



CURRENT PROSPECTIVES ON CEPHALOMETRIC PARAMETERS USED IN SKELETAL DISCREPANCY ASSESSMENT

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ABSTRACT :

Background

Accurate identification and characterization of skeletal discrepancies are fundamental to orthodontic diagnosis, treatment planning, and assessment of treatment outcomes. Conventional cephalometric parameters, particularly the ANB angle and Wits appraisal, have been extensively used to evaluate anteroposterior skeletal relationships. However, their interpretation may be influenced by cranial-base morphology, jaw rotation, growth-related changes, occlusal-plane inclination, and variability in anatomical landmark identification. These limitations have encouraged the development and investigation of alternative cephalometric parameters and advanced imaging approaches.

1. Introduction

Cephalometric analysis remains an important component of contemporary orthodontic diagnosis. It enables quantitative assessment of craniofacial morphology and provides standardized measurements for evaluating skeletal, dental and soft-tissue relationships. Lateral cephalometry has traditionally been used to characterize sagittal and vertical skeletal patterns, monitor growth and treatment changes, and assist in orthodontic and orthognathic surgical planning.

Despite its longstanding clinical value, cephalometric interpretation is not equivalent to direct measurement of skeletal discrepancy. Most conventional measurements are constructed from anatomical landmarks and reference planes that can themselves vary because of biological morphology, growth, jaw rotation, radiographic projection and landmark-identification error. Consequently, a numerical measurement should be interpreted within the broader craniofacial context rather than treated as an isolated diagnostic label.

The ANB angle is perhaps the most familiar measurement for assessing the sagittal relationship between the maxilla and mandible. However, its value can be altered by the position of nasion, cranial-base configuration, vertical facial pattern and rotation of the jaws. Wits appraisal was introduced as a complementary approach, but it is dependent on the occlusal plane. These limitations stimulated development of alternative measurements including the Beta angle, W angle and Yen angle. Recent research continues to compare these measurements and has introduced additional indices, including the K angle.

At the same time, digital radiography, CBCT and artificial intelligence have transformed the technical environment in which cephalometric assessment is performed. Contemporary AI systems can identify landmarks, generate cephalometric measurements and assist with skeletal classification. Nevertheless, systematic reviews continue to identify heterogeneity in datasets, algorithms, reference standards and clinical validation.

2. Objectives

The objectives of this review were to:

1. Describe the principal cephalometric parameters used for skeletal discrepancy assessment.
2. Examine the diagnostic rationale and limitations of conventional sagittal measurements.
3. Review contemporary alternatives to ANB and Wits appraisal.
4. Summarize important parameters used for vertical skeletal assessment.
5. Examine the contribution and limitations of CBCT and three-dimensional cephalometry.
6. Evaluate recent evidence concerning AI-assisted landmark detection and cephalometric analysis.
7. Identify methodological and clinical research gaps.

8. Propose future directions for individualized and multidimensional skeletal assessment.

3. Literature-Search Methodology

3.1 Review design

A structured systematic literature-search methodology was used for this critical narrative review. The search was designed to identify contemporary evidence concerning cephalometric parameters, skeletal discrepancy assessment, three-dimensional imaging and AI-assisted cephalometry.

The reporting framework was informed by principles of *PRISMA*, although this manuscript should not be represented as a formally registered systematic review unless the search, duplicate removal, independent screening and protocol registration are subsequently completed.

3.2 Databases and sources

The primary search was performed in:

- PubMed/MEDLINE
- Google Scholar
- Scopus-indexed literature identified through supplementary searches
- Web-based biomedical literature sources
- Reference lists of relevant systematic reviews

The final literature update was performed in *September 2026*.

3.3 Search concepts

Representative search combinations included:

“cephalometric parameters” AND “skeletal discrepancy”

“ANB” AND “Wits appraisal” AND “skeletal discrepancy”

“Beta angle” AND “W angle” AND “Yen angle”

“vertical skeletal dysplasia” AND cephalometry

“three-dimensional cephalometry” AND orthodontics

“CBCT” AND “cephalometric analysis”

“artificial intelligence” AND “cephalometric landmark”

“machine learning” AND “skeletal classification” AND orthodontics

“automatic cephalometric analysis” AND artificial intelligence

3.4 Eligibility criteria

Inclusion criteria

Studies were considered when they:

- Evaluated cephalometric parameters used for skeletal assessment.
- Investigated sagittal or vertical skeletal discrepancies.
- Evaluated reliability, validity or reproducibility of cephalometric measurements.
- Investigated CBCT/3D cephalometry relevant to skeletal assessment.
- Evaluated AI or machine-learning approaches to cephalometric landmark detection or skeletal classification.
- Were systematic reviews, meta-analyses, diagnostic studies, comparative studies, observational studies or relevant methodological

investigations.

