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The Impact of Nasolabial Angle on Nose and Teeth Morphology: An Evaluation Using Artificial Intelligence in Orthodontics and Cleft Lip/Palate Treatment

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Abstract

Background: The nasolabial angle (NLA) plays a crucial role in facial aesthetics and is particularly significant in individuals with cleft lip and/or palate (CLP). The integration of artificial intelligence (AI) has opened new avenues for analyzing facial morphology and its relationship with dental structures.

Methods: This literature review examined recent advancements in AI technologies, focusing on their efficacy in assessing the NLA and its implications for nose and teeth morphology. A comprehensive analysis of various AI methodologies, including deep learning and automated landmark detection, was conducted to synthesize existing research findings.

Results: The review highlighted that AI algorithms demonstrated high accuracy in identifying cephalometric landmarks, with studies reporting an accuracy of over 95%. The analysis showed a notable correlation between the NLA and facial aesthetics, particularly in CLP patients. Furthermore, variations in NLA measurements across different populations were documented, indicating the influence of genetic and environmental factors on facial morphology.

Conclusion: AI technologies are revolutionizing by providing precise and automated assessments of facial features. The findings underscore the significance of the nasolabial angle in determining optimal treatment plans for patients, particularly those with CLP. Future research should focus on standardizing NLA measurements and further exploring the interplay between facial aesthetics and dental structures, with an emphasis on leveraging AI for personalized treatment strategies.

Keywords: Nasolabial angle, artificial intelligence, cleft lip and palate, facial aesthetics.

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1. Introduction

Artificial intelligence (A.I.) is a rapidly advancing technology that dominates several aspects of our existence. Recently, algorithms developed by A.I. have been incorporated into everyday technology and are being used widely. Applications connected to it include internet search engines, online assistants, spam email screening, voice recognition, and picture identification on social media. Recent scoping studies have emphasized the increasing interest of the scientific community in the use of A.I. within orthodontics and cleft lip and/or palate treatment [1,2]. Artificial intelligence has been used to identify landmarks on lateral cephalograms, assist in diagnosis, and formulate patient treatment plans. In individuals with a cleft lip and/or palate, it has been used for prenatal diagnosis, investigating its genesis, identifying landmarks, and forecasting the need for future surgical intervention [3,4]. These systems have used deep learning methodologies, including neural networks, decision trees, random forests, and k-nearest neighbor algorithms, to create A.I. models that assist orthodontists [5,6].

Numerous recent research studies have emphasized the exceptional precision of algorithms in landmark detection [7,8]. Kunz et al. [7] demonstrated the use of artificial intelligence in orthodontics, whereby AI-developed software effectively analyzed unfamiliar lateral cephalograms (Late. Ceph.) with a quality almost equivalent to that of the gold standard, which involves manual interpretation by a professional. Lee et al. [8] used similar AI-driven deep convolutional neural networks to assess Late. Ceph. for the differential diagnosis of Surgical Orthodontic patients, achieving an accuracy of 95.6%. The analysis said it was the inaugural study to successfully facilitate such applications. Recent advancements in computing, such as AI-driven tasks, may be used for many functions. In the healthcare sector, artificial intelligence has shown significant efficacy in supporting physicians, radiologists, and experts in analyzing medical X-rays and imaging, facilitating the identification of certain illnesses, and different cancers, and the early detection of Alzheimer's disease [9]. Consequently, AI-driven systems may facilitate therapeutic decision-making. In Orthodontics, accurate landmark identification is essential for successful lateral cephalometric analysis for appropriate diagnosis and therapy. The incorrect recognition of features in Late Cephalometric analysis may result in inaccurate diagnosis for orthodontic treatment [10]. A new artificial intelligence system for landmark recognition exhibited accuracy akin to that of professionals [11]. Therefore, a completely automated and consistent identification method powered by artificial intelligence for the Late Ceph landmarks is necessary [8,12].

