Original Article

A scoping review of cephalometric normative data in children

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Objective: Understanding the orofacial characteristics and growth patterns in children is essential for both orthodontics and research on children with orofacial abnormalities. However, a concise resource of normative data on the size and relative position of these structures in different populations is not available. Our objective was to aggregate normative data to assess the growth of the orofacial skeletal structures in children with a well-balanced face and normal occlusion. **Methods:** The MEDLINE, Embase, and Scopus databases were searched. Inclusion criteria included longitudinal and cross-sectional studies on cephalometric measurement of skeletal tissues and a study population ≤ 18 years with a well-balanced face and normal occlusion. Key study parameters were extracted, and knowledge was synthesized. A quality appraisal was performed using a 10-point scale. **Results:** The final selection comprised of 12 longitudinal and 33 cross-sectional studies, the quality of which ranged from good to excellent. Our results showed that from childhood to adulthood, the length of the cranial base increased significantly while the cranial base angle remained constant; both the maxilla and mandible moved forward and downward. The profile becomes straighter with age. **Conclusions:** Growth patterns in children with a well-balanced face and normal occlusion follow accepted theories of growth.

Key words: Cephalometrics, Normative data, Pediatric dentistry

INTRODUCTION

The bones of the face (e.g., the maxilla and mandible) form the oral cavity and airway, support the dentition, and provide a framework for the aesthetic appearance of the face. During childhood and adolescence, the facial skeleton grows in size, with the bones changing their relative positions.[1,2] Knowledge of how the orofacial skeleton grows is important in orthodontic diagnosis and treatment planning, as well as an essential resource for research on the effects of diseases, disorders, or abnormal functional patterns on orofacial skeletal growth.[3]

Lateral cephalometry is a popular method with ample normative data.[4] Currently, 3D imaging techniques are increasingly used; however, 2D cephalometric normative data are still important because they are interchangeable with 3D measures.[5] Many parameters have been defined to describe the positions and sizes of various elements of the facial skeleton. Normative data include an average value and a measure of variability, such as the standard deviation (SD). This is important because there is not one number that describes the average values of the orofacial skeletal parameters, but a range. Normative cephalometric data were originally captured to inform orthodontic treatment. Currently, soft tissue esthetics and occlusion may be prioritized in orthodontic treatment. However, knowledge and familiarity with orofacial skeletal normative values is essential in health sciences.

When assessing normative values, the inclusion and exclusion criteria of the study design establish the study population and must be carefully considered. Several investigations of cephalometric parameters in random populations of children during growth have been compiled;[6-10] however, this type of study design included individuals with different skeletal class types and even malocclusion. If a random population is specified, the skeletal type and occlusion are not controlled. Another approach involves specifying a study population with a well-balanced face and normal occlusion. Although occlusion is defined in the dental literature, well-balanced face criteria can be more subjective. A well-balanced face implies a skeletal Class 1 facial type, no asymmetry, and good facial proportions.

The process of postnatal orofacial growth has been qualitatively described by Enlow and Hans[11] partly from the cephalometric data of random populations. The growth of the anterior cranial base is completed at approximately 7 years of age, whereas the growth of the posterior cranial base is slower and considered to be complete during puberty.[12] Recent studies have shown that the anterior and posterior cranial bases continue to grow until early adulthood.[13,14] The maxilla is translated forward by the growth of the cranial base; then, around 7 years of age, the maxilla grows forward and down-

ward, mainly due to bone formation or resorption at the sutures.[15] In the mandible, both endochondral ossification of the condyle and bone modeling on the surface increased the height of the ramus. In the anteroposterior direction, the position of the ramus changes considerably owing to periosteal apposition at its posterior border and resorption at its anterior border, resulting in the elongation of the mandibular body. The growth of the lower jaw is almost complete by the age of 16 years for men and 14 years for women.[16,17] Broadbent and Golden[18] have investigated the sexual dimorphism of craniofacial structures. An adolescent growth spurt occurs between 10 and 12 years of age in females, and active growth ceases at 14 years; in contrast, males have a growth spurt between the ages of 12 and 14 years, and growth remains active until 18–19 years.[18]

Here, we identify and map the research area investigating the size and relative position of the orofacial structures during growth in children with a well-balanced face and normal occlusion. A scoping review framework was implemented because the purpose of this investigation was to provide an overview of normative data.[19,20] Our objectives were to 1) identify the characteristics of the orofacial skeleton during growth, 2) determine whether patterns are similar between males and females, and 3) discuss whether the trends fit established frameworks for orofacial growth measured in random populations.

MATERIALS AND METHODS

The protocol for this scoping review was registered on PROSPERO with ID CRD42022308725. The PRISMA-ScR checklist was followed, see Supplementary Material 1.[21] Ethical approval was not required as this scoping review used exclusively anonymous information from publicly accessible documents.

Research question

The research question was "What are normative cephalometric characteristics of orofacial skeletal structures in children with well-balanced face and normal occlusion as a function of age and sex?" Regarding the PICO framework, the population (P) included children with a well-balanced face and normal occlusion less than or equal to 18 years of age; the intervention (I) was the growth of orofacial skeletal structures; the comparisons (C) were between different age groups as well as between males and females; and the outcomes (O) were cephalometric measurements.

Search methods

A search strategy was designed with a combination of Medical Subject Headings (MeSH), title/abstract key-

words, truncations and Boolean operators, and included the concepts of 'children,' 'orofacial skeletal structure,' 'normative data,' and 'cephalometry.' The search was performed on December 23, 2020, using the MEDLINE, Embase, and Scopus databases and repeated on 2 Dec 2022. Full searches of each database are provided in Supplementary Materials 2–4. Language restrictions were not imposed. The years of coverage of the databases spanned from 1947 to 2022. Citation tracking was also performed to identify additional articles. The records were duplicated using EndNote (Clarivate PLC, Philadelphia, PA, USA).

Selection criteria

In the first screening phase, titles and abstracts were viewed using Rayyan.[22] At least two reviewers (EAZ, TKN, and AC), blinded to the other reviewer's decision, assessed the inclusion or exclusion of articles based on the eligibility criteria. Disagreements were resolved through discussion. In the second screening phase, two reviewers (EAZ, TKN) assessed the full text of the articles for the final selection.

The included studies comprised 1) longitudinal and cross-sectional studies, 2) studies measuring orofacial hard tissues using 2D radiographs or 3D tomography techniques, and 3) studies with data reported as mean ± SD or standard error. Studies were included if the measurements were performed on children and adolescents (age less than or equal to 18 years) with a well-balanced face and normal occlusion, which focused on patient selection criteria for normative purposes and to reduce variability. Terms indicating a well-balanced face include balanced or harmonious facial profiles, good facial proportions, no craniofacial malformations, and no asymmetry. A well-balanced face is subjective and was assessed in each individual study, presumably based on local cultural norms. Terms indicating normal occlusion included Class I molar, canine, and incisor relationship; normal overjet; normal overbite; mild or no tooth crowding or spacing; and adequate space in dental arches. Studies were excluded if they included treatment groups (e.g., orthodontics, tooth extraction, implants, and maxillofacial surgery); cohorts with malocclusion; cohorts with underlying diseases, disorders, or syndromes; and studies involving animals or case studies.

