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An In-Depth Analysis of the Predictive Value of Nasolabial Angle on Nasal and Dental Morphology: Utilizing Machine Learning Techniques for Enhanced Orthodontic Assessment

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Abstract

Protrusive facial abnormalities, characterized by the anterior positioning of the lips relative to the facial profile, are prevalent malocclusions that significantly impact dental and facial aesthetics. These conditions can result from complex interactions among dental, skeletal, and soft tissue components, necessitating a comprehensive diagnostic approach.This review systematically evaluates the predictive value of the nasolabial angle on nasal and dental morphology, utilizing machine learning techniques. A literature search was conducted in databases such as PubMed and Scopus, focusing on studies that assess the relationship between nasolabial angle measurements and the corresponding morphological features of the nasal and dental structures.The analysis of selected studies demonstrates that variations in the nasolabial angle are predictive of underlying nasal and dental morphologies. Machine learning models have been applied successfully to identify patterns and correlations, offering improved diagnostic accuracy and treatment planning for orthodontic interventions. However, the review also highlights the need for standardized metrics in assessing the nasolabial angle to enhance the generalizability of findings across diverse populations.The nasolabial angle serves as a crucial indicator of both nasal and dental morphology, with machine learning techniques providing valuable insights into its predictive capabilities. This underscores the importance of integrating advanced analytical methods in orthodontic assessments to optimize treatment outcomes for patients with protrusive facial abnormalities. Further research is recommended to establish uniform definitions and methodologies for measuring the nasolabial angle in clinical practice.

Keywords: *Protrusive Facial Abnormalities, Nasolabial Angle, Nasal Morphology, Dental Morphology, Machine Learning.*

Introduction

The protrusive facial malformation generally denotes a malocclusion in which the top and lower lips are advanced in relation to the facial feature [1-3]. It encompasses skeletal Class I extension, defined by projecting top as well as lower incisors, with or sans anteriorly placed jaws, and a primarily neutral molar connection [4,5]. The predominant facial abnormality is skeletal second-degree protrusion, a malocclusion marked by a disparity in the three-dimensional alignment of the upper and lower jaws, supported by dental correction, including distal or neutral molar connections [6-8]. The overall thickness of soft tissues may influence the shape of hard tissues, in addition to numerous discrepancies in the sagittal, longitudinal, as well as vertical dimensions. Compensatory interaction between the perioral muscles, dentition, and mandibles may provide markedly distinct soft tissue profiles [9].

Neglecting the holistic coordination of teeth, jaws, and soft tissues, along with the intricate mechanics of malocclusion, while devising orthodontic plans may often result in erroneous evaluations by orthodontists about treatment objectives, complexities, and results. Consequently, a comprehensive examination and assessment of the etiological processes of protrusive facial deformity are essential for formulating

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appropriate treatment strategies [10,11]. The development of orthodontic treatment programs often includes the examination of many dimensions and comprehensive factors [12].

Multiple dimensions encompass the conventional three-dimensional framework, comprising sagittal, vertical, and transverse dimensions, alongside growth and developmental maturity [13,14]. Multi-elements include dental alignment, jaw relationships, facial contours, periodontal health, upper airway patency, temporomandibular joints, and perioral muscle equilibrium [15,16]. The treatment plan, derived from multidimensional analysis, diverges from traditional orthodontic methodologies that predominantly emphasize diagnosis and treatment paradigms confined to teeth, jaws, and facial profiles. This consensus emphasizes the application of diverse orthodontic techniques, including mandibular advancement, anterior tooth retraction, and maxillofacial vertical control [17]. These techniques are designed to diminish anterior tooth and lip protrusion, enhance chin prominence, synchronize nasolabial and chin-lip relationships, and refine the facial profile of patients with protrusive facial deformities. In instances with pronounced skeletal protrusive face abnormalities, a synergistic approach including orthodontic and orthognathic interventions may be advised [18-20].