Cleft lip and/or palate (CLP) is a common congenital anomaly of the head and neck, characterized by a diverse range of etiological factors [13]. CLP may occur as a component of extensive chromosomal anomalies, in isolation, or conjunction with teratogenic disorders. The origin of non-syndromic cleft lip and/or palate is ascribed to environmental and genetic variables, as well as their interactions [14,15]. Patients with CLP have various dental and craniofacial issues. Altered facial aesthetic harmony and maxillary development retardation are often seen in patients with cleft lip and palate [16]. Recent research indicated that orthodontists and surgeons uninvolved in cleft treatment deemed the facial features of patients with surgical bilateral cleft and/or palate to be aesthetically displeasing [17]. The face is the most diverse region of the body. The adaptability of the face is shown via the changed dimensions and forms of individual features, as well as the relationships among these characteristics. Facial soft tissue features exhibit variation according to differing skeletal relationships of the jaws. Prior research has shown that the impression of face aesthetics is affected by many biopsychosocial variables [18]. Modified upper lip morphology, particularly in the nasolabial area, seems to illustrate the facial harmony of individuals with cleft lip and palate (CLP) [19]. Patients with cleft lip and palate often get lip surgery between 0 to 6 months and palate surgery between 12 to 18 months of age, respectively [20]. The abnormality and frequent surgeries may affect growth retardation in the maxillary area, resulting in LM and NLA disorientation.

This literature review aimed to study the effect of nasolabial angle on nose shape and teeth shape using artificial intelligence.

2. AI-driven image recognition technologies in the medical and dental imaging sectors

Recent advancements in orthodontic instruments have led to the introduction of AI-driven image recognition technologies in the medical and dental imaging sectors [7,8,21]. In Orthodontics, despite the multitude of techniques, the application of digital image recognition and processing technology, particularly for lateral cephalometric analysis, is employed in this study. The use of A.I.-driven automated lateral cephalometric analysis represents an innovative approach and is posited as the future of digital Orthodontics. This approach successfully identified Late. Ceph. anatomical landmarks within a clinically acceptable range, equivalent to the human-measured gold standard methodology [7,8,12]. Automated identification of landmarks and Late Cephalometric analysis powered by A.I. demonstrated satisfactory success rates in comparison to the most used digital approaches [12].

CLP modifies the face soft tissues primarily in the oro-nasal region, leading to the deviation and change of the nose and upper lip. Consequently, we identified abnormalities in LM-1 and NLA resulting in aesthetically undesirable face soft tissue morphology [22]. Numerous dental abnormalities, occlusal alterations, and maxillary development retardation are prevalent characteristics of cleft lip and palate (CLP). Nonetheless, these modifications fluctuate on a case-by-case basis across the various forms of NSCLP [15,23]. Celikoglu et al. [23] discovered that the BCLP group had more vertical development, increased retrusion of the maxilla as well as the maxillary as well as mandibular incisors, and reduced thicknesses of the subnasale and labrale superior in comparison to the well-matched controls (NC). These discrepancies must be considered while devising treatment plans for Orthodontic and Orthognathic Surgery for these individuals.

The assessment of the lips about the Ricketts E-line [21] emphasizes the connection between the nose, lips, and chin. Kocadereli [24] examined alterations in soft tissue profiles after orthodontic treatment, with and without extractions, in 80 Turkish patients with Angle Class I malocclusion. The study indicated that the mean values for LM-1 and LM-2 were somewhat more protrusive than the Ricketts aesthetic ideal. Satravaha and Schlegel [25] demonstrated that 30% of the Thai population and 45% of the Thai population of Chinese descent had protrusive lips. Alcalde et al. [26] demonstrated that the LM-1 and LM-2 of the Japanese were consistently located anteriorly in all investigations.

Rhee et al. [27] reported NLA measurements of 103.43 degrees in Korean females, 99.87 degrees in Japanese females, 113.51 degrees in Chinese females, and 106.52 degrees in Western females. Almoammar et al. [28] examined 96 people with NSUCCLP, divided into two groups of 33 and 63 participants, categorized by the presence or absence of missing teeth, with NLA measurements of 107.78 ± 12.76 and 107.3 ± 11.46, respectively. Oh et al. [29] discovered that the NLA for American and Chinese patients were 127.3 ± 8.2 and 97.1 ± 9.6, respectively. The discrepancies in NLA are attributed to the more pronounced noses of American patients compared to those of Chinese patients. Russell et al. [30] elucidate that the inequalities arise from the base of the nose in CLP patients encroaching into the top lip, resulting in a down-turned appearance. Consequently, the NLA of CLP patients is inferior to that of the general population.