- Were published primarily between 2020 and September 2026.

Exclusion criteria

Excluded literature included:

- Studies unrelated to skeletal/cephalometric assessment.
- Non-human studies where clinical relevance could not be established.
- Case reports without methodological relevance.
- Articles lacking sufficient methodological information.
- Duplicate publications.

Seminal studies describing the original development of established parameters were retained despite publication before 2020 because excluding them would remove the historical basis of the measurements discussed.

3.5 Evidence synthesis

Because substantial heterogeneity exists in patient populations, skeletal classifications, imaging modalities, landmark definitions, diagnostic thresholds and statistical methods, quantitative pooling was not undertaken for the entire body of evidence.

Evidence was instead synthesized according to:

1. Diagnostic purpose.
2. Anatomical reference system.
3. Measurement type.
4. Major sources of error.
5. Reliability/reproducibility.
6. Clinical applicability.
7. Emerging technological applications.

4. Conventional Cephalometric Assessment

Skeletal discrepancy can broadly be considered in three dimensions:

- *Sagittal*
- *Vertical*
- *Transverse*

Traditional lateral cephalometry primarily evaluates sagittal and vertical relationships.

4.1 SNA angle

The SNA angle evaluates the anteroposterior position of the maxilla relative to the anterior cranial base.

Clinical usefulness

It can help determine whether a sagittal discrepancy is associated with:

- Maxillary retrusion
- Maxillary protrusion
- Relative mandibular positional change

Limitations

SNA does not directly measure maxillomandibular discrepancy. It is influenced by:

- Cranial-base morphology
- Nasion position

- Orientation of the cranial base
- Individual anatomical variation

Therefore, SNA should generally be interpreted together with SNB and a direct maxillomandibular relationship measurement.

6. ANB Angle

ANB is calculated as the difference between SNA and SNB and has traditionally been used to characterize the sagittal relationship between the maxilla and mandible.

Advantages

- Simple to determine.
- Familiar to clinicians.
- Extensive historical normative data.
- Useful for communication and longitudinal assessment.
- Easily incorporated into conventional cephalometric analyses.

Limitations

ANB may be affected by:

- Nasion position.
- Cranial-base length and angulation.
- Vertical facial morphology.
- Clockwise/counterclockwise jaw rotation.
- Growth.
- Individual anatomical variation.

Consequently, ANB should be considered a *relative angular indicator rather than a direct measurement of skeletal discrepancy*.

Contemporary literature continues to investigate individualized or “floating” norms for ANB and Wits appraisal rather than assuming that identical cut-offs are appropriate for every craniofacial morphology.

7. Wits Appraisal

Wits appraisal projects points A and B onto the occlusal plane and evaluates the relationship between the projected points.

Advantages

- Provides information complementary to ANB.
- Less directly dependent on the cranial-base reference.
- Useful in cases where cranial-base morphology makes ANB difficult to interpret.

Limitations

The major limitation is dependence on *occlusal-plane inclination*.

Changes in:

- Occlusal-plane angulation
- Dental compensation
- Vertical skeletal morphology
- Tooth position

can affect the measurement.

Thus, Wits is best regarded as a complementary measurement rather than a universal replacement for ANB.

Recent comparative work has continued to demonstrate differences in the diagnostic behavior of Wits, Beta, Yen and other measurements.

8. Beta Angle

The Beta angle was introduced to provide a sagittal skeletal measurement less dependent on some of the limitations of ANB.

Potential advantages

- Uses skeletal landmarks rather than the occlusal plane.
- Provides an alternative assessment of sagittal jaw relationship.
- May be useful when ANB and Wits produce apparently inconsistent results.

Recent studies continue to support the value of Beta angle as a complementary measurement, particularly when jaw rotation or occlusal-plane changes complicate interpretation of conventional measurements.