The Causal Processes and Clinical Presentations of Protrusive Facial Abnormalities

Protrusive facial abnormalities are defined by the anterior positioning of the lips in relation to the face profile, evaluated by the alignment of three essential anatomical landmarks: the glabella, subnasale, and pogonion [21]. Diagnosed by the examination of soft tissue morphology, these deformities include a range of intricate maxillofacial anomalies characterized by impaired soft-tissue shapes, intimately associated with the upper airway, temporomandibular joint, and perioral muscle equilibrium [22]. The "functional matrix theory" of growth asserts that face development is a reaction to functional requirements and neurotrophic factors [23, 24]. Proper lip competence and nasal respiration are crucial for the coordinated development of maxillofacial components, since appropriate airflow during these functions promotes the growth of associated anatomical regions, consequently improving craniofacial features [25]. Protrusive facial deformities often coincide with diminished muscle tone, influencing the morphology of the underlying osseous structures and necessitating compensatory adaptations in the lips, teeth, and jaws, eventually leading to an asymmetrical soft tissue shape. These deformities may also result from obstructive airway disorders that aggravate structural anomalies, characterized by constricted dental arches, raised palates, facial and nasal hypoplasia, and pronounced divergent skeletal Class II deformities referred to as "adenoid facies." [26-28].

The morphological processes and clinical symptoms of protrusive facial abnormalities are varied and complex. The uncomplicated type often exhibits proclination of both lower and upper incisors, with a Class I molar relationship, perhaps coupled with maxillary as well as mandibular protrusion. Severe protrusive facial deformities may be associated with sagittal discrepancies between the jaws, excessive vertical growth, and abnormal molar relationships, potentially leading to dentofacial dysfunction. The intricate etiology and pathogenesis of these deformities are varied, resulting in a broad spectrum of craniofacial morphologies that require classification based on specific skeletal sagittal and vertical determinants (Figure 1) [29].

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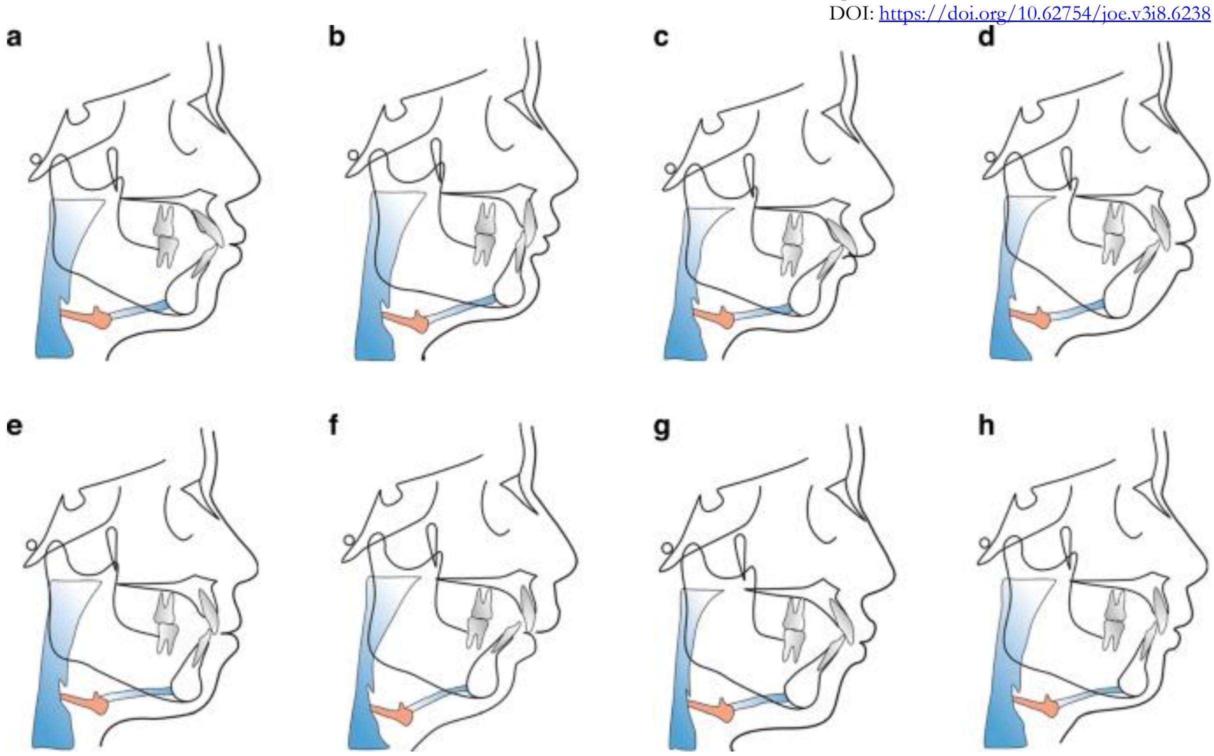

Figure 1. Schematic Representation of Several Protrusive Facial Abnormalities

Epidemiological data indicate an elevated incidence of protrusive facial defects, generally defined by a normal maxilla and an underdeveloped mandible. Due to the multifactorial etiology and intricate clinical presentation of these deformities, a comprehensive evaluation is crucial for precise evaluation and treatment planning, which should be complemented by multifaceted and total-element analysis methods to attain the aesthetic, functional, and stable objectives of orthodontic treatment [30].

