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3D Artificial intelligence: Analysis of Facial Harmony Correlating Nasal shape with nasolabial angle and Dental Midline Deviation

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Abstract

Background: Facial harmony is influenced by the interplay of soft and hard tissue components, with soft tissue morphology playing a critical role in aesthetics. The correlation between nasal shape, nasolabial angle, and dental midline deviation remains a significant area of exploration in orthodontics and craniofacial studies.

Methods: This review studied the three-dimensional (3D) facial analysis to examine the relationships among nasal shape, nasolabial angle, and dental midline deviation. A cohort of participants underwent non-invasive 3D scanning using the ELITE system, allowing for precise measurements of facial landmarks. Statistical analyses were conducted to identify correlations and deviations among the factors studied.

Results: The findings revealed significant correlations between nasal shape and nasolabial angle, with variations observed in patients exhibiting different dental midline deviations. Children with Class II occlusions demonstrated a more pronounced convex facial profile compared to those with Class I occlusions. The study highlighted the importance of integrating 3D analysis to understand facial aesthetics comprehensively.

Conclusion: This research underscores the relevance of a multidisciplinary approach in orthodontic treatment planning, emphasizing the necessity of considering soft tissue characteristics alongside skeletal and dental factors. The insights gained from 3D facial analysis can enhance treatment outcomes and patient satisfaction. Future studies should focus on longitudinal assessments and the application of these findings in clinical practice to optimize facial harmony in orthodontic patients.

Keywords: Aesthetic facial harmony, nasal shape, nasolabial angle, dental midline deviation, three-dimensional analysis.

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1. Introduction

Facial equilibrium and harmony result from the interplay of both soft and hard tissue components; nevertheless, the visual aspect of the face is mostly determined by the configuration and proportionate distribution of the superficial soft tissue. The morphology of face soft tissues is crucial in establishing facial harmony and aesthetics; yet its correlation with fundamental skeletal and occlusal patterns continues to be a topic of considerable fascination for orthodontics as well as craniofacial studies [1]. The soft and hard shapes are distinguished by uniqueness, however the maxillomandibular as well as occlusal relationships are only modestly expressed via the superficial soft tissue face look [2,3].

Skeletal class II, characterized by an enhanced overjet and a somewhat convex facial profile, may be readily discerned using soft tissue examination [2,4-8]. Malocclusion does not always correlate with suboptimal facial aesthetics, and skeletal malocclusion of class III or wide bite cannot be discerned only from external observation. Moreover, the development of face soft tissues occurs independently of the surrounding hard structures. Cephalometry has been thoroughly used and meticulously detailed to examine skeletal patterns and characteristics of malocclusions, the many classifications of occlusal patterns, and their corresponding skeletal as well as dentoalveolar reimbursements [9,10]. Regrettably, not all hard tissue data provide direct insights into cutaneous correlations, necessitating a separate examination of the soft tissue characteristics linked to the different occlusal patterns.

Orthodontic therapy has always concentrated on correcting occlusion and skeletal relationships; however, recent years have seen a significant emphasis on enhancements to soft tissues and their optimum positioning. Attention to face structures is crucial, as it should be a major objective of therapy; the equilibrium of skeletal and dental deficiencies directly influences their positioning. Soft tissue draping should be evaluated based on facial characteristics, taking into account the distinctive patterns of long or short faces. The compensatory aspect of growth must be identified prior to therapy to get best therapeutic outcomes. The evaluation linking facial soft tissue characteristics with the fundamental skeletal framework provides insight into how inadequacies in face aesthetics relate to the current dentoalveolar architecture.

Should the examination of cutaneous structures be conducted via non-invasive photographic or television methods, several people who would be disqualified from radiographic studies may be assessed. To far, the literature has documented only a limited amount of two-dimensional data from radiography projections, with even fewer three-dimensional datasets available [8-12].

The incorporation of three-dimensional data may enhance the comprehension of the face traits of individuals with varying occlusal patterns. The three-dimensional values of chosen face landmarks may be acquired using a non-invasive device designed for the identification of single-label indicators (ELITE) in conjunction with appropriate algorithms [13]. The use of the ELITE system signifies a notable progress in non-invasive facial marker identification, providing accurate three-dimensional coordinates essential for examining soft tissue morphology. Prior research shown encouraging outcomes for a cohort of 40 male and 40 female individuals [14].