Data collection and analysis

From the included studies, the key parameters were extracted from each study, stored in a Microsoft Excel spreadsheet, performed by TKN, and then discussed with EAZ to reach a consensus. The following parameters were extracted: study design (longitudinal, cross-sectional), geographical location, cephalometric measurements, measurement technique (2D radiograph,
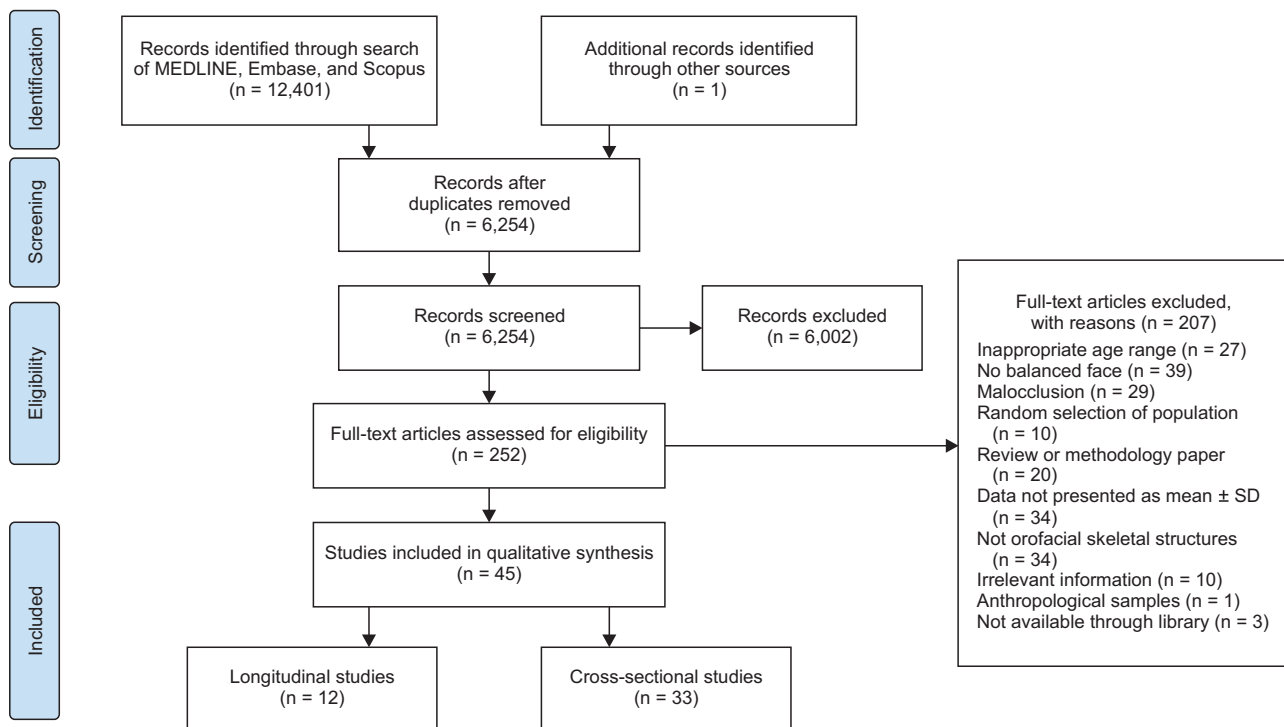

Figure 1. PRISMA flow diagram. Flow diagram of the final selection process.
SD, standard deviation.

cone-beam computed tomography), and key results concerning the study population, including sample size, age groups, and sex. In most studies, a statistical analy-

sis was performed, and the results and implications were discussed. For further knowledge synthesis, cephalometric measurements were grouped into five categories:

Table 1. Summary of characteristics of included longitudinal studies

Study	Nationality, sex, sample size (age at measurement timepoint)	Orthodontic measurement	Result
Jamison et al. (1982)[43]	White American: M: n = 20, F: n = 15 Biannually from: 8–12 yr Annually from: 12–17 yr	A-Ptm (Ptm-Jamison)* SNA ANB, NAPg	A-Ptm significantly increased from 8–17 yr; change in M > in F. SNA increased significantly M, insignificantly in F. ANB, NAPg insignificantly decreased in either sex from 8–17 yr.
Bishara et al. (1984)[1]	White American: M: n = 20, F: n = 15 Biannually from: 4.5–12 yr Annually from: 12–17 yr Final set at 25.5 yr GP I: 5–10 yr GP II: 10–15 yr GP III: 15–25.5 yr Measures at 6, 9, 12, 14, 16, 18 yr	A-PNS SNA Ar-Pg SNB, SNPg ANB, NAPg N-ANS', N-Me, N-ANS'/N-Me,† Ar-Go, S-Go Ar-Go/S-Go S-Go/N-Me SN/MP NSGn	A-PNS: changes in GP II≈ GP I > GP III for M, changes in GP I > GP II > GP III for F. SNA: greatest increase by 1.4° occurred in M in GP II. Ar-Pg: changes in GP II≈ GP I > GP III for M; changes in GP I > GP II > GP III for F. SNB, SNPg: changes in GP I≈ GP II≈ GP III for M; the least amount of increase occurred in GP III in F. ANB, NAPg: decreased mostly in GP I, GP III for M; and decreased in GP I, GP II for F. N-ANS', N-Me increased the most in GP I, the least in GP III in both sexes. N-ANS'/N-Me increased mostly in GP I in both sexes. Ar-Go, S-Go: changes in GP I≈ GP II≈ GP III for M; but in F, the greatest increase was in GP I. Ar-Go/S-Go decreased in GP I and increased in GP II, GP III in both sexes. S-Go/N-Me, SN/MP changed the most in M, and the least in F during GP III. NSGn: changes in GP I≈ GP II≈ GP III.
Ursi et al. (1993)[2]	White American: M: n = 16, F: n = 16 Measures at 6, 9, 12, 14, 16, 18 yr	S-N S-Ba, NSBa SNA, A-Nperp Co-A SNB, Pg-Nperp, Co-Gn N-ANS, ANS-Me FH/MP (Go-Me), NBa/PtmGn	S-N: M > F at all ages, especially at 16, 18 yr ($P < 0.001$). S-Ba: M > F at 16, 18 yr; NSBa: M≈ F. SNA, A-Nperp: M≈ F. Co-A: M > F at 9, 14, 16, 18 yr; especially at 16, 18 yr ($P < 0.001$). SNB, Pg-Nperp: M≈ F (except at 14 yr, M < F in SNB); Co-Gn: M > F at 16, 18 yr. N-ANS: M > F at 14, 16, 18 yr; ANS-Me: M > F at 16, 18 yr. FH/MP: M≈ F; NBa/PtmGn: M < F at 14 yr.
el-Batouti et al. (1994)[41]	Norwegian: M: n = 35, F: n = 39 Measures at 6, 9, 12, 15, 18 yr	NSBa SNA SNB ANB, NAPg N-ANS ⊥FH, ANS-Me ⊥FH, N-ANS/ANS-Me (⊥FH†), S-Go ⊥FH†, SN/FH, SN/PP, SN/MP (Go-Me)	NSBa: M≈ F from 6–18 yr. SNA: M > F at 9, 12, 15, 18; M≈ F at 6 yr. SNA increased more in M than F from 6–18 yr; the greatest increase occurred between 9–15 yr. SNB: M > F at 18; M≈ F at 6, 9, 12, 15 yr. SNB increased in both sexes from 6–18 yr (increase in M > in F). ANB, NAPg: M > F at 15; M≈ F at 6, 9, 12, 18 yr. N-ANS ⊥FH: M > F at 18; M≈ F at 6, 9, 12, 15 yr. N-ANS/ANS-Me (⊥FH): M < F at 6, 9, 12; M≈ F at 15, 18 yr. ANS-Me ⊥FH, S-Go ⊥FH: M > F at all ages. N-Me ⊥FH, S-Go ⊥FH: increase in M > in F. SN/FH: M≈ F, SN/PP: M < F at all ages. SN/MP: M≈ F at 6, 9, 12, 15 yr; M < F at 18 yr; SN/MP decreased from 6–18 yr in both sexes.