Principles of Orthodontic Intervention for Protrusive Facial Abnormalities

Due to the complex causes and diverse clinical presentations, it is essential to enhance the diagnostic approach for protrusive facial abnormalities marked by protrusion to improve orthodontic results and patient satisfaction. Orthodontic methods often include comprehensive evaluations and holistic considerations.

Multidimensional analysis entails a thorough assessment of sagittal, vertical, and horizontal dimensions, as well as growth potential, in the diagnostic and decision-making processes of orthodontic cases. Complex protrusive facial deformities frequently involve abnormalities across multiple dimensions. Patients with hyperdivergent malocclusion demonstrate excessive vertical facial growth and mandibular rotation, leading to an increased mandibular plane angle [31-33]. In these individuals, the lower lip appears more prominent in relation to the chin due to the clockwise rotation of the mandible, indicating that excessive retraction of incisors is inadvisable, resulting in pronounced flattening of the lips [34]. A vertical control strategy can be employed to diminish vertical height and mitigate sagittal discrepancies. Favorable chin and hypodivergent skeletal Class II patients can achieve an improved profile through incisor retraction, which lessens lip prominence. Consequently, the extraction plan must be meticulously chosen to prevent excessive incisor retraction that could result in a concave profile [35,36].

The standard width of the upper arch is crucial for directing the sagittal development of the mandible. In pediatric and adolescent populations, a constricted upper arch restricts the anterior growth of the mandible, leading to a persistent retrusive position and the manifestation of skeletal Class II malocclusions [37,38].

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The transverse discrepancy significantly impacts facial aesthetics. For individuals with normal to broad facial dimensions, excessive intrusion of the posterior teeth and counterclockwise rotation of the mandible is inadvisable to prevent the degradation of the facial width-to-length ratio [39].

We underscore the fourth dimension—growth and development—based on the three-dimensional study in the sagittal, vertical, and horizontal dimensions. The idea of growth and development in orthodontics is often restricted by many orthodontists to children and teenagers, which lacks comprehensiveness. The growth and development we highlight pertain to the alterations of dentofacial hard and soft tissues over the life cycle and the critical influence of genetic variables on growth patterns [40].

The etiology of malocclusion is complex, including tooth alignment, jaw connection, facial structure, periodontal health, upper airway openness, temporomandibular joints, and muscular equilibrium. Neglecting the clinical symptoms and the mechanisms of malocclusion may result in inaccurate predictions about treatment objectives, difficulty levels, strategies, and the effectiveness of orthodontic interventions. Consequently, the ideal treatment strategy must be developed based on the total-element diagnosis and thorough analysis.

Dental Alignment and Occlusion

Tooth alignment encompasses various factors, including mesiodistal angulation, labiolingual angulation, rotation, crowding, labiolingual malposition, and arch form. The objective of orthodontic treatment is to harmonize these factors with optimal occlusal function, ensuring that the roots are centered within the alveolar bone to preserve periodontal health. In patients undergoing camouflage orthodontics, the root may be moderately displaced from the center within the alveolar bone and demonstrate compensatory inclination within a safe range, thereby achieving ideal tooth alignment and occlusion [41-43].

Moreover, the soft tissue peculiarities of specific patients must also be taken into account. The arrangement of teeth must be tailored to various vertical skeletal patterns and facial forms [44,45]. The dental arch should correspond to the face shape. The suitable breadth of the dental arch enhances a harmonious buccal corridor. Conversely, it may adversely affect the aesthetics of the smile [46].

Osseous Connection

The skeletal relationship encompasses sagittal and vertical skeletal patterns. In diagnosing a patient's sagittal skeletal pattern, it is essential to evaluate both the relative positions of the maxilla and mandible, as well as their absolute sagittal jaw positions in relation to the cranial base, which is vital for establishing target positions in orthodontic treatment planning [47,48]. The influence of the vertical skeletal pattern on the sagittal pattern must also be taken into account during diagnosis and treatment design [49]. A hyper divergent skeletal pattern exacerbates skeletal Class II malocclusion, whereas a hypodivergent skeletal pattern exacerbates skeletal Class III malocclusion. The positional relationship of the jaws is a critical component of the dentofacial complex, necessitating integration with soft tissue analysis to develop the most suitable treatment plans for patients with protrusive facial deformities [50].

