 years in females, estimated from the mean ages of the six measurements. The inflection points of the lower arch generally occurred slightly later than those of the upper arch. The growth rate, represented by the slope of the linear-fitting line, was higher in males than in females, both before and after the inflection points (Supplemental Figure 3). Overall, in both males and females, a rapid growth period occurs between the ages of 7 and 13, after which the development enters a plateau phase with reduced growth. However, dental arch growth in males continues to be considerable growth from ages 14 to 18, especially in terms of width (including UDW and LDW).

Analysis of factors influencing dental arch dimensions

The previous curve analysis demonstrated the impact of age and sex on dental arch width. Beyond these factors, considering that tooth crown width and geographical latitude are associated with dental arch dimensions[33,34] and given our nationwide sample, we also observed regional differences in mean values across seven regions (Supplemental Table 1 and Supplemental Figure 4). Therefore, we further conducted a univariate analysis on all the above factors. Unsurprisingly, the results confirmed a strong correlation between age, sex, and tooth crown width with dental arch dimensions (Supplemental Table 2), corroborating previous findings. Additionally, we identified an interesting relationship between dental arch dimensions and geographical factors: a significant correlation with latitude, but not with longitude (Figure 5).

Furthermore, we performed Lasso regression on all variables and identified the top factors influencing these dental arch metrics as follows (Supplemental Table 3). This analysis indicated that, in addition to age, gender, and individual tooth crown width, latitude significantly affects both upper and lower dental arch widths. This finding suggests that the diagnosis and treatment of dental arch width should take into account the geographical differences between northern and southern populations.

Dental arch development pattern curves of southern and northern adolescents

Next, the dental arch development curves were analyzed separately for adolescents in the southern and northern regions. The width of both the upper and lower dental arches (UDW and LDW) significantly increased with increasing latitude, indicating wider dental arches in the northern population (Figure 6). The results indicated that, in terms of dental arch length, southern adolescents experience a longer peak developmental duration. However, in terms of dental arch width, at the age of 13.5 in southern females and 15 in northern females, the maxillary dental arch width enters a slow growth stage. This inflection point is 13.7 and 12.6 years old for the width of the mandibular arch, respectively. This finding suggests that, clinically, it is important to begin expanding upper dental arch width in southern female adolescents at an earlier stage (Figure 6).

Discussion

Our study investigated dental arch measurements and development trends in Chinese adolescents across 31 provinces, with a predominant distribution in central and eastern regions. Apart from age and gender, geographical differences in dental arch width between the north and the south regions had been identified, as well as distinct developmental patterns. Strong influencing factors associated with dental arch measurements in Chinese adolescents included. Several curves were fitted to accurately depict dental arch growth in Chinese adolescents, providing critical insights for planning early orthodontic treatment strategies.

Our findings are consistent with previous research indicating that dental arch size is generally larger in males compared to females.[35-40] Stern, et al (2020) conducted a longitudinal cohort study in Germany involving 31 untreated subjects aged 2 to 26 years.[36] Their study, based on dental impressions and oral examination photographs, revealed age-related changes in the dimensions of the dental arch and similar gender differences as observed in our study. Specifically, the dental arch dimensions were significantly larger in males until the late mixed dentition stages.[36] The reduction

Table – Dental arch measurements between male and female adolescents.

(a)

	Upper dental arch length (mean [SD])(mm)			Lower dental arch length (mean [SD])(mm)		
Age	Female	Male	P value	Female	Male	P value
7	45.62 (3.15)	46.95 (3.73)	0.025	42.07 (2.46)	42.44 (3.16)	0.436
8	47.07 (3.71)	48.76 (3.23)	<0.001	42.18 (2.94)	43.47 (2.88)	<0.001
9	48.58 (3.05)	49.80 (3.49)	0.001	43.39 (2.84)	44.15 (2.98)	0.024
10	49.59 (3.42)	50.30 (3.29)	0.040	44.48 (3.42)	44.76 (3.38)	0.418
11	50.67 (3.42)	51.39 (3.61)	0.019	45.80 (3.08)	46.18 (3.81)	0.217
12	51.29 (3.57)	52.83 (3.62)	<0.001	46.67 (3.14)	48.18 (3.35)	<0.001
13	52.32 (3.12)	53.99 (3.65)	<0.001	47.48 (2.81)	49.40 (3.18)	<0.001
14	52.33 (3.06)	54.27 (3.28)	<0.001	47.52 (2.71)	49.43 (2.95)	<0.001
15	52.54 (3.09)	54.40 (3.26)	<0.001	47.71 (2.80)	49.99 (2.95)	<0.001
16	52.71 (2.92)	54.58 (3.39)	<0.001	48.07 (2.65)	50.03 (3.06)	<0.001
17	53.01 (3.25)	54.75 (3.45)	<0.001	48.14 (3.08)	50.66 (3.43)	<0.001
18	53.03 (3.91)	55.99 (4.86)	<0.001	48.48 (3.46)	50.67 (4.33)	<0.001