Table 1. Continued

Study	Nationality, sex, sample size (age at measurement timepoint)	Orthodontic measurement	Result
el-Batouti et al. (1995)[61]	Norwegian: M: n = 35, F: n = 39 White American: M: n = 20, F: n = 15 Measures at 6, 9, 12, 15, 18 yr	SNA, SNB, SNPg, FH/NPg, ANB, NAPg, Wits, N-ANS′, N-Me, N-ANS′/N-Me,[†] Ar′-Go, S-Go, Ar′-Go/S-Go,[§] S-Go/N-Me, SN/MP, FH/MP, NSGn, FH/SGn	Norwegian had larger SNA, SNB, SNPg, FH/NPg, Ar′-Go/S-Go; and smaller S-Go, S-Go/N-Me, FH/SGn, NSGn (only in F for NSGn) than white American.
Thilander et al. (2005)[39]	Swedish: Group Umeå: M: n = 55, F: n = 67; measures in 3 age groups at 1) 7 and 10 yr, 2) 10 and 13 yr, 3) 13, 16, 19 and 31 yr Group Enköping: M: n = 20, F: n = 27; measures at 5, 7, 10 and 13 yr	S-N NSAr, NSBa SNA Ar-Pg, Goi-Me[‖] SNB, SNPg ANB NAPg N-ANS′, N-Me, S-Goi ANS′-Me[†,‖] ANS′-Me/N-Me Ar–Goi N-Me/S-Goi SN/PP, SN/MP (Downs), MP/PP	S-N increased with age; an increase of 1–1.5 mm was even observed from 16–19 yr. In M, one-third of the total increase was noted between 13–16 yr. NSAr was stable; NSBa decreased around 4°. SNA remained constant. Ar-Pg, Goi-Me increased until the young adult period and increase in M > in F. A growth acceleration was noticed between 13–16 yr in M. SNB, SNPg increased continuously during the observation period. ANB decreased during growth. NAPg changed from slight convexity to straight. In M, growth acceleration in N-ANS′, N-Me, S-Goi was noted between 13–16 yr. ANS′-Me increased the most between 13–16 yr for both sexes. ANS′-Me/N-Me was constant during the follow-up. Ar–Goi increased the most from 13–16 yr in M. N-Me/S-Goi decreased continuously. Only small variations in SN/PP could be seen in both sexes. A continuous decrease in SN/MP, MP/PP with age in both sexes.
Al-Taai et al. (2022)[40]	Swedish (Umeå): measures at T1 (13 yr), T2 (16 yr), T3 (31 yr) T1: M: n = 11, F: n = 19 T2: M: n = 10, F: n = 19 T3: M: n = 11, F: n = 19	S-N, N-Ba, NSAr, NSBa, point N SNA, ANS-PNS, point A SNB, SNPg, Ar-Pg, Go-Me, Ar-Go, Point B, Pg, Me ANB N-Me, ANS″-Me,[¶] S-Go, PNS″-Go,[¶] SN/MP (Go-Me), SN/PP, PP/MP, ArGoMe	S-N, N-Ba, NSAr increased significantly from T1-T2, T2-T3; NSBa changed insignificantly. Point N moved forward significantly from T1-T2, T2-T3; and downward from T2-T3. SNA increased significantly from T1-T2. ANS-PNS increased significantly from T1-T2, T2-T3. Point A moved forward significantly from T1-T2 and downward from T1-T2, T2-T3. SNB, SNPg increased significantly from T1-T2. Ar-Pg, Go-Me, Ar-Go increased significantly from T1-T2, T2-T3. Point B, Pg, Me moved forward significantly from T1-T2 and downward from T1-T2, T2-T3. ANB increased significantly from T1-T2, T2-T3. N-Me, ANS″-Me, S-Go, PNS″-Go increased significantly from T1-T2, T2-T3. SN/MP, PP/MP decreased significantly from T1-T2. SN/PP increased significantly T1-T2. ArGoMe decreased significantly from T1-T2, T2-T3.

Table 1. Continued

Study	Nationality, sex, sample size (age at measurement timepoint)	Orthodontic measurement	Result
Stahl de Castrillon et al. (2013)[30]	German: M: n = 16, F: n = 16 Yearly measures from 6–17 yr (except at the age of 14)	NSBa, NSAr S-N, S-Ba, S-Ar	NSBa, NSAr: M≈ F, remained constant in both sexes. The length of cranial base (S-N, S-Ba, S-Ar) increased in both sexes. S-N: M > F at 6, 16, 17; S-Ba: M > F at 6 yr.
		SNA, A-Nperp Co-A, ANS-PNS	SNA, A-Nperp: increased with age in M, remained constant in F. Co-A: M > F at 6, 16, 17; ANS-PNS: M > F at 16 yr.
		SNB, SNPg, Pg-Nperp Co-Gn, Ar-Gn, Go-Me, Co-Go	SNB, SNPg, Pg-Nperp became larger with age in both sexes. Mandibular length increased with age. Co-Gn: M > F at 6, 7, 15, 16, 17 yr; Ar-Gn: M > F at 6, 15, 16, 17 yr; Go-Me: M > F at 15, 17 yr; Co-Go: M > F at 17 yr.
		ANB, Wits	ANB, Wits: M≈ F at all ages. ANB became smaller with age; Wits value remained constant in both sexes.
		SN/PP, SN/MP (Downs), PP/MP, ArGoMe N-Me, ANS-Me, S-Go	SN/PP remained constant; SN/MP, MP/PP and ArGoMe became smaller in both sexes: counter-clockwise rotation of mandible with age. N-Me: M > F at 15, 16, 17; ANS-Me: M > F at 15, 17; S-Go: M > F at 17 yr.
Alió-Sanz et al. (2011)[45]	Spanish: M: n = 22, F: n = 16 Sample divided into 3 age groups GI: 8–11 yr GII: 12–14 yr GIII: 15–18 yr Annual measures for 6 yr	Co-A ANS-PNS SNA Point A	Co-A increased progressively, means at GIII > GII > GI; the biggest differences were found between GI and GII; increase in M > in F. ANS-PNS: means at GI< GII≈ GIII; increased the most in the GI group. Co-A, ANS-PNS: M > F. SNA increased insignificantly from GI to GIII. The advance of the point A is greater in F than M.
		Point ANS Point PNS N-ANS, SN/PP	Point ANS: moved downward in GI≈ GII≈ GIII. Point PNS: moved downward in GIII < GII, GI. From GI to GII, PNS move downward more than ANS. N-ANS: mean at GI< GII≈ GIII; the greatest vertical growth of the maxilla was noted in the GI group; SN/PP: M < F.
Hamamci et al. (2006)[44]	Turkish: M: n= 22, F: n= 16 Measures at 9, 14, 18 yr	SNA A-Nperp Co-A	SNA significantly increased from 9–14 in F, from 14–18 yr in M. A-Nperp significantly increased in F from 9–14 and 14–18 yr, in M from 9–14 yr. Co-A significantly increased in both sexes between 9 and 14, 14 and 18 yr.
		SNB Pg-Nperp Co-Gn	SNB, Pg-Nperp, Co-Gn significantly increased in both sexes from 9–14, 14–18 yr. Pg-Nperp increased by 6.03 mm for F and 4.71 mm for M from 9–18 yr. Co-Gn increased by 18.7 mm in F and 19.9 mm in M from 9–18 yr.
		ANB Mx-Md diff	ANB decreased significantly from 9–14 in F, 14–18 yr in M. Mx-Md diff increased significantly from 9–14, 14–18 yr in M, F.
		ANS-Me FH/MP (Go-Me) NBa/PtmGn	ANS-Me increased significantly from 9–14, 14–18 yr in both sexes. FH/MP decreased significantly from 9–14 yr in F, from 9–14 and 14–18 yr in M. NBa/PtmGn changed insignificantly in both sexes.

cranial base, maxilla, mandible, relationship between the maxilla and mandible, and vertical parameters. For each category, qualitative data synthesis was performed to

aggregate knowledge regarding changes during growth between the sexes.

A critical appraisal was performed using a 10-point

Table 1. Continued

Study	Nationality, sex, sample size (age at measurement timepoint)	Orthodontic measurement	Result
Jiménez et al. (2020)[28]	Colombian mestizo (white, African, Amerindian) Baseline: M: n = 19, F: n = 30 Follow-up: M: n = 10, F: n = 23 Annually from 6–24 yr	S-N	S-N: M≈ F from 6–14 yr, M> F from 16–24 yr. S-N: F had a constant acceleration from 8–16 yr, after that growth rate slowed down. M had a significant acceleration of growth between 14–16 yr, which decreased after 20 yr.
		Co-A, Co-Gn	Co-A, Co-Gn: M≈ F from 6–14 yr, M> F from 16–24 yr. Growth of Co-A, Co-Gn plateaued from 8–14 yr in both sexes; M had a pubertal peak between 14–16 yr, while growth in F decreased after 14 yr.
		N-Me	N-Me: M > F from 16–24 yr; F had a constant acceleration from 8–14 yr, after that growth rate slowed down; significant pubertal spurt occurred between 14–16 yr in M.
		ANS-Me	ANS-Me: M > F from 16–24 yr; the growth spurt was between 12–14 in F, and 14–16 yr in M.
		S-Goi[‖]	S-Goi: M > F from 16–24 yr; the growth spurt was between 10–12 in F, and 14–16 yr in M.
		SN/MP (Downs)	SN/MP decreased with age, no difference between sexes.
Chuang (2000)[27]	Taiwanese: M: n = 24, F: n = 24 Biennially at 8, 10, 12 yr	S-N, S-Ba, N-Ba, S-Ar, NSBa	S-N, S-Ba, N-Ba, S-Ar increased significantly from 8–10, 10–12 yr in both sexes. S-N, S-Ba, N-Ba: M≈ F; S-Ar: M > F at 8, 12 yr. NSBa: M≈ F; remained constant from 8–12 yr.
		SNA, ANS-PNS	SNA, ANS-PNS: M≈ F at 8, 10, 12 yr; SNA insignificantly changed in both sexes. ANS-PNS increased significantly from 10–12 yr in both sexes.
		SNB, SNMe, SNGn	SNB, SNMe, SNGn: M < F; increased insignificantly from 8–12 yr in both sexes.
		Go-Gn, Ar-Gn,	Go-Gn, Ar-Gn increased significantly from 8–10, 10–12 yr; Go-Gn: M≈ F; Ar-Gn: M < F at 12 yr.
		Ar-Go	Ar-Go: M≈ F; increased significantly from 10–12 yr.
		ANB, NAPg	ANB, NAPg: decreased significantly from 8–12 yr; M< F at 12 yr.
		SN/MP (Go-Me), FH/MP, PP/MP, ArGoMe	SN/MP, FH/MP, PP/MP, ArGoMe: decreased insignificantly from 8–12 yr, M≈ F.