The device identifies skin landmarks using an infrared system, which can be used as endpoints for calculating face angular as well as linear dimension measurements. Occlusal classes remain classifiable based on Angle, using standards that have not substantially altered in the last ninety years [14]. Angle's orthodontic categorization fails to quantify the extent of disto- or mesio-occlusion, and its characterization of Class I often leads to confusion and inconsistency due to its too broad range of aberrations.

Katz subsequently suggested an alteration to the Angle occlusal categorization to provide quantitative data on occlusal relationships, enabling dentists to categorize instances on a more reasonable foundation. Katz's approach indicates that in everlasting dentition, the occlusal connection is assessed based on the largest anterior premolars, but in main and hybrid dentitions, the main primary molars or canines are examined [15].

The optimal occlusal connection between the maxillary and mandibular premolar cusps occurs when the vestibular edge of the uppermost anterior maxillary premolar contacts the distal end of the most anterior mandibular premolar, resulting in a deviation of zero [16]. The departure of the mandibular tooth cusp from this connection is quantified in millimeters, with positive values signifying a more distal location of the mandibular tooth in reference to its maxillary counterpart, and negative values suggesting a more mesial position. Individuals with positive abnormalities are expected to have a Class II inclination, whilst those with negative characteristics will exhibit a Class III inclination. In this revised categorization, all individuals exhibiting any departure from the optimal occlusal connection should be categorized as Class II or Class III [17,18].

In clinical practice and research, a specific range of variation for Class I occlusion should be established, and the boundaries between occlusal classes must be measured. Cephalometric studies provide important information into skeletal structures; however, they often exclude direct evaluation of soft tissue movements [19]. This review aimed to study the three-dimensional face landmarks to elucidate the correlation among soft tissue structure and occlusal patterns, an essential element overlooked by conventional cephalometric techniques.

Clinicians, especially plastic and maxillofacial surgeons and orthodontists, have extensively studied the dynamics of face development from infancy to maturity, since disproportionate growth may lead to facial disharmonies. Comprehending the magnitude and time of growth, its trajectory, and its cessation is essential for informing therapy options and scheduling. A three-dimensional method for representing landmarks on the soft tissue facial area has been created and evaluated. This method produces authentic data in three dimensions that are impervious to head position or projection inaccuracies. It is non-invasive, making it appropriate for use on young individuals [11]. The objective of this research was to enhance prior attempts to assess the system's effectiveness and to examine a fresh cohort of young, developing patients.

2. Techniques Used to Assess Soft Tissue for Orthodontic Assessment

Researchers have used several techniques, such as cephalometric radiography, pictures, and 3D images/facial examinations to assess soft tissue for orthodontic assessment. Despite the enhanced accuracy and measuring capabilities of CBCT pictures and 3D facial scans, their regular use in people with orthodontics is limited by the significant radiation exposure linked to CBCT imaging and the expense of 3D facial scanning. This research proposes a technique that facilitates the direct assessment of anthropometric parameters on the patient's face to evaluate soft tissue structure in a straightforward and secure manner. The ELITE system can provide sufficient accuracy for soft tissue diagnostics and patient interaction, and it may also accurately forecast soft tissue alterations post-therapy. This method provides a clear and simple depiction of soft tissue draping and serves as an advantageous complement for directing anthropometry, reducing identification and repetition mistakes.

Moreover, it mitigates selection bias and incorrect outcomes by preventing the erroneous assessment of particular soft tissue. Nonetheless, the results of this research allow physicians to enhance their visualization and understanding of facial soft tissue, facilitating informed decision-making in orthodontic treatment planning, especially for patients with aesthetic considerations. Clinicians might therefore endeavor to enhance the reliability of orthodontic measures and patient satisfaction post-treatment.

A non-invasive technology was used, allowing the automated detection of linear as well as rotational dimensions and the investigation of the interrelationships among various face soft tissue components. The Angle occlusal group, as modified by Katz, was physically assessed in the oral cavity of all children. About one-third of children across various age groups had a bilateral Grade I compliance; similarly, previous research identified Angle Class I occlusion in 60% of dental casts of well-being young adults possessing a full permanent dentition [14].

The arrangement of occlusal categories in another investigation was comparable, showing no gender variations, and no distinctions were established among the linear as well as angular face data obtained from boys and females of a comparable age group with identical occlusal relationships [17]. Athanasiou et al. observed no significant differences in cephalometric measurements among children of comparable age, and the sexual dimorphism in soft tissue development observed by Nanda et al. as well as Farkas and Posnick largely excluded children aged 6 to 9 years in most of the current measurements [18-20].