Limitations

- Accurate landmark identification is required.
- Measurement may still vary according to individual skeletal morphology.
- Normative ranges may not be universally applicable across populations.
- It should not be interpreted independently of clinical findings.

9. W Angle

The W angle is another sagittal skeletal measurement designed to provide information about maxillomandibular relationships using skeletal reference structures.

Its clinical appeal lies in reducing some dependence on the nasion and occlusal plane.

However, the same general principle applies: *an alternative parameter does not eliminate biological and landmark-related variability.*

Therefore, W angle is best used as part of a battery of complementary sagittal measurements.

10. Yen Angle

The Yen angle was developed as another sagittal dysplasia indicator.

Its construction uses skeletal reference points designed to characterize the maxillomandibular relationship while reducing dependence on conventional cranial-base measurements. The original description proposed ranges for skeletal Class I, II and III relationships.

More recent comparative research continues to investigate Yen angle alongside ANB, Wits and Beta measurements. A 2025 study of 120 adults reported strong correlations of Yen and Beta measurements with the evaluated sagittal classification framework, although its single-center design limits generalization.

11. K Angle and Emerging Sagittal Parameters

The emergence of newer measurements illustrates an important contemporary trend: researchers are attempting to design parameters that minimize dependence on potentially unstable reference structures.

A 2025 comparative investigation evaluated *Yen, Beta, Wits and K angles* alongside ANB in 120 adults. The study reported stronger relationships for Yen and Beta than for Wits within its sample. Such findings are useful for hypothesis generation, but they should not be interpreted as establishing universal superiority because population, sample size and methodological differences influence diagnostic performance.

This illustrates why future research should prioritize *external validation across multiple populations.*

12. Comparative Assessment of Sagittal Parameters

Table 1. Major sagittal cephalometric parameters

Parameter	Principal reference	Measurement type	Major application	Important limitation
SNA	SN–A	Angular	Maxillary sagittal position	Cranial-base dependence
SNB	SN–B	Angular	Mandibular sagittal position	Cranial-base and rotational influence
ANB	A–N–B	Angular	Maxillomandibular sagittal relationship	Nasion, cranial base and jaw rotation
Wits	AO–BO	Linear	Sagittal discrepancy	Occlusal-plane dependence
Beta	Skeletal A/B/condylar references	Angular	Sagittal discrepancy	Landmark identification
W angle	Skeletal reference points	Angular	Sagittal discrepancy	Normative variability
Yen	S–M–G configuration	Angular	Sagittal dysplasia	Limited universal normative validation
K angle	Contemporary skeletal reference	Angular	Sagittal classification	Emerging evidence

Interpretation: No measurement should be treated as independently definitive. The measurements answer somewhat different anatomical questions.

13. Vertical Skeletal Discrepancy

Vertical skeletal assessment is particularly important because vertical morphology can influence interpretation of sagittal measurements.

Common parameters include:

- FMA
- SN-MP
- SN-GoGn
- Y-axis
- Facial axis
- Jarabak ratio
- Anterior facial height
- Posterior facial height
- Lower anterior facial height

A 2024 comparative investigation specifically evaluated multiple parameters used for vertical skeletal dysplasia, reinforcing the need to examine the relationship between alternative vertical measurements rather than rely on a single angular indicator.

Table 2. Important vertical parameters

Parameter	Main purpose	Interpretation
FMA	Mandibular plane inclination	Vertical skeletal pattern
SN-MP	Mandibular plane relative to cranial base	Vertical growth tendency
SN-GoGn	Mandibular plane relative to SN	Vertical skeletal relationship
Y-axis	Direction of mandibular growth	Growth pattern
Facial axis	Direction of facial growth	Vertical/sagittal growth tendency
Jarabak ratio	Anterior/posterior facial height	Growth pattern
LAFH	Lower anterior facial height	Vertical disproportion
PFH/AFH	Facial-height relationship	Vertical skeletal morphology

14. Interaction Between Sagittal and Vertical Parameters

One of the most important contemporary concepts is that skeletal relationships are *interdependent*.

For example, mandibular clockwise rotation can:

- Increase lower anterior facial height.
- Alter SNB.
- Alter ANB.
- Change facial convexity.
- Modify Wits appraisal.

Thus, a patient may demonstrate an apparently increased ANB because of vertical or rotational morphology rather than because of a simple sagittal maxillary-mandibular discrepancy.