M, male; F, female; ≈, no significant difference; Mx-Md diff, maxillomandibular difference; GP, growth period; NAPg, facial convexity.
*Point Ptm in measurement of maxillary length (A-Ptm), described in Jamison's study.[43]
[†]Point ANS′, projection of point ANS on N-Me plane.
[‡]⊥FH, perpendicular line to Frankfort plane was used as reference plane to measure facial height.
[§]Point Ar′, projection of point Ar on S-Go plane.
[‖]Point Goi, gonial intersection, intersection of mandibular plane (Downs) and tangent of mandibular ramus.
[¶]ANS″, PNS″ are the intersection between the palatal plane with N-Me and S-Go, respectively.
See Figure 2 for definition of each landmark or measurement.

grading system, as shown in Supplementary Table 1. Quality appraisal was based on the 'Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies' developed by the National Heart, Lung, and Blood Institute (NHLBI)[23] and the checklist published by Afrand et al.[13] Quality appraisal was performed by one reviewer (TKN), and the appraisal was presented and discussed with another reviewer (EAZ).

RESULTS

As outlined in the PRISMA diagram (Figure 1), 6,254 unique articles were identified, of which 12 longitudinal studies and 33 cross-sectional studies met the inclusion/exclusion criteria and were published between 1954 and 2022. All articles were published in English, except for one article in Mandarin.[24] Most of these studies were conducted in white populations. All studies included both males and females except for two that investigated

Table 2. Summary of characteristics of included cross-sectional studies

Study	Nationality, sex, sample size, and age	Orthodontic measurement	Result
Bishara and Fernandez (1985)[51]	North Mexican: M: n = 36, 12.76 yr (11–14.16 yr), F: n = 45, 13 yr (11.08–14 yr) Iowan: M: n = 20, F: n = 15, 12–14 yr	SNA, SNB, SNPg, FH/NPg, ANB, NAPg, Wits, N-ANS', N-Me, N-ANS'/N-Me,* Ar-Go, S-Go, Ar-Go/S-Go, S-Go/N-Me; SN/MP, FH/MP, FH/SGn, NSGn	Significantly larger N-ANS', N-Me, S-Go in North Mexican M than F; Significantly larger N-ANS', N-Me, Ar-Go, S-Go in Iowan M than F.
Bishara et al. (1990)[34]	Egyptian: M: n = 39, F: n = 51, 12.5 ± 0.6 yr Iowan: M: n = 33, 13 ± 0.9 yr, F: n = 22, 13 ± 0.8 yr	NSAr, NSBa, N-Ba, S-Ba, S-N, SNA, SNB, SNPg, FH/NPg, ANB, NAPg, Wits, N-ANS', N-Me, N-ANS'/N-Me, Ar'-Go, S-Go, Ar'-Go/S-Go,*,† S-Go/N-Me; SN/MP, FH/MP, FH/SGn, NSGn	Greater N-Ba, S-Ba, S-N and N-ANS', Ar'-Go, S-Go in Iowan M than F; Larger N-Ba, S-N and smaller NSGn in Egyptian M than F.
El-Batran et al. (2008)[36]	Egyptian: M: n = 61, F: n = 34, 7.5–9.5 yr (mean, 8.5 yr)	NSBa, N-Ba, S-Ba, S-N, SNA, ANS-PNS, SNB, Go-Me, ANB, NAPg, N-Gn, N-ANS, ANS-Gn; SN/FH, SN/PP, SN/MP (Downs), ArGoiMe‡	Larger ANS-Gn, SN/MP, and ArGoiMe in Egyptian M than F.
Thilander et al. (1982)[42]	Swedish: M: n = 27, F: n = 36, 10 yr 9 mo	NSAr, NSBa, S-N, S-Ar, SNA, ANS-PNS, SNB, SNPg, Ar-Goi, Goi-Pg,‡ FH/NPg, ANB, NAPg, N-ANS, N-Me; SN/FH, SN/PP, SN/MP (Downs), FH/PP, FH/MP, PP/MP, ArGoiMe‡	Smaller S-N, ANS-PNS in 10 yr Norwegian than Swedish.
Humerfelt (1970)[32]	Norwegian: M: n = 36, 10 yr 9 mo (10 yr–11 yr 11 mo), F: n = 20, 10 yr 8 mo (10 yr–11 yr 5 mo)	NSAr, NSBa, S-N, S-Ar, SNA, ANS-PNS, SNB, SNPg, Ar-Goi, Goi-Pg,‡ ANB, NAPg, N-ANS, N-Me; SN/PP, SN/MP (Downs), PP/MP, ArGoiMe‡	No significant differences between sexes for angular measurements; Greater linear measurements in M than F.
Obloj et al. (2008)[33]	Polish: M: n = 39, F: n = 34, 9.25–11.22 yr (10.37 ± 0.52 yr)	NSBa, S-N, SNA, A-Nperp, Co-A, SNB, Pg-Nperp, Co-Gn, ANB, Wits, N-Me, N-ANS, ANS-Me, S-Go, S-Go/N-Me, SN/MP, NBa/PtmGn, ArGoiMe‡	Greater S-N, N-Me, ANS-Me, S-Go and smaller SNA, A-Nperp, Pg-Nperp, NBa/PtmGn in M than F.
Kilic et al. (2010)[55]	Turkish: M: n = 33, 13.65 ± 1.47 yr, F: n = 83, 13.42 ± 1.13 yr	A-Nperp, Co-A, Pg-Nperp, Co-Gn, Mx-Md diff, ANS-Me, FH/MP (Go-Me), NBa/PtmGn	Greater Co-A, Co-Gn, ANS-Me in M than F.
Hassan (2005)[53]	Saudis: M: n = 29, F: n = 33, 9–12 yr	SNA, SNB, FH/NPg, ANB, NAPg, ANS-Me; FH/MP (Downs), SN/MP (Downs), FH/SGn	No significant differences between M and F children; Significantly greater NAPg, smaller ANS-Me in children than Saudis adults.
AlShayea et al. (2022)[26]	Saudis: F: n = 140, 11 ± 1 yr (10–13 yr)	S-N, S-Ar, NSAr, SNA, A-Nperp, Co-A, SNB, Pg-Nperp, Pg-NB, FH/NPg, Co-Gn, Go-Me, ANB, NAPg, ANS-Me, N-Me, Ar-Go, S-Go, S-Go/N-Me, SN/OP, FH/OP, FH/MP (Go-Me), FH/SGn, NBa/PtmGn, ArGoMe	Greater SNA, SNB, ANB, SN/OP, FH/OP, FH/MP (Go-Me), FH/SGn; NBa/PtmGn; and smaller S-Ar, NSAr, Co-A, Pg-Nperp, Pg-NB, FH/NPg, Co-Gn, Go-Me, ANS-Me, S-Go/N-Me, ArGoMe in Saudis girls than British Caucasian adults.
Hamdan and Rock (2001)[62]	Jordanian: M: n = 33, F: n = 32, 14–17 yr (15.5 ± 0.5)	SNA, SNB, ANB, PP/MP	Smaller PP/MP in 15.5 yr Jordanian than British adults.
Gleis et al. (1990)[54]	Israeli: M: n = 18, 12–16.5 yr, F: n = 22, 11–14 yr	SNA, SNB, Pg-NB, FH/NPg, ANB, NAPg, SN/GoGn, FH/MP (Downs), FH/PP, FH/SGn	Greater FH/SGn in M than F.