(b)

	Upper dental arch width			Lower dental arch width		
Age	Female	Male	P	Female	Male	P
7	59.52 (2.66)	61.45 (3.64)	0.001	56.31 (2.44)	57.35 (3.31)	0.038
8	60.68 (2.87)	62.16 (3.09)	<0.001	56.91 (2.73)	58.96 (2.82)	<0.001
9	60.99 (2.52)	62.62 (3.37)	<0.001	57.11 (2.51)	58.88 (2.80)	<0.001
10	62.22 (3.24)	63.14 (3.11)	0.005	58.56 (3.36)	59.63 (2.94)	0.001
11	63.39 (3.29)	64.65 (3.48)	<0.001	59.99 (3.30)	61.07 (3.16)	<0.001
12	64.84 (3.52)	66.19 (3.64)	<0.001	61.33 (3.10)	62.90 (3.23)	<0.001
13	65.95 (3.63)	67.84 (3.91)	<0.001	62.03 (2.96)	64.05 (3.20)	<0.001
14	66.51 (3.31)	69.56 (3.63)	<0.001	62.45 (2.97)	64.90 (3.47)	<0.001
15	67.12 (3.63)	69.40 (3.77)	<0.001	62.74 (3.21)	65.07 (3.45)	<0.001
16	67.00 (3.49)	70.23 (3.91)	<0.001	62.56 (3.23)	65.46 (3.47)	<0.001
17	66.73 (3.71)	70.66 (3.78)	<0.001	62.83 (3.25)	66.01 (3.44)	<0.001
18	66.81 (3.66)	70.97 (4.05)	<0.001	62.85 (3.47)	66.46 (3.57)	<0.001

(c)

	Upper dental arch circumference			Lower dental arch circumference		
Age	Female	Male	P	Female	Male	P
7	99.35 (5.46)	101.50 (6.40)	0.034	93.35 (4.57)	93.68 (5.73)	0.707
8	100.95 (6.60)	104.67 (5.88)	<0.001	93.37 (5.13)	96.38 (5.23)	<0.001
9	103.21 (5.54)	105.75 (6.11)	<0.001	95.09 (5.03)	97.09 (5.25)	0.001
10	105.26 (6.18)	106.76 (6.20)	0.019	96.77 (6.16)	97.99 (5.97)	0.051
11	107.19 (5.92)	108.97 (6.27)	0.001	99.12 (5.76)	100.20 (6.69)	0.048
12	108.69 (6.19)	112.00 (6.39)	<0.001	101.04 (5.68)	103.90 (5.93)	<0.001
13	110.48 (5.48)	114.50 (6.16)	<0.001	102.49 (5.11)	106.47 (5.72)	<0.001
14	110.79 (5.37)	114.86 (5.95)	<0.001	102.90 (4.83)	106.51 (5.51)	<0.001
15	111.23 (5.21)	115.04 (5.71)	<0.001	103.10 (4.93)	107.44 (5.15)	<0.001
16	111.57 (5.12)	115.41 (5.93)	<0.001	103.93 (5.17)	107.74 (5.64)	<0.001
17	111.89 (5.30)	116.37 (6.10)	<0.001	103.85 (5.45)	109.18 (6.53)	<0.001
18	111.84 (6.89)	117.99 (8.95)	<0.001	104.37 (6.29)	109.21 (8.01)	<0.001

in gender differences in arch size found in our study may be attributed to the peak of dental arch growth occurring approximately two years earlier in females compared to males, despite individual variation. This suggests that early intervention should be considered in female patients in clinical practice.