This is an important reason to interpret cephalometric measurements as a *pattern* rather than as isolated values.

15. Population-Specific Norms

Another important limitation is the use of universal cephalometric norms.

Craniofacial morphology varies with:

- Age
- Sex
- Ethnic background
- Population
- Growth stage

For example, studies evaluating Saudi populations have demonstrated differences between local skeletal/dentoskeletal characteristics and North American reference standards.

Therefore, future cephalometric research should prioritize:

population-specific and, where appropriate, individualized reference ranges

rather than assuming that a single numerical standard is universally applicable.

16. Individualized Cephalometric Norms

The concept of individualized norms is increasingly relevant.

Instead of:

Measured value → fixed normal range → diagnosis

a more sophisticated approach is:

Measured value + age + sex + facial pattern + skeletal morphology + reference-plane characteristics → individualized interpretation

Research examining “floating norms” for ANB and Wits has specifically explored the use of guiding variables to individualize cephalometric interpretation.

This represents an important bridge between traditional cephalometry and computational personalized diagnostics.

17. Two-Dimensional Versus Three-Dimensional Cephalometry

17.1 Advantages of 2D cephalometry

- Lower radiation exposure than CBCT.
- Relatively inexpensive.
- Widely available.

- Large historical databases.
- Established normative values.
- Useful for longitudinal comparison.

17.2 Limitations

- Anatomical superimposition.
- Magnification.
- Projection-related distortion.
- Difficulty representing asymmetry.
- Dependence on head positioning.
- Limited representation of three-dimensional morphology.

18. CBCT and 3D Skeletal Assessment

CBCT has expanded the ability to evaluate craniofacial morphology in three dimensions.

Potential advantages include:

- Visualization of bilateral structures.
- Assessment of asymmetry.
- Three-dimensional skeletal measurements.
- Improved visualization of complex craniofacial anatomy.
- Volumetric analysis.
- 3D surgical planning.

However, *greater information does not automatically mean better routine diagnosis*.

A 2024 scoping review identified substantial applications of CBCT in orthodontics but emphasized that the evidence and clinical indications vary among applications.

Similarly, a systematic review evaluating CBCT-synthesized lateral cephalograms examined their accuracy relative to conventional lateral cephalograms, demonstrating the importance of validating whether technically different image-generation approaches yield clinically interchangeable measurements.

Table 3. 2D versus 3D assessment

Feature	2D cephalometry	CBCT/3D
Dimensional representation	2D	3D
Bilateral superimposition	Present	Reduced
Asymmetry	Limited	Better assessment
Radiation	Lower	Generally higher
Cost/accessibility	Better	More limited
Established norms	Extensive	Less standardized
Landmark visualization	Established	Potentially enhanced
Routine screening	Common	Selective
Surgical planning	Useful	Particularly valuable
Standardization	Relatively mature	Still evolving

19. Digital Cephalometry

Digital tracing has progressively replaced traditional manual tracing in many clinical environments.

Potential benefits include:

- Faster measurement.
- Automated calculations.
- Easy storage.
- Repeatability.

- Digital comparison.
- Integration with treatment-planning software.

A 2024 systematic review and meta-analysis comparing digital and manual tracing demonstrates the continued importance of assessing whether computational convenience translates into equivalent measurement performance.

Digitalization therefore represents more than a change in workflow; it provides the infrastructure for AI-based cephalometric analysis.

20. Artificial Intelligence in Cephalometric Analysis

AI applications in orthodontics can broadly be divided into:

1. Landmark detection.
2. Cephalometric measurement.
3. Skeletal classification.
4. Growth-stage assessment.
5. Treatment planning.
6. Surgical decision support.
7. Facial morphology prediction.

AI systems commonly employ:

- Convolutional neural networks (CNNs)
- Deep learning
- YOLO architectures
- Artificial neural networks
- Bayesian CNNs
- Regression models
- Computer vision algorithms

Recent reviews show rapid growth in this field.

21. AI-Based Landmark Detection

Manual landmark identification is time-consuming and affected by intra- and inter-examiner variability.

AI systems attempt to automatically locate landmarks such as:

- Sella
- Nasion
- Point A
- Point B
- Pogonion
- Menton
- Gonion
- Incisor landmarks
- Soft-tissue landmarks

A 2024 systematic review and meta-analysis included 34 studies evaluating AI landmark detection on 2D and 3D images. For 2D images, pooled error was approximately *1.39 mm*, although the 3D evidence was more heterogeneous, with reported errors ranging from approximately 1.0 to 5.8 mm.