Table 2. Continued

Study	Nationality, sex, sample size, and age	Orthodontic measurement	Result
Aleksić et al. (2012)[35]	Serbian: M: n = 36, 9 ± 0.17 yr, F: n = 42, 9 ± 0.43 yr	S-N, SNA, SNB, N-Me, S-Goi, S-Goi/N-Me; SN/PP, SN/MP (Downs), ArGoiMe[†]	Larger S-N, N-Me, SN/MP and smaller S-Goi/N-Me, SNA, SNB in M than F.
Huang et al. (1998)[48]	White American: M: n = 32, F: n = 35 African American: M: n = 39, F: n = 30 2 groups: young (6–12 yr), old (12–18 yr)	SNA, SNB, ANB, Wits	No significant differences between M and F.
Alexander and Hitchcock (1978)[63]	Black American: n = 50, 8–13 yr (10.18 ± 1.38 yr)	SNA, SNB, SNPg, ANB, SN/MP (Downs), NSGn	Greater SNA, ANB, SN/MP in 10 yr black American than 10 yr white Southern American.
Barter et al. (1995)[38]	South-African: M: n = 50, 14 yr 1 mo (11 yr 4 mo–16 yr 1 mo), F: n = 54, 13 yr 6 mo (11 yr 4 mo–16 yr 9 mo)	S-N, SNA, Co-A, SNB, FH/NPg, Co-Gn, Go-Gn, ANB, Wits, N-ANS, ANS-Me; SN/PP, SN/GoGn, ArGoGn, NSGn	Smaller SN/PP in M than F.
Ajayi (2005)[47]	Nigerian Igbo: M: n = 66, F: n = 34, 11–13 yr (12.6 ± 0.6 yr)	SNA, SNB, ANB, FH/MP (Go-Me)	No significant differences between M and F.
Folaranmi and Isiekwe (2013)[59]	Nigerian: M: n = 40, F: n = 60, 12.2 yr (12–15 yr)	N-ANS, ANS-Me, N-Me, ANS-Me/N-Me	No significant differences between M and F.
Beugre et al. (2007)[64]	Ivorian: M: n = 26, F: n = 27, 9.5–17 yr Senegalese: M: n = 25, F: n = 25, 12–16 yr Chadian: M: n = 31, F: n = 31, 12–16 yr	SNA, SNB, SNPg, ANB, Wits, S-Go, N-Me, S-Go/ N-Me; FH/MP, SN/MP (Go-Gn), SN/PP	No sexual dimorphism in any ethnic group (except greater S-Go, N-Me in Senegalese M than F).
Kapila (1989)[49]	Kikuyu: M: n = 28, 11.5 yr, F: n = 28, 10.85 yr	SNA, SNB, ANB, FH/MP (Go-Gn)	Smaller SNB in M than F.
Sobreira et al. (2011)[25]	Black Brazilian: F: n = 35 White Brazilian: F: n = 35 3 groups: 8 yr (n = 22), 9 yr (n = 18), 10 yr (n = 30)	ANS-Me/N-Me, S-Go/N-Me, Ar-Go/S-Go, Ar-Go/ANS-Me	No significant differences among 3 age groups in both races.
de Freitas et al. (2010)[65]	White Brazilian: M: n = 25, F: n = 25, 13.17 ± 1.07 yr Black Brazilian: M: n = 28, F: n = 28, 13.24 ± 0.56 yr	SNA, A-Nperp, SNB, Co-Gn, Pg-Nperp, Pg-NB, ANB, NAPg, Wits, FH/MP (Go-Me), SN/GoGn	Greater SNA, A-Nperp, SNB, Pg-Nperp, ANB, NAPg; and smaller Co-Gn, Pg-NB, FH/MP, SN/GoGn in black than white Brazilian.
de Freitas et al. (2007)[50]	White Brazilian: M: n = 37, F: n = 37, 13.71 ± 0.84 yr Black Brazilian: M: n = 28, F: n = 28, 13.86 ± 0.92 yr	SNA, SNB, ANB, N-Me, N-ANS', ANS'-Me, N-ANS'/N-Me, ANS'-Me/N-Me, S-Go, S-Ar', Ar'-Go, S-Ar'/S-Go, Ar'-Go/S-Go*,†	Significantly greater S-Go, N-ANS', S-Ar', S-Ar'/S-Go; and smaller Ar'-Go/S-Go in black M than F; Significantly greater S-Ar', S-Ar'/S-Go and smaller Ar'-Go/S-Go in white M than F.

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Table 2. Continued

Study	Nationality, sex, sample size, and age	Orthodontic measurement	Result
Janson et al. (2011)[52]	White Brazilian: M: n = 20, F: n = 20, 13.02 yr (11.89–15.03 yr) Afro-Caucasian Brazilian: M: n = 20, F: n = 20, 13.02 yr (12–14.30 yr)	SNA, SNB, ANB, N-Me, N-ANS', ANS'-Me, S-Go, S-Ar', Ar'-Go*,†	No significant differences between Caucasian Brazilian M and F; Greater SNB, S-Go, S-Ar' in Afro-Caucasian Brazilian M than F.
Storniolo-Souza et al. (2021)[57]	White Brazilian: M: n = 20, 13.57 ± 1.03 yr, F: n = 20, 13.70 ± 0.87 yr Japanese: M: n = 16, 15.56 ± 2.51 yr, F: n = 17, 15.65 ± 2.45 yr Japanese-White-Brazilian: M: n = 15, 14.19 ± 1.01 yr, F: n = 17, 13.22 ± 1.04 yr	A-Nperp, Co-A, Pg-Nperp, Co-Gn, Mx-Md diff, ANS-Me, FH/MP (Go-Me), NBa/PtmGn	Significantly greater Co-A, Co-Gn, Mx-Md diff, and smaller A-Nperp in Japanese M than F; Significantly greater ANS-Me, and smaller Pg-Nperp in Japanese-White-Brazilian M had than F; No significant differences between White-Brazilian M and F.
Vieira et al. (2014)[58]	Japanese-Caucasian-Brazilian: M: n = 15, F: n = 15, 14 yr (11.91–16.61 yr)	N-Me, N-ANS', ANS'-Me, N-ANS'/N-Me, ANS'-Me/N-Me, S-Go, S-Ar', Ar'-Go, S-Ar'/S-Go, Ar'-Go/S-Go*,†	Greater N-Me, ANS'-Me, S-Go, S-Ar' in M than F.
Singh Rathore et al. (2012)[60]	Mewari: M: n = 50, F: n = 50, 11–13 yr	SNA, SNB, ANB, SN/MP (Go-Gn)	Greater ANB, and smaller SNB in Mewari children than white adults.
Anuradha et al. (1991)[46]	North Indian: M: n = 30, F: n = 30, 4–5 yr	SNA, SNB, ANB, SN/ MP (Go-Gn)	Insignificant difference between M and F.
Singh et al. (2019)[56]	Lingayat: M: n = 110, F: n = 110, 11–13 yr	FH/NPg, NAPg, FH/MP (Downs)	Greater NAPg in M than F.
Moldez et al. (2006)[31]	Filipino: M: n = 78, F: n = 79 4 groups: GI: 7 yr, GII: 9.5 yr, GIII: 14 yr, GIV: 22 yr	S-N, SNA, SNB, Co-Gn, Co-Go, FH/NPg, ANB, NAPg, N-Me, N-ANS, ANS-Me; FH/PP, SN/FH, SN/PP, SN/MP (Go-Me), FH/SGn	Greater S-N, N-Me, N-ANS, Co-Go, Co-Gn in M than F in GI, GIII, GIV; Greater ANS-Me in M than F in GIII, GIV; Insignificant differences between sexes for linear measurements in GII; Insignificant differences between sexes in GI, GII, GIII for angular parameters; larger SNB, SN/FH, and smaller SN/PP, SN/MP in M than F in GIV.
Zhao et al. (2013)[37]	Chinese: M: n = 16, F: n = 16, 12 yr 11 mo–13 yr 1 mo White: M: n = 16, F: n = 16, 13 yr	S-N, S-Ba, NSAr, SNA, ANS-PNS, SNB, SNPg, FH/NPg, Go-Pg, Ar-Go ANB, NAPg, N-ANS, ANS-Me, N-Me; FH/MP (Go-Gn), SN/MP, PP/MP, FH/SGn	Insignificant differences between white M and F; Greater N-ANS in Chinese M than F.
Gu et al. (2011)[66]	Southern Chinese: M: n = 70, 12.4 ± 0.6 yr, F: n = 60, 12.5 ± 0.4 yr Northern Chinese: M: n = 50, 12.8 ± 1.8 yr, F: n = 50, 12.4 ± 1.2 yr British: M: n = 43, F: n = 43, 12 yr	A-Nperp, Co-A, Pg-Nperp, Co-Gn, Mx-Md diff, FH/MP (Go-Me), ANS-Me	The smallest FH/MP in British; The greatest Co-A, Co-Gn, FH/MP, ANS-Me; and smallest Pg-Nperp in Northern Chinese.