3. Conventional cephalometric evaluation techniques and Artificial Intelligence

Despite the longstanding dominance of conventional cephalometric evaluation techniques, the emergence of contemporary instruments has enabled the automated refinement of these records using computing or artificial intelligence [24]. Nonetheless, the quantity of literature on the topic is minimal, necessitating the assertion that other such research should be conducted extensively. AI-enhanced software has been documented in many publications about general dentistry, emphasizing its impact on dental sensations, occlusion, prosthodontics, and overall conservative dentistry [31-35]. Every orthodontic treatment aims to attain a harmonious and functional occlusion to enhance the patient's bite, mastication, and general quality of life. AI and 3D-CBCT seem to enhance orthodontics, resulting in improved and more precise patient results from orthodontic interventions. A thorough assessment of the face skeleton, with soft tissue proportions, skeletal characteristics, dentition, and occlusion, is crucial in modern orthodontic therapy and orthognathic surgery procedures. Significant progress in orthodontic and orthognathic research has been documented, as shown by Prasad et al. [36] and Starch-Jensen et al. [37]. The primary conclusions indicate that emerging technologies in cephalometric evaluation represent the future; yet substantial efforts are required to maximize their efficacy.

Historically, calculating angles and distances on X-ray film and transferring reference points onto tracing paper was a laborious operation [38]. The time needed to manually plot points and construct lines on tracing paper, measure using a ruler and protractor, and then document cephalometric measures was around 30 minutes. The digitalization of X-rays and the capability to identify reference points using a computer mouse on the display constituted a substantial advancement. The ability to enlarge certain structures on the display while designating consecutive reference points, together with the continuous improvement of digital cephalograms, has significantly increased measurement accuracy. Simultaneously, the duration needed for analysis using computer software, which autonomously quantifies the specific parameters of cephalometric evaluations and organizes the data into tables and graphs after the physician's input of points, has reduced to around one to two minutes. It is essential to acknowledge the advantages of emerging technology and software that may improve the practices of dentists, especially orthodontists. In the last ten years, developments in virtual reality methods, computer-assisted technology, and cone-beam computed tomography (CBCT) have markedly advanced dental treatment outcomes. Currently, 3D cephalometric measurements, 3D virtual treatment planning for skeletal, facial, jaw/bone, and dental assessments, as well as comprehensive 3D analyses of superficial, skeletal, and dermal anatomy, significantly improve success rates and diminish the likelihood of problematic complications or constraints in treatment protocols [39-43]. Notwithstanding the developments in novel methodologies, it is crucial to account for the possibility of human and computational errors. Consequently, after each assessment, it is essential to verify the findings and ascertain that the recommended therapy or diagnostic protocol is appropriate and suitable for each patient's situation.

Certain computer systems use artificial intelligence to do duties once designated for medical experts, such as detecting and annotating reference points [44]. Nonetheless, the developers of these tools continuously urge medical practitioners to confirm that the software has accurately recognized the pertinent aspects. This occurs because some overlapping bone and skin features in an X-ray picture may be misconstrued by the computer algorithm. Moreover, the challenge that computer systems have in interpreting visual content is a prevalent characteristic used to identify dangerous bots using CAPTCHA methods.

An exemplary instance of this challenge in orthodontic practice is the identification of Downs' A-point [45]. In such cases, the osseous structure may be mistakenly recognized as the silhouette of the buccal fat pad. An inaccurate assessment of this location will lead to a substantial inaccuracy in diagnosing the sagittal position of the maxilla relative to the mandible, as shown by erroneous ANB and WITS measurements. The decrease in time for applying reference points using the automated approach is a negligible benefit, since it saves at most two minutes of analysis time. Nonetheless, this does not ensure the accuracy of the diagnosis, particularly in challenging circumstances. It is essential to underscore that orthodontic diagnosis is not exclusively reliant on the pace of the procedure.

Consequently, other parameters, including patient placement, sustaining an optimal neutral head position, and establishing suitable resting postures of the jaw, teeth, facial features, skull, and body posture throughout examination, need further consideration [1,61]. The paramount consideration in assessing face pictures, CBCT scans, and 3D evaluations is attaining a natural, physiologically balanced head posture and patient profile. A multitude of writers seems to concur with this viewpoint [46]. Therefore, the use of craniometric analyses in anatomical and radiological mappings may be more reliable. Once the patient's head posture is firmly stabilized, more cephalometric analysis may proceed [47]. Historically, the posture of patients during examinations was crucial for achieving the most correct placement of craniometric and anthropometric points in the analyzed data. This situation remains very relevant in the current setting. Although automated tracing software may pinpoint specific anatomical landmarks, the precision of proportions, angles, and inter-point correlations may be undermined by head posture in the normal head position (NHP). The NHP and patient position during the examination are critical aspects, regardless of whether manual, automated, or AI-assisted tracing techniques are used. The experience and skill of clinicians, together with the competency and knowledge of junior clinicians, may significantly impact the accuracy of cephalometric tracings [48]. Manual tracings depend on the clinician's expertise and understanding to apply craniometric reference points, while automatic or AI-driven software assesses pictures using algorithms or other automated mechanisms. Nonetheless, it seems that the issue of proper patient posture remains outside the scope of optimization using computer algorithms.