Cranial variation has geographical differences, and so does dental arch variation. This may be attributed to differences in diet and subsistence strategies between different regions. Compared to individuals with a preference for highly processed foods, those who favor tougher and harder foods generally exhibit larger craniofacial bone dimensions. Moreover, diet and subsistence are often closely linked to socioeconomic factors, as well as latitude and climate.[41] Smith, et al (1978) described the patterns of geographic microdifferentiation for the size and shape of the dental arches for 14 villages on Bougainville Island, Papua New Guinea. They found that occlusal variables varied less among villages than did dental arch length and width and dental arch length and width decreased in size from north to south.[42] There are other studies which have reported larger craniofacial dimensions among northern compared to southern Han Chinese.[43,44] Our findings are consistent with their research as we identified significant correlations between dental arch measurements and latitude. The observed increases in dental arch widths with rising latitude are consistent with north-south

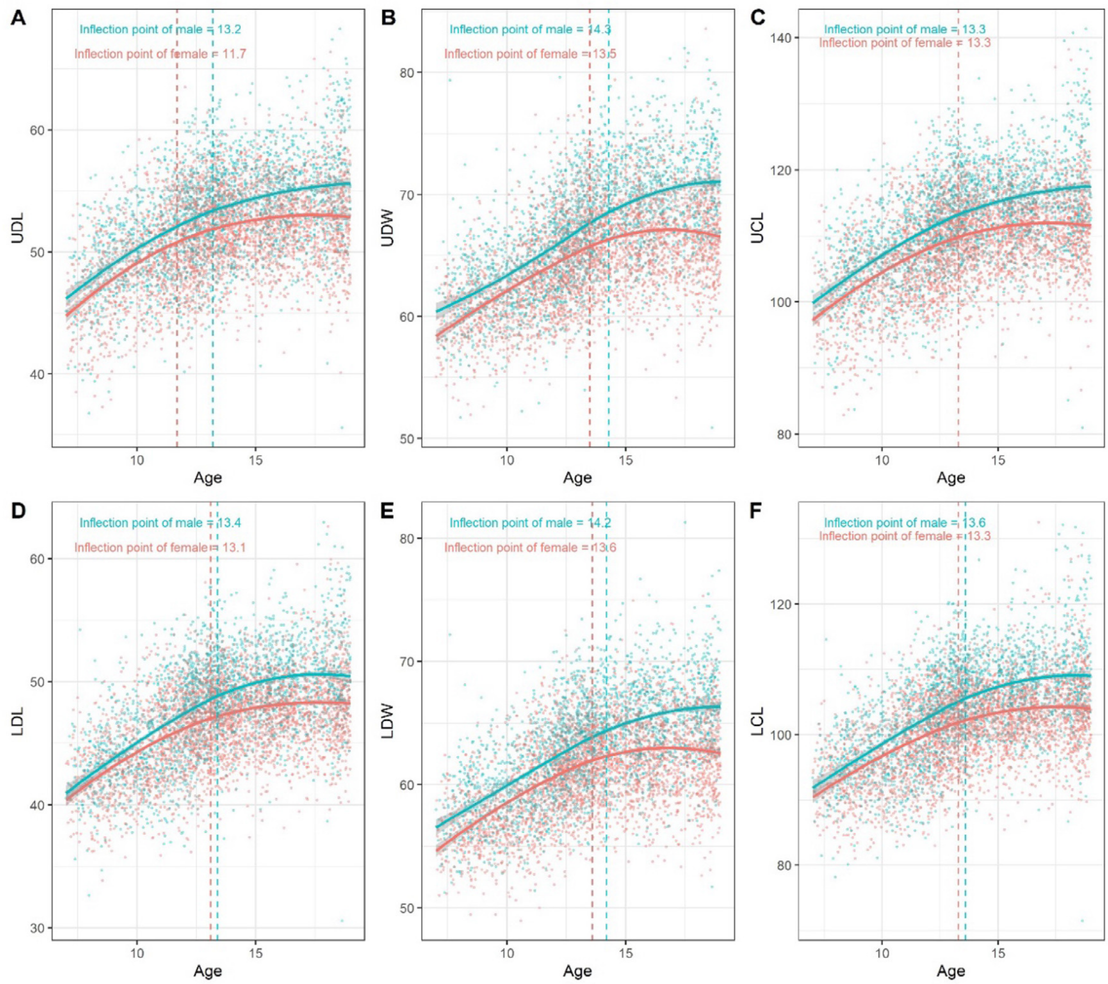

Figure 4 – Dental arch development curves between different genders in Chinese adolescents.

Notes: UDL: Upper dental arch length; LDL: Lower dental arch length; UDW: Upper dental arch width; LDW: Lower dental arch width; UCL: Upper dental arch circumference length; LCL: Lower dental arch circumference length. The x-axis represents age, ranging from 7 to 18 years old. The Y-axis is the dental arch parameter, measured in millimeters.

differences in maxillofacial and body size. Additionally, literature indicated that the height and weight of Chinese people tend to correlate with changes in Earth's latitude.[45,46] Larger dental arch may be linked to the less pronounced craniofacial protrusion observed in northerners,[47] as greater craniofacial protrusion tends to result in more inclined anterior teeth which will lead to the larger dental arch dimensions. It is generally believed that different latitude and longitude distributions represent different climates, lifestyles, socio-economic factors, and other factors.[48,49] These prompts us to pay attention to the impact of different climates, lifestyles, etc. in future research.