22. The 2-mm Threshold: Important Critical Consideration

The frequently used *2-mm error threshold* should not automatically be equated with clinical interchangeability.

An umbrella review published in 2024 specifically criticized simplistic interpretation of the 2-mm threshold and emphasized that different landmarks have different levels of difficulty and clinical importance.

For example:

- A small landmark displacement may have little influence on one parameter.
- The same displacement may substantially alter another measurement.
- Multiple small landmark errors can accumulate when an angle is calculated from several points.

Therefore, future AI research should report:

- Landmark error.
- Parameter-level error.
- Clinical decision agreement.
- Sensitivity/specificity.
- Interclass correlation.
- Bland–Altman agreement.
- External validation.

23. AI Versus Manual Cephalometry

Evidence is increasingly nuanced.

An earlier meta-analysis reported promising AI performance but emphasized very low certainty of evidence and substantial heterogeneity.

A 2024 systematic review/meta-analysis found a pooled 2D landmark-detection error below 2 mm but could not quantitatively pool 3D studies because of heterogeneity.

A newer parameter-level systematic review found that AI-generated cephalometric measurements were generally comparable with manual measurements for many parameters, but evidence certainty remained low to moderate and multicenter validation was limited.

This suggests that the appropriate clinical model is currently:

AI-assisted cephalometry + expert verification

rather than:

AI-only cephalometric diagnosis

24. Commercial AI Systems

Commercial platforms are increasingly available.

Comparative research has shown high agreement between some systems for many measurements but also clinically relevant discrepancies for selected parameters.

Other studies have reported significant differences between commercial systems and expert measurements.

A particularly important finding is that performance may improve after *manual correction of automatically identified landmarks*.

Thus, commercial AI output should be regarded as a *draft analysis requiring verification*, particularly for treatment planning.

25. AI and Severe Skeletal Discrepancies

An important research issue is whether AI trained on predominantly routine orthodontic cases performs equally well in severe Class II and Class III patterns.

A 2024 study specifically investigated automated cephalometric tracing in severe Class II and Class III cases, providing evidence from a more challenging clinical population.

Similarly, research in unilateral cleft palate patients demonstrates why AI systems require validation in populations with altered craniofacial anatomy.

This is highly relevant because AI models trained predominantly on routine cases may not generalize well to:

- Severe skeletal Class III.
- Severe Class II.
- Facial asymmetry.
- Cleft lip/palate.
- Craniofacial syndromes.
- Previous orthognathic surgery.
- Mixed dentition.

26. AI-Based Skeletal Classification

AI is progressing beyond landmark detection toward direct classification of skeletal patterns.

Machine-learning models have been developed to classify:

- Skeletal Class I
- Skeletal Class II
- Skeletal Class III
- Vertical growth patterns

A 2023 study developed a machine-learning workflow based on cephalometric geometry using 408 lateral cephalograms for sagittal and vertical skeletal-pattern classification.

More recent systematic-review evidence specifically examining AI for sagittal skeletal classification highlights methodological limitations and the need for better clinical translation and external validation.

27. AI-Based Prediction From Facial Photographs

An emerging direction is prediction of cephalometric parameters from facial photographs.

Studies have investigated whether deep-learning models can estimate cephalometric variables and skeletal patterns from lateral facial photographs.

Potential applications include:

- Preliminary screening.
- Remote orthodontic assessment.
- Teleorthodontics.
- Patient triage.
- Identification of patients requiring radiographic evaluation.

However, photographs cannot currently replace radiographic evaluation when precise skeletal diagnosis is required.