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Table 2. Continued

Study	Nationality, sex, sample size, and age	Orthodontic measurement	Result
Pan et al. (1996)[24]	Chinese: M: n = 25, F: n = 32, 12 yr	A-Nperp, Co-A, Pg-Nperp, Co-Gn, ANS-Me	Greater Co-A, A-Nperp in M than F.
Chang et al. (1993)[29]	Taiwanese: M: n = 80, F: n = 80 2 groups: 11 yr 1 mo–12 yr 8 mo (M: n = 40, F: n = 40), young adult (M: n = 40, F: n = 40)	S-N, S-Ar, NSAr, Co-A, Co-Gn, Ar-Goi, Goi-Pg,[‡] ATFH, AUFH, ALFH, PTFH, PUFH, PLFH, AUFH/ATFH, ALFH/ATFH, AUFH/ALFH, PUFH/AUFH, PLFH/ALFH, PTFH/ATFH,[§] SN/FH, SN/PP, FH/PP, SN/MP (Downs), FH/MP, PP/MP	No differences between 2 age groups in NSAr, AUFH/ATFH, ALFH/ATFH, AUFH/ALFH, PUFH/AUFH, SN/FH, SN/PP, FH/PP; Greater S-N, S-Ar, Co-A, Co-Gn, Ar-Goi, Goi-Pg, ATFH, ALFH, AUFH, PTFH, PUFH, PLFH, PLFH/ALFH, PTFH/ATFH (except for PTFH/ATFH in F) in adult than child; Smaller SN/MP, FH/MP, PP/MP (only in M) in adult than child; Greater parameters in M than F in child and adult for S-N, S-Ar, Co-Gn, ATFH, ALFH; and only in adult for Co-A, Ar-Goi, Goi-Pg, AUFH, PTFH, PUFH, PLFH; Smaller PLFH/ALFH, PTFH/ATF in M child than F, but greater in adult M; Greater SN/MP, FH/MP, PP/MP in M child than F, but smaller in adult M.

M, male; F, female; ≈, no significant difference; Mx-Md diff, maxillomandibular difference; NAPg, facial convexity; ATFH, anterior total facial height; AUFH, anterior upper facial height; ALFH, anterior lower facial height; PTFH, posterior total facial height; PUFH, posterior upper facial height; PLFH, posterior lower facial height.
*Point ANS', projection of point ANS on N-Me plane.
†Point Ar', projection of point Ar on S-Go plane.
‡Point Goi, gonial intersection, intersection of mandibular plane (Downs) and tangent of mandibular ramus.
§Perpendicular line to palatal plane was used as reference plane to measure facial height.
See Figure 2 for definition of each landmark or measurement.

only females.[25,26] All articles used lateral cephalometric radiographs and none used cone-beam computed tomography. The characteristics of the selected articles are presented in Tables 1 and 2. Critical appraisal of the included articles (Supplementary Table 2) ranged from good to excellent. However, all the included studies, except two, had similar a weakness, which was that they did not justify or calculate the sample size. Additionally, these studies did not report similar measurements.[1,2,24-66]

Cranial base

Three studies observed a significant increase in the anterior cranial base length (S-N) and posterior cranial base length (S-Ba) (Figure 2) in both sexes from childhood to young adulthood,[27-29] while two others showed the same trend, with no statistical analysis.[2,30] Longer S-N was generally observed in males than females in longitudinal[2,28,30] and cross-sectional study designs.[29,31-35] Stahl de Castrillon et al.[30] recorded longer S-N in males at 6, 16, and 17 years. Ursi et al.[2] found that S-N was larger in males than in females at all ages, whereas Jiménez et al.[28] only found a significant difference between males and females from the age of 16 years onwards. Thus,

females had a constant acceleration of S-N from 8 to 16 years of age, followed by a decrease in the growth rate, whereas males had an acceleration in growth between 14 and 16 years of age, which decreased after 20 years of age. However, insignificant differences between males and females were reported in five studies.[27,31,36-38]

For the cranial base angle (Figure 2), most studies observed that NSAr was stable in both sexes from the primary to adult period,[29,30,39] while Al-Taai et al.[40] reported that NSAr increased significantly from early to late adolescence. Thilander et al.[39] observed that NSBa decreased slightly during the growth period (no statistical analysis), whereas Stahl de Castrillon et al.,[30] Chuang,[27] and Al-Taai et al.[40] showed that NSBa remained constant with age. No significant differences between the sexes were found for NSBa or NSAr.[2,27,29,30,32-34,36,37,41,42]

Maxilla

SNA and A-Nperp describe the position of the maxilla relative to the cranial base (Figure 2). Six longitudinal studies observed increases in SNA during growth,[1,30,40,41,43,44] with the majority observing greater growth in males than females. In contrast, three other

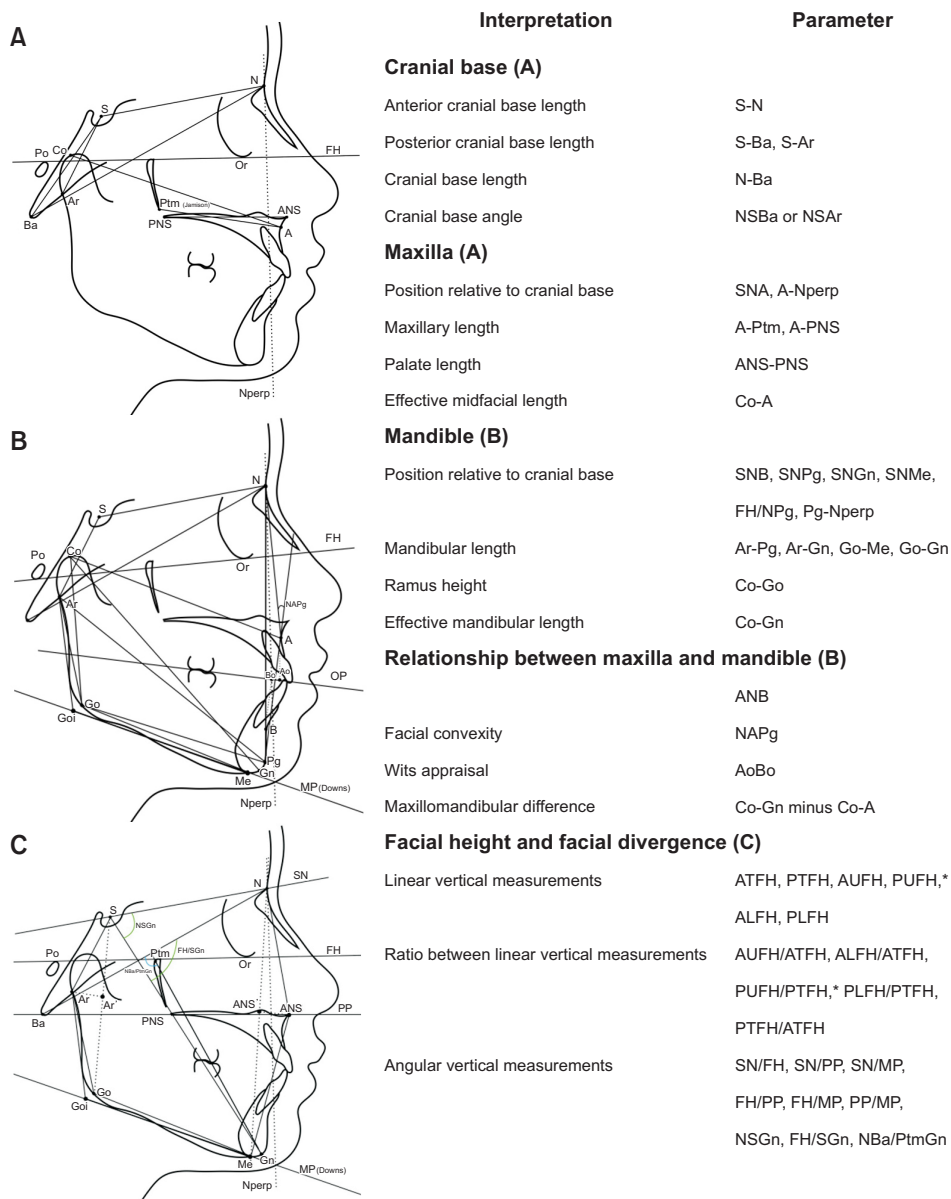| Interpretation	Parameter
Cranial base (A)	
Anterior cranial base length	S-N
Posterior cranial base length	S-Ba, S-Ar
Cranial base length	N-Ba
Cranial base angle	NSBa or NSAr
Maxilla (A)	
Position relative to cranial base	SNA, A-Nperp
Maxillary length	A-Ptm, A-PNS
Palate length	ANS-PNS
Effective midfacial length	Co-A
Mandible (B)	
Position relative to cranial base	SNB, SNPg, SNGn, SNMe, FH/NPg, Pg-Nperp
Mandibular length	Ar-Pg, Ar-Gn, Go-Me, Go-Gn
Ramus height	Co-Go
Effective mandibular length	Co-Gn
Relationship between maxilla and mandible (B)	
	ANB
Facial convexity	NAPg
Wits appraisal	AoBo
Maxillomandibular difference	Co-Gn minus Co-A
Facial height and facial divergence (C)	
Linear vertical measurements	ATFH, PTFH, AUFH, PUFH,* ALFH, PLFH
Ratio between linear vertical measurements	AUFH/ATFH, ALFH/ATFH, PUFH/PTFH,* PLFH/PTFH, PTFH/ATFH
Angular vertical measurements	SN/FH, SN/PP, SN/MP, FH/PP, FH/MP, PP/MP, NSGn, FH/SGn, NBa/PtmGn