Irrespective of the used methodology, the paramount consideration is to conduct the most precise, thorough, and adequate analysis for each patient's situation. The accurate positioning of anatomical cephalometric landmarks is crucial for improving the linear, angular, and planar comparison of chosen landmarks, essential for the design of orthodontic and orthognathic surgical treatments [49]. Various authors, including Chen et al. [50] and Kuyl et al. [51], have examined the proficiency in positioning anatomical and cephalometric points, concluding that an experienced specialist with extensive clinical practice exhibits superior skill in accurately placing essential reference points for precise cephalometric analysis [52]. Moreover, it is essential to recognize that doctors, dentists, surgeons, and orthodontists who conduct such assessments regularly have greater expertise than those who do it sometimes or seldom.

Advancements in 3D software and computer-assisted review of radiographs, CBCT tests, and face pictures have led to the widespread use of novel procedures in orthodontics and orthognathic surgery for their fast and accurate analysis. Comparable research undertaken by Baker et al. [53], Mario et al. [54], Turner et al. [55], Mosley et al. [56], and Tsorovas et al. [57], among others, generally supports similar conclusions. Contemporary software seeks to provide exact measurements while also reducing possible human mistakes or inaccuracies in craniometric assessment [58]. From the author's viewpoint, this issue is apparent; nonetheless, when patients' head posture in NHP during radiographs, face pictures, and CBCT assessments is misaligned, the findings may remain inaccurate despite the availability of many modern instruments and software. This circumstance is crucial in planning surgical interventions, particularly in orthognathic surgery, where it is essential to determine the whole spectrum of soft and hard tissue contours and balance without any interruptions. When this criterion is unmet, multiple measurement problems are evident, regardless of the computational-enhanced/AI or traditional manual assessment techniques used in different investigations. This element is regarded as one of the most important components of any cephalometric assessment and has been well documented [52,59]. From the author's viewpoint, some instances of severe skeletal malocclusion exceed the efficacy of conventional planning approaches, independent of the anthropometric reference points and procedures used, hence requiring an integrated manual approach and 3D/AI-driven software.

The discourse on the contrast between traditional manual cephalometric assessment and AI-assisted software analysis is becoming prominent in the current literature. Both procedures have distinct benefits and limitations, and it is especially significant that some intricate and demanding instances still need conventional manual assessment, cephalometric measurements, and estimate. The rapid advancement of AI and computed CBCT assessment offers significant potential for the future of next-generation orthodontic and orthognathic surgical therapies. Nonetheless, much work has to be done, chiefly due to the need for further enhancements [6]. The paramount clinical observation is that modern orthognathic surgery predominantly depends on 3D-CBCT patient assessment, supplemented by facial, bite, and occlusal photographs, which are synthesized to evaluate, quantify, and forecast the optimal treatment strategy for each patient case. Achieving this degree of accuracy would be unfeasible without the assistance of advanced technologies, like CBCT and AI-driven software tracings. Nonetheless, it is crucial to acknowledge that some extremely intricate instances of severe skeletal malocclusion may still need manual assessments, especially those linked to considerable skeletal jawbone discrepancies and analogous circumstances [60,61]. The main findings articulated by the writers While there is partial alignment with findings from other pertinent studies, it is essential to recognize the heterogeneity in results across various research, which is due to the distinct capabilities and resources of each instrument and software used for cephalometric tracings.

The research experienced the following limitations: an insufficient number of papers comparing natural head position (NHP) and the usage of AI-driven software, leading to gaps in understanding; significant variability in the software and computer-enhanced programs utilized, along with their 3D/measurement capabilities, complicating comparisons and standardization; a limited number of studies on patients discussing and describing the preparation, positioning, and evaluation process before and during the study, which hinders reproducibility and generalizability; diverse cephalometric measurements utilized across various orthodontic protocols, making it challenging to establish consensus and comparability; limitations in the size, resolution, and accuracy of CBCT scans, traditional radiographs, scanners, and software utilized, affecting the quality and reliability of the data; and a plethora of radiographic software, programs, and companies involved in the dental market, contributing to heterogeneity and potential inconsistencies in methodologies and results. The considerable variability among the included papers precludes the execution of a meta-analysis. Nonetheless, further study must be undertaken to facilitate the advancement of meta-analysis.