28. Critical Comparison of Current Approaches

Table 4. Conventional and emerging approaches

Approach	Main strength	Main limitation	Current role
ANB	Simple and established	Cranial-base/jaw-rotation effects	Core complementary parameter
Wits	Less cranial-base dependent	Occlusal-plane dependent	Complementary
Beta	Alternative sagittal assessment	Landmark dependence	Complementary
W angle	Skeletal reference	Limited universal validation	Emerging/complementary
Yen angle	Alternative sagittal indicator	Population validation needed	Emerging/complementary
Vertical angular measures	Evaluate vertical pattern	Interdependence with rotation	Essential
Conventional lateral cephalogram	Accessible, low dose	2D projection	Routine
CBCT	3D morphology	Radiation/cost/standardization	Selective
Digital tracing	Efficient	Software variability	Routine
AI landmark detection	Speed and automation	Landmark-specific errors	Adjunct

AI skeletal classification	Pattern recognition	External validation	Emerging
Multimodal AI	Potential integration	Limited evidence	Future

29. Major Research Gaps

29.1 Lack of a universal sagittal parameter

Despite decades of research, no single parameter consistently captures all dimensions of sagittal skeletal discrepancy.

This suggests that future research should investigate *parameter combinations* rather than search indefinitely for a single replacement for ANB.

29.2 Population diversity

Many studies are:

- Single-center.
- Retrospective.
- Based on relatively small samples.
- Restricted to specific ethnic populations.

AI models face the same problem.

The 2026 scoping review of AI landmark identification emphasized substantial heterogeneity in datasets, algorithms and validation methods.

29.3 Lack of external validation

A model can perform extremely well on its training or internal test population while performing poorly in a different population.

Future studies should use:

Training cohort → internal validation → external multicenter validation → prospective clinical validation

29.4 Inconsistent error reporting

Studies use different:

- Error thresholds.
- Landmark definitions.
- Statistical methods.
- Reference standards.

This limits direct comparison.

A standardized reporting framework is needed.

29.5 Landmark error versus diagnostic error

This is a critical distinction.

A model may locate landmarks with a small error but still produce a clinically different diagnosis.

Future studies should therefore evaluate:

Landmark accuracy → parameter accuracy → skeletal classification → clinical decision agreement

rather than stopping at landmark error.

30. Future Perspectives

30.1 Multidimensional cephalometric indices

Future studies could develop composite indices incorporating:

ANB + Wits + Beta + W angle/Yen + vertical measurements + mandibular rotation

Such models could potentially provide a more robust representation of skeletal discrepancy.

30.2 Personalized reference ranges

Instead of fixed cut-offs, future algorithms could account for:

- Age.
- Sex.
- Population.
- Growth stage.
- Vertical skeletal pattern.
- Cranial-base morphology.
- Facial divergence.

This would allow *patient-specific cephalometric interpretation*.

30.3 3D individualized cephalometry

Future 3D models may move beyond conventional 3D versions of 2D landmarks toward:

- Volumetric skeletal analysis.
- Surface-based morphometrics.
- Asymmetry quantification.
- Three-dimensional jaw relationships.
- Patient-specific reference planes.

30.4 AI-assisted human interpretation

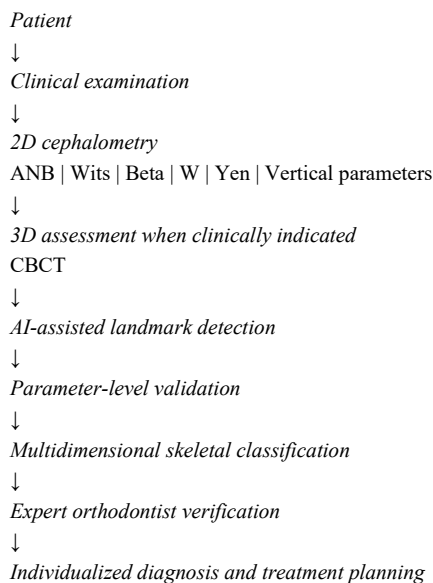
The most clinically realistic model is likely:

Radiograph/CBCT
 ↓
Automated landmark detection
 ↓
Automated measurements
 ↓
AI pattern recognition
 ↓
Orthodontist verification
 ↓
Integrated clinical diagnosis

This human-AI collaborative approach is more consistent with the current evidence than complete automation.

31. Proposed Future Research Model

Figure concept



32. Recommended Standardization for Future Studies

Future cephalometric studies should report:

1. Sample size calculation.
2. Age and sex distribution.
3. Population/ethnicity.
4. Skeletal classification method.
5. Imaging modality.
6. Imaging equipment.
7. Patient head positioning.
8. Landmark definitions.
9. Examiner training.
10. Intraobserver reliability.
11. Interobserver reliability.
12. Measurement error.
13. ICC.
14. Bland–Altman analysis where appropriate.
15. Diagnostic accuracy.
16. External validation.
17. Clinical relevance of measurement differences.
18. AI model architecture where applicable.
19. Training/test dataset separation.
20. Independent external dataset.