Anterior and Lateral Profile

The objectives and constraints of contemporary orthodontic and orthognathic treatment are influenced not only by dental and skeletal structures but also by the facial soft tissues [51]. The "soft tissue paradigm" promoted by modern orthodontics involves determining the optimal position of incisors based on soft tissue aesthetics, which informs treatment design aspects such as space requirements, extraction patterns, and anchorage strategies [52,53]. In formulating treatment plans, orthodontists must prioritize the patient's frontal and lateral profiles, aiming to align the treatment plan with the patient's subjective aesthetic preferences. Additionally, it is crucial to consider potential adverse alterations in profile resulting from orthodontic intervention, particularly in individuals with prominent zygomatic bones or sunken cheeks [54].

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Additional Components

The upper airway is intrinsically linked to health and life, serving as a critical factor in the diagnosis and treatment of malocclusion. Following incisor retraction, the velopharyngeal, glossopharyngeal, and hypopharyngeal airways may experience constriction [55]. The optimal position of incisors must not only satisfy aesthetic considerations but also account for the implications of incisor retraction on the dimensions of the upper airway [56]. In patients with upper airway stenosis, the degree of incisor retraction should be meticulously regulated to preserve the natural oral space and ensure normal nasal respiratory function [57]. Bimaxillary advancement surgery should be performed, if required, to rectify protrusion and enhance airway volume [58].

Oral behaviors, including sucking, incorrect tongue positioning, and tongue thrust swallowing, may disrupt the equilibrium of internal and external forces on the jaw and arch, resulting in malocclusion [59]. Within the stomatognathic system, muscles often have a predominant influence on bones. Orthodontists must ensure that alterations in teeth, arches, and jaws are synchronized with muscle function for individuals displaying oral habits throughout therapy. Long-term stability of orthodontic treatment can only be ensured by eliminating oral habits and attaining normal perioral muscle activity [60].

Temporomandibular disorders (TMD) are chiefly defined by joint pain, joint sounds, and disturbances in mandibular movement. It is essential to acknowledge the intricate etiology and pathophysiological mechanisms of TMD and their influence on the stability of mandibular positioning and occlusion [61,62]. A significant prevalence of TMD is observed in skeletal class II patients referred for orthognathic surgery, particularly in those exhibiting a pronounced overjet and elevated mandibular plane angle. During orthodontic treatment, it is essential to develop a robust cusp-fossa connection of the teeth, since this significantly influences the long-term stability of dental alignment and occlusion [63,64].

The periodontal condition, encompassing gingival texture, periodontal pocket depth, tooth mobility, gingival recession, and alveolar bone level, must be assessed prior to and throughout orthodontic treatment [65]. CBCT may also be employed to analyze alveolar ridge height, alveolar bone thickness, alveolar ridge integrity (including bone dehiscence and fenestration), and the relationship between roots and bone [66]. For patients with periodontal disease, the orthodontic treatment plan should be modified, the extent of tooth movement should be minimized, and communication between orthodontists and periodontists should be prioritized throughout the treatment process [67].

Orthodontic Treatments for Protrusive Facial Abnormalities

Mandibular functional treatment involves orthodontists repositioning the mandible following a thorough assessment of the stomatognathic system [68]. Based on adolescents' growth potential, the trajectory and magnitude of jaw development must be effectively directed to mitigate the extent of skeletal malocclusions and enhance soft tissue contours [69]. Orthodontic functional treatment should commence during the combination of teeth and early permanent dentition phases to capitalize on growth potential [70,71]. The guidance of mandibular growth should be three-dimensional, integrating sagittal advancement alongside vertical and transverse adjustments. Notably, vertical control should be prioritized during the mandibular advancement process [73,74].

Retraction of Anterior Teeth for Protrusive Facial Abnormalities

The pathophysiology of protrusive facial abnormalities presents in two primary types: dental projection and Class II skeletal malocclusion. In all these instances, soft tissue characteristics often include upper lip projection and an impaired nasolabial connection. The sagittal positioning and torque of the front teeth, both upper and lower, affect the prominent position of the upper and lower lips. Modifying the nasolabial and mentolabial aesthetics may improve lateral appearance, hence enhancing overall face harmony [75].

In instances of dental-facial protrusive defects, tooth extraction serves as an efficacious intervention. For adolescent and adult patients with skeletal malocclusion exhibiting inadequate functional correction, and

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who forgo orthognathic surgery, their alternatives are restricted to compensatory strategies that entail modifications of teeth and alveolar bone to rectify sagittal jaw discrepancies. This generally encompasses orthodontic removal camouflage treatment, which frequently undermines both aesthetic appeal and stability [76-78].