4. Conclusion

In recent years, the significance of the nasolabial angle (NLA) in determining facial aesthetics has garnered increased attention, particularly in orthodontics. This literature review has illuminated the intricate relationship between the NLA, nose shape, and teeth morphology, especially in patients with cleft lip and palate (CLP). The findings indicate that the NLA serves not only as a vital aesthetic marker but also as a critical factor in the planning and execution of orthodontic treatments.

The integration of artificial intelligence (AI) in the assessment of the NLA presents a transformative opportunity within the field. AI-driven image recognition technologies have demonstrated remarkable accuracy in identifying cephalometric landmarks, thereby facilitating more precise evaluations of facial structures. The ability of these algorithms to analyze large datasets allows for a more nuanced understanding of how variations in the NLA affect overall facial aesthetics and dental alignment. Moreover, the discrepancies observed in NLA measurements across different ethnic groups suggest that treatment protocols should be tailored to account for these variations. This personalization is essential in achieving optimal aesthetic outcomes and functional improvements for patients.

Moving forward, it is imperative for researchers and practitioners to collaborate in standardizing NLA measurement techniques, ensuring that AI tools are utilized effectively in clinical settings. Continued exploration of the relationship between the NLA, nose shape, and teeth morphology will not only enhance our understanding of facial aesthetics but also improve treatment strategies for individuals with CLP. With ongoing advancements in AI technology, the future of orthodontics is poised for significant improvement, offering the potential for more effective and individualized patient care.

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تأثير الزاوية الأنفية الشفوية على شكل الأنف والأسنان: تقييم باستخدام الذكاء الاصطناعي في تقويم الأسنان وعلاج الشفة الأرنبية والحنك المشقوق

الملخص

الخلفية :تلعب زاوية الأنف الشفوية (NLA) دورًا حيويًا في جماليات الوجه، وتكتسب أهمية خاصة لدى الأفراد المصابين بشق الشفة و/أو الحنك (CLP).أدى دمج الذكاء الاصطناعي (AI) إلى فتح آفاق جديدة لتحليل مورفولوجيا الوجه وعلاقتها بالبُنى السنية.

الطرق :استعرضت هذه المراجعة الأدبية التقدمات الحديثة في تقنيات الذكاء الاصطناعي، مع التركيز على كفاءتها في تقييم زاوية الأنف الشفوية وآثارها على مورفولوجيا الأنف والأسنان. تم إجراء تحليل شامل لأساليب الذكاء الاصطناعي المختلفة، بما في ذلك التعلم العميق واكتشاف النقاط المرجعية التلقائي، لتجميع نتائج الأبحاث الحالية.

النتائج :أبرزت المراجعة أن خوارزميات الذكاء الاصطناعي أظهرت دقة عالية في تحديد النقاط المرجعية السيفالومترية، حيث أبلغت الدراسات عن دقة تتجاوز 95%. وأظهرت التحليلات ارتباطًا ملحوظًا بين زاوية الأنف الشفوية وجماليات الوجه، خاصةً لدى مرضى شق الشفة والحنك. علاوة على ذلك، تم توثيق تباين في قياسات زاوية الأنف الشفوية بين مختلف السكان، مما يشير إلى تأثير العوامل الوراثية والبيئية على مورفولوجيا الوجه.

الخلاصة :تُحدث تقنيات الذكاء الاصطناعي تحولًا كبيرًا من خلال توفير تقييمات دقيقة وآلية لملامح الوجه. تُبرز النتائج أهمية زاوية الأنف الشفوية في تحديد خطط العلاج المثلى للمرضى، لا سيما المصابين بشق الشفة والحنك. ينبغي على الأبحاث المستقبلية التركيز على توحيد قياسات زاوية الأنف الشفوية واستكشاف العلاقة بين جماليات الوجه والبُنى السنية بشكل أكبر، مع التركيز على استخدام الذكاء الاصطناعي لوضع استراتيجيات علاجية مخصصة.

الكلمات المفتاحية :زاوية الأنف الشفوية، الذكاء الاصطناعي، شق الشفة والحنك، جماليات الوجه.