33. Critical Discussion

The historical development of cephalometry reflects a continual attempt to convert complex three-dimensional craniofacial morphology into reproducible numerical measurements. ANB remains valuable because of its simplicity and extensive clinical familiarity, but its limitations demonstrate a fundamental problem: *the numerical value of a cephalometric measurement depends on the reference system from which it is derived.*

Wits appraisal illustrates a similar issue from a different perspective. By reducing dependence on the cranial base, it provides useful complementary information, but its dependence on the occlusal plane introduces another source of variability.

Alternative sagittal parameters such as Beta, W and Yen angles attempt to address some of these limitations. Contemporary comparative studies suggest that these measurements can contribute useful additional information, but evidence does not justify treating any one alternative as universally definitive.

The more important clinical implication is therefore the transition from *single-parameter diagnosis to pattern-based diagnosis.*

The same principle applies to vertical discrepancies. Mandibular plane angles, facial-height ratios and growth-direction measurements provide different aspects of vertical morphology. Their combined interpretation is generally more informative than one isolated measurement.

CBCT introduces an additional dimension. Three-dimensional imaging can reduce certain projection-related limitations, but it also introduces radiation considerations and the problem of establishing standardized 3D reference systems. A 3D measurement is not automatically more clinically meaningful simply because it is geometrically more sophisticated.

AI represents perhaps the most important contemporary technological development. Recent systematic reviews show substantial improvement in automated landmark detection. However, evidence remains heterogeneous and performance is landmark- and dataset-dependent.

The evidence therefore supports a *supportive rather than autonomous role* for AI. Recent parameter-level evidence indicates that AI-generated measurements can be comparable with manual measurements for many parameters, but certainty is still limited by heterogeneity and lack of multicenter validation.

The next stage of cephalometric research should consequently move beyond the question:

“Can AI identify point A?”

and address:

“Can an AI-assisted, multidimensional system reliably characterize the patient's actual skeletal morphology and provide clinically reproducible information across diverse populations?”

That is a substantially more clinically meaningful research question.

34. Research Opportunities

Based on the reviewed evidence, the following research topics are particularly relevant:

Study 1

Comparative diagnostic accuracy of ANB, Wits, Beta, W and Yen angles in different skeletal populations

Study 2

Development of a multidimensional cephalometric index for sagittal skeletal discrepancy

Study 3

AI-assisted prediction of skeletal Class I, II and III using multiple cephalometric parameters

Study 4

Comparison of manual, digital and AI-generated cephalometric measurements

Study 5

External validation of AI cephalometric models across Indian populations

Study 6

CBCT-based three-dimensional skeletal discrepancy assessment versus conventional lateral cephalometry

Study 7

Population-specific cephalometric norms for Indian orthodontic patients

For an Indian research setting, the last two directions could be particularly valuable because external validity and population-specific reference standards remain important research needs.

35. Conclusion

Cephalometric analysis remains an essential component of orthodontic skeletal assessment, but contemporary evidence challenges the concept that a single measurement can adequately represent complex craniofacial relationships.

ANB remains clinically useful but is affected by cranial-base morphology, nasion position and jaw rotation. Wits appraisal provides complementary information but is influenced by occlusal-plane orientation. Beta, W and Yen angles provide additional approaches to sagittal assessment, while newer parameters such as the K angle remain under investigation.

Vertical skeletal assessment similarly requires interpretation of multiple angular and proportional parameters because sagittal and vertical morphology are closely interconnected.

Three-dimensional imaging has expanded the ability to characterize craniofacial morphology, although CBCT should be used according to clinical indication and not simply because it provides more anatomical information.

AI-assisted cephalometric analysis represents a rapidly developing field. Current evidence supports its ability to improve efficiency and automate many aspects of cephalometric analysis, but substantial variation remains among algorithms, landmarks, populations and commercial systems. Recent evidence supports the use of AI as an adjunct with expert verification rather than as a replacement for clinical diagnosis.

The future of skeletal discrepancy assessment is therefore likely to involve *multidimensional, individualized and human-AI collaborative assessment*, integrating conventional cephalometric parameters, three-dimensional morphology, patient-specific reference values and validated computational models.

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