Evaluation of Soft Tissue Morphology

Optimizing extraction space and accurately regulating the sagittal location and torque of the front teeth are vital for assuring treatment effectiveness. Sufficient room is necessary for the anterior teeth to retract properly to create a good retraction result. Changes in lip and tooth projection are disproportionate. Typically, a 1 mm retraction of incisors leads to an approximately 0.6 mm reduction in lip protrusion. Effective management of root retracting of the upper incisors is crucial for diminishing maxillary basal bone prominence [79].

The selection of the appropriate extraction method for the management of protrusive facial abnormalities is contingent upon the degree of protrusion. The extraction of front teeth mitigates anterior congestion and extension, whereas the extraction of posterior teeth alleviates posterior crowding and regulates vertical dimensions [80]. In adolescents and adults requiring extraction, a prevalent method involves the removal of four first or second premolars or the extraction of maxillary first premolars alongside mandibular second premolars. Furthermore, in instances of open bite, the extraction of second premolars may assist in rectifying occlusal discrepancies and enhancing vertical control [81].

Orthodontists must use caution when deciding to pull teeth. For instance, individuals with periodontitis and minor protrusion may be managed without tooth extraction. Interproximal enamel reduction, when warranted, can mitigate mild crowding and reduce the formation of "black triangles." Orthodontic devices such as implant anchorage, the Pendulum appliance, the Frog appliance, and the extraoral arch can facilitate extensive distal movement of the teeth, rectifying protrusion and deep overjet. Implant anchorage, judiciously positioned in the subzygomatic ridge region, permits distal movement of the upper teeth without inducing root interference [82].

Vertical Management Approaches for Protrusive Facial Malformations

Prior research and clinical observations have demonstrated that orthodontic treatment without vertical control may result in tooth elongation and an elevation in facial height. While this may be advantageous for individuals with low-angle facial deformities, it frequently exacerbates the facial profile in those with high-angle facial protrusion. Vertical control may induce a counterclockwise rotation of the mandible; nevertheless, this remains a debated topic. Our viewpoint is that vertical control techniques include both maintenance and mandibular counterclockwise rotation types, with the MP-SN angle serving as a critical index [83].

The preservation of vertical control alone often fails to enhance facial profile. Nonetheless, when integrated with teeth extraction therapy, it may markedly enhance the appearance of persons with protrusive facial abnormalities. Conversely, the alternative form of vertical control entails mandibular counterclockwise rotation, accomplished by diminishing the height of the dental arches through various techniques. Notably, this method of mandibular counterclockwise rotation signifies a potentially autonomous and efficacious strategy for rectifying protrusion deformities [84].

Adolescents with facial protrusion often present with a retrusive mandible. When utilizing orthodontic devices, including Twin-Block, Activator, Frankle II, and inclined guide plates in adolescents with high-angle protrusion, the potential risk of augmenting vertical height must be meticulously evaluated. In such instances, adjunctive methods such as J-hook appliances, auxiliary archwires, and implant anchorage may be employed to regulate vertical facial height and align the occlusal plane. This method seeks to elicit a counterclockwise rotational influence on mandibular growth and facilitate the formation of a Class I skeletal facial kind [85].

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In adults, the presence of occlusal contact during closure, irrespective of an open anterior bite or deep overbite, obstructs the counterclockwise rotation of the jaw. The axis of resistance for the mandible's counterclockwise rotation is situated in the condylar area. The vertical height of both sides of the tooth-alveolar bone complex is reduced, causing the mandible to rotate forward and upward, propelled by the contraction of the jaw-closing muscles. The vertical control approach using mandibular counterclockwise rotation principally aims to intrude teeth, diminish vertical dimension, and generate room for mandibular rotation, hence enhancing overall face aesthetics and occlusal function [86].

Preoperative orthodontics is essential in preparing individuals for orthognathic surgery by fulfilling numerous crucial goals. The key objectives include the eradication of compensatory tooth tilting, the synchronization of the morphology and dimensions of the maxillary as well as mandibular dental arches, the facilitation of jaw displacement, occlusal alignment, and the formation of a stable occlusion after surgery [87]. Postoperative orthodontics improves treatment outcomes by fine-tuning tooth alignment and optimizing occlusal relationships, thereby significantly enhancing the durability of combined orthodontic as well as orthognathic treatments. Close collaboration between orthodontic as well as orthognathic surgery specialists is essential for achieving optimal results, with orthodontic treatment serving as a crucial element of the overall therapeutic strategy [88].