Scammon classified human growth patterns into four types: 1) general type, characterized by an S-shaped curve (including height, weight, and jaws); 2) neural type, reaching 90% of adult development by age 6 with slow growth thereafter; 3) genital type; and 4) lymphatic type.[50] Females' dental arch development aligns closely with jaw growth, falling between neural and general types. Facial, body, and pubertal development peaks are aligned, with the face developing slightly later than the body, and males developing later than females.[51,52] By age 13.6, permanent dentition is typically achieved, with about 90% of maximum eruption height attained.[38] Our study found that dental arch growth peaks occur between ages 13-14, with males lagging behind females by approximately 7 months (females at 13.1 years, males at 13.7 years). The lower dental arch generally peaks 1-2 months later than the upper, consistent with jawbone growth dynamics.[53,54] This growth peak informs optimal timing for early orthodontic treatment.[55,56] Importantly, dental arches continue to grow until adulthood, so orthodontic plans, particularly those involving extractions, must account for significant growth potential in males after age 14. In terms of dental arch length, southern adolescents experience a longer peak developmental duration. However, regarding dental arch width, they enter the slow growth phase earlier. This indicates that clinicians should start monitoring dental arch width in southern adolescents at an earlier stage.

Our dental arch development fitting curves are instrumental in planning teeth spacing for orthodontic treatments.

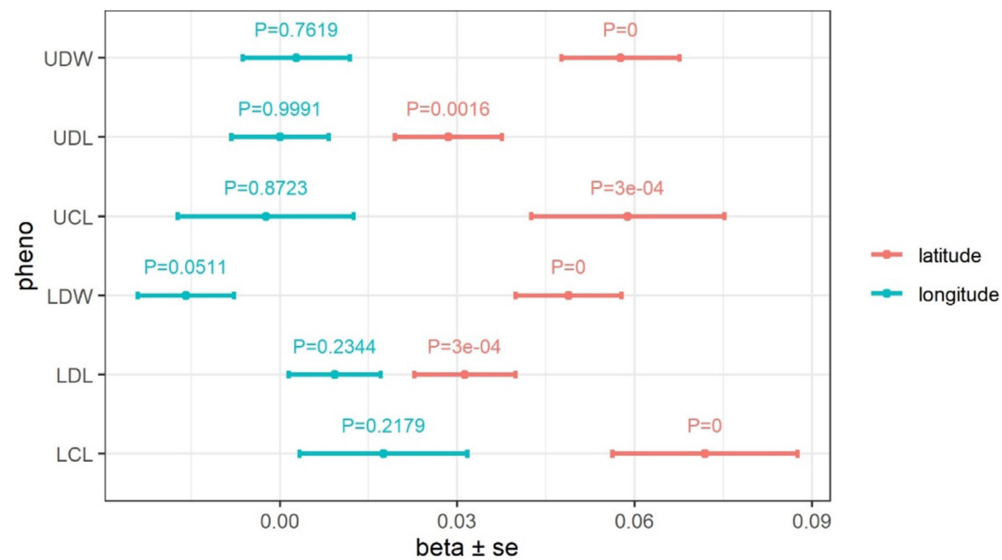

Figure 5 – The correlations between dental arch dimensions and geographical location of sample collection.
Notes: Latitude had a significant correlation with dental arch dimensions (P<0.05).

These findings help to determine optimal and target dental arch dimensions for dental arch expansion in early orthodontic interventions, improving the precision of orthodontic treatment. Our study outcomes offered valuable guidance for early orthodontic interventions, particularly concerning the frequency of appliance replacements, such as clear aligners, to ensure treatments do not impede natural dental arch development.

As AI technology develops, it has become an efficient and benificial tool to help orthodontists with analysis, dignosis, treatement planning and decision-making.[57,58] In the application of AI, ethical factors need to be strictly considered, especially regarding patient data privacy issues. In this study, we only collected and analyzed the age, gender, region, and 3D impressions of the studied cases, fully ensuring their privacy.[59] This is the first study to investigate the influencing factors of dental arch development among Chinese adolescents using a large, representative sample size. Using 3D impressions and a CNN model for dental measurements has minimized the potential for measurement biases. Additionally, employing LASSO regression enabled the creation of fitting curves for dental arch parameters, offering valuable insights for early orthodontic treatment strategies.