Figure 2. Cephalometric measurements. Cephalometry measures angles and distances on lateral radiographs of the head to quantify the size and relative position of the cranial base, maxilla, and mandible. The parameters for the cranial base and maxilla are illustrated in (**A**), while those of the mandible and maxillomandibular difference are shown in (**B**). Facial height and divergence measurements are shown in (**C**).
ATFH, anterior total facial height; PTFH, posterior total facial height; AUFH, anterior upper facial height; ALFH, anterior lower facial height; PUFH, posterior upper facial height; PLFH, posterior lower facial height; SN, plane formed by connecting point Sella and Nasion; FH, Frankfort horizontal plane; PP, palatal plane; MP, mandibular plane.
*Evaluation of PUFH is assessed through S-Ar', in which, Ar' is projection of Ar on S-Go plane (S-Ar is considered posterior cranial base).

longitudinal studies did not observe increases in SNA during growth.[27,39,45] In general, no difference between males and females was observed in SNA in three longitudinal[2,27,45] and fifteen cross-sectional studies.[31,32,34,36-38,46-54] However, one study found greater SNA in boys than in girls[41] and two cross-sectional studies found greater SNA in girls than in boys.[33,35] The difference in A-Nperp between sexes was inconsistent among studies.[2,24,33,55]

Maxillary length (A-Ptm, A-PNS) and palate length

(ANS-PNS) (Figure 2) significantly increased with age in both sexes.[1,27,40,43,45] Midfacial dimensions (Co-A, ANS-PNS) (Figure 2) are similar in males and females, until later time points during adolescence, when males have significantly longer dimensions.[27-30,33,36,37,44] However, other studies observed greater midfacial dimensions in males than females at earlier time points, such as 8 years of age.[2,24,32,45,55]

Mandible

Anterior growth of the mandible with respect to the anterior cranial base (SNB, SNPg, and Pg-Nperp; Figure 2) was observed in longitudinal studies spanning 5–31 years of age in both sexes.[1,30,39-41,44] Only one study conducted by Chuang[27] reported an insignificant increase in SNB, SNMe, and SNGn (Figure 2) from 8–12 years in both sexes. Sixteen cross-sectional studies found no sex-related differences in mandibular position relative to cranial base (SNB, SNPg, FH/NPg; Figure 2) in children at different timepoint between the ages of 4–14 years.[32-34,36-38,42,46,48,50-56] Two longitudinal and two cross-sectional studies found more protrusive mandibles in females than in males,[2,27,35,49] where SNB was greater in female children below 14 years of age. Three other studies[30,31,41] observed significantly greater SNB in males over 17 years at 22, 18, and 17 years of age.

The length of the mandible (Ar-Pg, Goi-Me, Co-Gn, Ar-Gn, Go-Me, Ar-Goi, Ar-Go, Goi-Pg, or Go-Pg; Figure 2) increased from childhood until young adulthood and was greater in males than in females.[1,27,28,39,40,44] Males may have a later or longer period of growth than females,[1,28,39] whose growth may slow at approximately 14 years of age.[1,28] Thus, mandibular length is generally longer in males, especially at later time points.[1,2,27-32,39,55,57] Other cross-sectional studies found insignificant sex-related differences in Co-Gn from the age of 10–14 years.[24,33,38]

Only two studies have measured the mandibular height (Co-Go), with conflicting results. Moldez et al.[31] found significantly greater values of Co-Go at 7, 14, and 22 years in males than females. However, Stahl de Castrillon et al.[30] only found a larger mandibular ramus height in males at 17 years of age throughout the evaluation of children from 6–17 years of age.

Maxillomandibular relationship

The relationship between the maxilla and mandible was assessed using ANB, facial convexity (NAPg), AoBo (Wits appraisal), and maxillomandibular difference (Mx-Md difference) (Co-Gn minus Co-A) (Figure 2). There is a consensus among the included longitudinal studies that the ANB decreases during growth[1,27,30,39,43,44] and NAPg becomes straighter in adults from slight convexity in childhood,[1,27,39,43] with one exception stating that the

ANB increased with age.[40] These decreases in ANB and NAPg indicate a relatively increased prominence of the mandibular base with respect to the maxillary base. Wit appraisal values were reported to be constant from 6 to 17 years of age in both sexes.[30]

Several longitudinal and cross-sectional studies have not observed significant differences between males and females in the maxillomandibular relationship: ANB,[30-33,36,38,46-49,51,54,55] NAPg,[31-33,36,42,51,55] Wits appraisal,[30,33,51] and Mx-Md differences.[55,57] There are a few exceptions;[27,56,57] however, the overall consensus is that males and females have a similar maxillomandibular relationship.

Vertical parameters

Most longitudinal studies have reported a significant increase in linear vertical parameters during growth (Figure 2).[1,28,39-41,44,45] Regarding the timing of growth, anterior upper facial height (AUFH) showed the greatest growth between approximately 5–11 years,[1,45] whereas anterior lower facial height (ALFH) showed the greatest growth later between 13–16 years.[39] In terms of sexual dimorphism, anterior facial height (anterior total facial height [ATFH], AUFH, ALFH) was significantly greater in males in most longitudinal studies but was inconsistent in cross-sectional studies. Specifically, beginning as early as 7 years of age in the majority of studies, males presented greater ATFH,[28,30-33,35,51,58] AUFH,[2,31,32,34,37,38,41,50,51] and ALFH[2,29,30,33,36,41,55,58] than females; however, the differences in ATFH,[26,40,42,55] AUFH,[33,36,50,52,58,59] and ALFH[24,38,50,52,53,59] were considered insignificant in other cross-sectional cohorts.