Conclusions

The protrusive abnormality is a primary factor influencing face aesthetics. Given the intricate etiology and varied symptoms of protrusive abnormalities, orthodontic diagnostic and treatment approaches need the examination of numerous dimensions and comprehensive considerations. Multidimensionality denotes the incorporation of a time dimension into the conventional three-dimensional framework, including sagittal, vertical, horizontal, and developmental dimensions. Comprehensive components include seven elements: dental alignment, jaw connection, face structure, periodontal health, upper airway openness, temporomandibular joints, and muscular equilibrium. This agreement offers a comprehensive analysis of the indications, intrusion methods, and risk management related to vertical control approaches for protrusive facial abnormalities.

Although much clinical research on the management of protrusive facial abnormalities is available, there is a potential demand for large-sample, multi-center-controlled studies. A notable deficiency exists in prospective research about vertical control strategies, and evidence-based reasoning must be included in the assessment of treatment effectiveness and postoperative stability evaluations for protrusive abnormalities. The ongoing advancement of non-bracket transparent orthodontic technology, together with its integration with other orthodontic methods, is progressively broadening the selection of orthodontic appliances for protrusion abnormalities, therefore helping an increasing number of patients. In recent years, computational intelligence has increasingly gained prominence in the medical domain, and its robust data collection and processing skills have led to substantial advancements in the identification, management, and prognostic evaluation of protrusive malformations.

The evaluation and therapeutic management of protrusive facial abnormalities constitute a comprehensive undertaking. As our comprehension of the the development of protrusive facial malformations advances, clinical research progresses, and improved research methodologies are implemented in clinical practice, it will inevitably yield more optimized outcomes for the management and long-term stability for individuals with protrusive facial defects.

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تحليل متعمق للقيمة التنبؤية للزاوية الأنفية الشفوية على شكل الأنف والأسنان: استخدام تقنيات التعلم الآلي لتحسين التقييم التقويمي

الملخص

الخلفية :تُعد التشوهات الوجهية البارزة، والتي تتميز بوضعية أمامية للشفتين بالنسبة للملف الوجهي، من حالات سوء الإطباق الشائعة التي تؤثر بشكل كبير على جمالية الأسنان والوجه. تنشأ هذه الحالات نتيجة تفاعلات معقدة بين المكونات السنية والهيكلية والأنسجة الرخوة، مما يستدعي نهجًا تشخيصيًا شاملاً.

الطرق :يقوم هذا الاستعراض بتقييم القيمة التنبؤية للزاوية الأنفية الشفوية على شكل الأنف والأسنان، باستخدام تقنيات التعلم الآلي. تم إجراء بحث في قواعد بيانات مثل PubMed وScopus، مع التركيز على الدراسات التي تحلل العلاقة بين قياسات الزاوية الأنفية الشفوية والخصائص الشكلية للأنف والأسنان.

النتائج :أظهرت تحليلات الدراسات المختارة أن التغيرات في الزاوية الأنفية الشفوية يمكن أن تتنبأ بالخصائص الشكلية الأساسية للأنف والأسنان. تم تطبيق نماذج التعلم الآلي بنجاح لتحديد الأنماط والارتباطات، مما ساهم في تحسين دقة التشخيص والتخطيط العلاجي لتدخلات تقويم الأسنان. ومع ذلك، يسلط هذا الاستعراض الضوء أيضًا على الحاجة إلى مقاييس موحدة عند تقييم الزاوية الأنفية الشفوية لتعزيز إمكانية تعميم النتائج على مختلف الفئات السكانية.

الاستنتاج :تُعد الزاوية الأنفية الشفوية مؤشرًا أساسيًا لكل من شكل الأنف والأسنان، حيث توفر تقنيات التعلم الآلي رؤى قيمة حول قدراتها التنبؤية. ويؤكد ذلك على أهمية دمج الأساليب التحليلية المتقدمة في التقييمات التقويمية لتحسين نتائج العلاج للمرضى الذين يعانون من التشوهات الوجهية البارزة. ويوصى بإجراء المزيد من الأبحاث لوضع تعريفات ومنهجيات موحدة لقياس الزاوية الأنفية الشفوية في الممارسات السريرية.

الكلمات المفتاحية :التشوهات الوجهية البارزة، الزاوية الأنفية الشفوية، شكل الأنف، شكل الأسنان، التعلم الآلي.