This study had several limitations. Firstly, the data was cross-sectional, lacking longitudinal tracking, and the age distribution in the cross-sectional data was biased, which

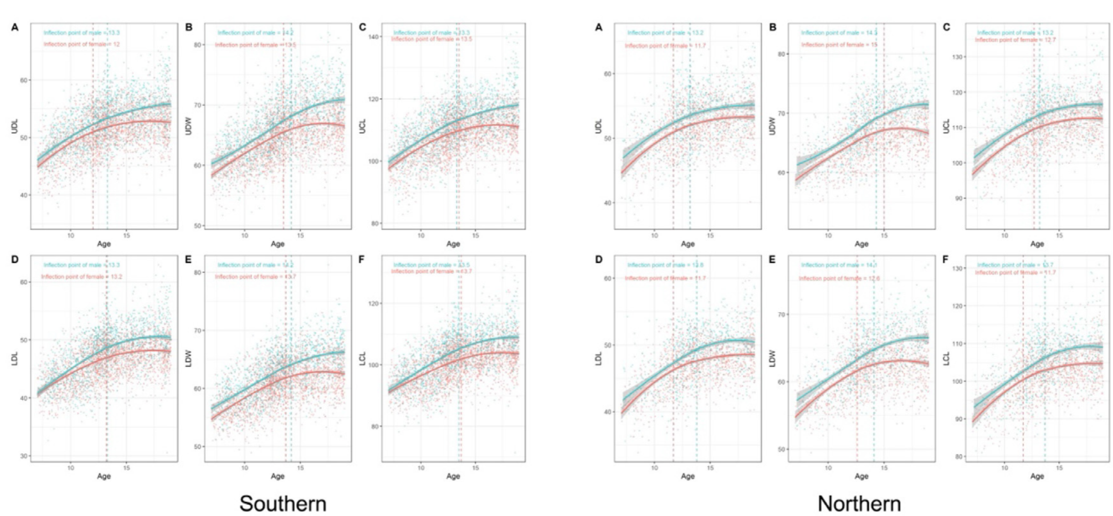

Figure 6 – Dental arch development pattern curves of adolescents in the southern and northern regions.
Notes: UDL: Upper dental arch length; LDL: Lower dental arch length; UDW: Upper dental arch width; LDW: Lower dental arch width; UCL: Upper dental arch circumference length; LCL: Lower dental arch circumference length. The x-axis represents age, ranging from 7 to 18 years old. The Y-axis is the dental arch parameter, measured in millimeters.

could affect the development patterns; thus, a larger sample size is needed to obtain more accurate developmental curves. Secondly, while geographical factors were considered, other influential factors such as lifestyle factors and oral habits were not collected, along with genetic information related to tooth crown size and skeletal dimensions. In subsequent studies, we will expand data collection to include genetic influences and lifestyle factors, such as clinical data from family members and information on lifestyle habits. Thirdly, the geographical factors used in this study were based on the collection locations without tracing ancestral origins; future research should gather more information to improve the accuracy of precision medicine. Additionally, the identified differences between northern and southern populations suggest that these variations should be considered in diagnosis and treatment.

Conclusions

In conclusion, we have presented age-specific dental arch dimensions and cross-sectional dental arch development curves for Chinese adolescents. Our developed fitting curves for dental arch dimensions can serve as a valuable tool for guiding early orthodontic treatment plans. The correlations observed between dental arch widths and latitude highlighted the importance of considering geographical factors in treatment planning.

Conflicts of interest

None disclosed.

Ethics approval statement

This study was approved by the Ethics Committee of Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine (No. SH9H-2021-T197-1) and registered in the Chinese Clinical Trial Registry (No. ChiCTR2100051700, Registration date: 01/10/2021). All procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and with the Declaration of Helsinki. Informed consent was obtained from legal guardians of the participants involved in the study.

Data availability

The datasets supporting the conclusions of this article are included within the article. Partial individual participant data collected during the trial and study protocol can be offered for academic use upon reasonable request. The whole data set is not publicly available due to privacy policies.

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Authors' contributions

CL and JC contributed equally to this paper. CL and JC designed the research, analyzed the data, and wrote the manuscript; MC, ZW, HZ, WS, SD and YF analyzed and interpreted the data; MZ, ZL, SG and BF designed the research, analyzed the data, and corrected the manuscript. All authors reviewed, revised, and approved the final version.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.identj.2025.02.026.

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