Posterior lower facial height (PLFH) and posterior total facial height (PTFH) constantly increased from childhood to adulthood in males, whereas they increased more significantly at 5–10 years than at 10–15 and 15–25.5 years of age in females.[1] The PLFH/PTFH ratio decreased from 5–10 years indicating that the increase in posterior facial height could be attributed to the vertical growth of the upper posterior segment at an early age. Then, PLFH/PTFH increased from 10–15 years and 15–25.5 years of age implying vertical growth of lower posterior component at a later age.[1] PTFH was greater in males[33,34,50-52,58] while two longitudinal articles reported a greater PTFH in males only starting from the age of 16 years onwards.[28,30] However, three studies did not observe significant differences between the sexes.[35,50,52] Posterior upper facial height (PUFH) was greater in males than females,[50,52,58] except in one study of Brazilian children.[52] Most studies concluded that there were no significant differences in PLFH between sexes,[50-52,58] except for two studies.[34,51]

These changes in the anterior vs. posterior facial heights indicated counter-clockwise rotation of the mandible with age. The ATFH/PTFH ratio continuously

decreases with age (approximately 16%)[39] resulting in an upward and forward rotation of the mandible. This was further supported by decreases in mandibular plane angle (SN/MP or FH/MP),[1,28,40,41,44] basal plane angle (MP/PP), and gonial angle[30,39,40] with age. Interestingly, PLFH/ALFH and PTFH/ATFH in males were smaller than those in females in children, but became greater in young adults; thus, posterior facial height increased more in males than in females.[1,29] However, no sexual dimorphism was found in SN/MP in most longitudinal studies[27,28,41] or cross-sectional studies,[31-34,37,38,46,53,54,60] except for two studies reporting larger values in males.[35,36]

DISCUSSION

This scoping review aggregated the most common cephalometric parameters in children with a well-balanced face and normal occlusion. This review has yielded a number of general results regarding 1) the growth of orofacial bones during childhood and adolescence by comparing normative cephalometric data in children of different ages and 2) sexual dimorphism pertaining to differences in mean values of parameters at specific ages, as well as the difference in the extent and timing of growth.

Regarding cranial base, here, we observed that the cranial base lengthened during growth from childhood to adulthood, while cranial base angle remained stable. The systematic review by Afrand et al.[13] supported these observations even though their inclusion criteria did not include well-balanced face and normal occlusion. Afrand et al.[13] observed that the point sella moved backward and downward, whereas the point nasion moved forward until adulthood, inducing a continuous increase in the length of the anterior cranial base. Elongation of the posterior cranial base S-Ba until adulthood was also reported in another systematic review of the growth of the posterior cranial base by Currie et al.[14] In this study, both points S and Ba moved downward and backward with age; however, the change at point Ba was greater, leading to an increase in S-Ba. Regarding the cranial base angle, the results of the literature review coincide with a recent longitudinal article published in 2017,[67] which showed that the cranial base angle NSBa remained constant from the age of 6–18 years in individuals with Class I normal occlusion or Class II division 2 occlusion (based on Angle's occlusal classification).

With regard to the maxilla, this review showed elongation (increased A-Ptm, A-PNS, ANS-PNS, and Co-A) as well as downward and forward growth of the maxilla (increased AUFH, SNA, and A-Nperp). These results correspond to Enlow and Hans,[11] Proffit et al.,[15] and Björk's description[68] of the growth of the nasomaxillary complex. Björk[68] observed that maxillary elongation was

attributable to bone modeling at the palatomaxillary suture and bone apposition at the posterior surface of the maxillary tuberosity. Vertical growth occurred in the sutures of the zygomatic and frontal processes. Additionally, according to Enlow and Hans[11] and Proffit et al.,[15] bone modeling processes in the palate, including bone removal at the nasal side and bone apposition at the oral side, also induce downward growth of the palate.

This scoping review showed that the mandible grows from childhood to adulthood (increased SNB, SNPg, and Pg-Nperp)[1,30,39,41,44] and lengthens with age (increased Ar-Pg, Co-Gn, Ar-Gn, Go-Me, Ar-Go, and Go-Pg),[1,27,28,44] which coincides with previous publications.[11,15] Enlow and Hans[11] observed that the mandibular condyle and ramus grow significantly in childhood in the superior and posterior directions, inducing forward and downward translation of the mandible. Furthermore, according to Proffit et al.,[15] bone modeling occurs at the ramus, including bone apposition at the posterior surface and bone resorption at the anterior surface, leading to an increased distance from the ramus to the chin, which indicates elongation of the mandible.

Regarding the maxillomandibular relationship, there was a consensus among the included studies about the stability of Wits appraisal, the decrease in ANB and NAPg during childhood and adolescence, and insignificant differences in those measurements between males and females. Both SNA and SNB increased with age. Thus, the decrease in ANB was attributed to the growth of the mandible, predominantly at later time points than that of the maxilla.

This review reports a significant increase in facial height with age in both sexes. This is because both the maxilla and mandible move forward and downward during growth.[11,15] According to Lowrey and Watson,[69] the midface and lower face account for a low proportion of the head in children; however, this proportion increases considerably during growth. Regarding growth differences in vertical parameters, the posterior facial height lengthened more than the anterior facial height during growth in both sexes, resulting in a continuous decrease in the mandibular plane angle and an increase in the PTFH/ATFH ratio, leading to a counterclockwise rotation of the mandible. This is consistent with the results of Björk and Skieller[7] and Hardin et al.[70,71] Hardin et al.[71] synthesized data from six longitudinal articles, showed that changes in the mandibular plane angle with age were significantly different among individuals with different facial types (hyperdivergent, well-balanced, and hypodivergent). Specifically, in individuals with hyperdivergent faces, the change in the mandibular plane angle was insignificant; a slight increase was observed in females. In contrast, a severe decrease in this angle was observed in individuals with hypodivergent faces, and a

moderate decrease was reported in individuals with well-balanced faces from childhood to young adulthood. In this study, the decrease in mandibular plane angle was greater in males than in females.

Our synthesis of the results showed sex-related trends in the size of orofacial bone structures and the timing of growth. In particular, the lengths of the anterior cranial base, maxilla, and mandible ceased to increase earlier in females resulting in significantly larger mean values in males aged 15–16 years of age. Our results were consistent with a longitudinal study by Nahhas et al.[72] that observed an increase in maxillary length (A-PNS) and mandibular length (Ar-Me) beginning at approximately 7 years in females and around 8 years in males, and ceasing around 16–17 years in females and nearly 20 years in males. Furthermore, Costello et al.[16] found that mandibular growth was nearly complete at the age of 14 years in females and 16 years in males. According to Björk,[68] males reached puberty and complete the maturation process 1.5 years earlier than females. These differences in growth also affected ANB, which remained relatively stable in females after 15 years of age, but continued to decrease in males past 15 years.[16,17]

LIMITATIONS

This scoping review had several limitations. First, the sample size was not justified in the included studies, except for one article.[56] This study achieved the highest score in the quality appraisal; however, it only examined a small number of cephalometric measurements. Second, several factors contributed to the risk of bias across studies in the scoping review: a few landmarks and reference planes used were inconsistent among studies, standardization of cephalometric radiographs can be difficult (different magnifications of cephalometric films among studies), and studies did not report a consistent set of cephalometric parameters. Third, the term well-balanced face was used in the eligibility criteria to include studies assessing normative data on children who would not be recommended for orthodontic treatment. However, the term well-balanced face is socially determined, subjective, and may be influenced by different cultural norms/values. Thus, the interpretation of well-balanced faces and harmonious profiles may differ between individuals and cultures or be influenced by Eurocentric norms;[73] all of these aspects could bias the selection of participants.

CONCLUSIONS

This scoping review aggregated normative data on the size and relative position of orofacial skeletal structures in children with a well-balanced face and normal occlusion to serve as a reference for orthodontics as well as for researchers investigating orofacial developmental abnormalities in children. In conclusion, the cranial base, maxilla, and mandible lengthen throughout childhood and adolescence. Growth of the maxilla and mandible occurred in forward and downward directions in both sexes. The maxillary and mandibular lengths reached their maximum values earlier in females; however, the duration of the growth period was longer in males. Therefore, age and sex should be considered during diagnosis and treatment planning, as well as during research on orofacial morphology.

AUTHOR CONTRIBUTIONS

Conceptualization: TKN, EAZ. Data curation: TKN. Formal analysis: TKN, MH, EAZ. Investigation: TKN, AC, EAZ. Supervision: EAZ. Writing–original draft: TKN. Writing–review & editing: TKN, AC, MH, EAZ.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

SUPPLEMENTARY MATERIAL

Supplementary data is available at https://doi.org/10.4041/kjod23.224

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