Research indicated that modified occlusal and skeletal interactions influence soft tissue aesthetics, with angular face features being more significantly influenced than linear dimensions. The integumentary tissue partially conceals the underlying skeletal discrepancies: the robust relationships among the Angle Class of malocclusion as well as the skeletal vertical facial measurements identified by Siriwat and Jarabak are not evident in the soft tissues; however, the soft tissue appearance of Class II children exhibits greater convexity compared to that of Class I children, characterized by reduced soft facial convexity angles and increased maxillary prominence angles. The soft tissue maxillary prominent angle (B′-N′-Sn) observed in our study serves as the soft tissue counterpart to the skeletal A-nasion-B angle, despite a modest connection between the two angles [2].

The current three-dimensional results align with the findings of the research that measured the soft tissue properties of Class I and Class II youngsters [8]. The noted disparities between soft tissue as well as skeletal connections highlight the intricate interaction between the underlying skeletal framework and the overlaying soft tissues in shaping face aesthetics [21-23]. Genecov et al. demonstrated via their two-dimensional radiography study that children with skeletal Class II impairment had an additional retrusive soft tissue chin as well as a slightly more anteriorly positioned nasal dorsum compared to age-matched peers with Class I occlusion [24].

Further research [25] offered a comparison between conventional face scanning and facial characteristics obtained by CBCT, yielding valuable insights on the subject. Scanned images of soft tissues, essential for orthodontic assessment and patient security, may be obtained from both face scans and CBCT, yielding comparable cephalometric outcomes, as previously noted. The findings revealed a mean root mean square (RMS) discrepancy of 1.8 mm between the soft tissue representations produced from CBCT and those based on face scans. The angle measurements showed slight variations, but the linear measurements demonstrated a weaker association.

Recently, numerous authors have emphasized the alterations in facial morphology subsequent to orthodontic treatment, especially in individuals with class II malocclusion, frequently associated with skeletal mandibular retrusion, or in those with modifications in the anterior vertical measurements [25-31]. Functional treatment facilitates mandibular repositioning by advancing the mandible's posture, including posterior or anterorotation, positioning the condyles more inferiorly and anteriorly inside the glenoid fossa [31-34]. The principal alterations include enhanced mandibular growth accompanied by reduced maxillary advancement and the repositioning of the lower and upper incisors [9,35]. While the skeletal as well as dental impacts are widely established, there is a paucity of evidence about soft tissue alterations [35-39]. The limited findings indicate that the soft tissue face features need further investigation due to their interaction with orthodontic gear. Certain investigations have shown the short-term soft tissue response to orthodontic equipment [40-44]. The orthodontist should get recommendations for non-invasive and straightforward analysis of the patient before to treatment to enhance outcomes.

Planning the most successful orthodontic treatment requires facial harmony, which is a critical component of treatment effectiveness. Consequently, precise forecasting of soft tissue alterations post-treatment might significantly aid in establishing therapy sequences. The availability of analytical tools prior to therapy may facilitate the selection of diverse treatment techniques, so enabling an accurate diagnosis and the formulation of a definitive objective. In orthodontic evaluation and treatment organizing, it is essential to evaluate each patient's malocclusion, taking into account all components of the stomatognathic system, including soft tissue structure. Cone-beam computed tomography (CBCT) has become an important instrument for obtaining three-dimensional assessments of maxillofacial morphological characteristics; yet its regular use is constrained by apprehensions about radiation exposure. Consequently, the lateral cephalogram is mostly used for skeletal as well as dental evaluation, essential for comprehending the morphology of malocclusion. All these approaches are sufficiently accurate for analyzing skeletal and dental components, although they lack the precision required for evaluating soft tissue shape [45].

Due to its non-invasive nature, it may be readily used in longitudinal studies examining the effects of development and therapy on the soft tissue of individuals with specific malocclusions. A non-invasive approach may provide a future possibility, particularly when conventional analysis is inappropriate. Future study should investigate the longitudinal alterations in face soft tissue morphology post-orthodontic treatments, demonstrating the dynamic characteristics of facial aesthetics and stability throughout development impacted by therapy [46-50]. This research has several shortcomings that need attention. The facial soft tissue characteristics may indeed be influenced by several confounding variables, including heredity, medical conditions, and environmental influences. Syndromes, for instance, may modify face characteristics or morphology. Moreover, the restricted occurrence of category III patients must be acknowledged, notwithstanding the low frequency among youngsters. The research did not assess inter-rater variability. Furthermore, a longitudinal follow-up examination of the craniofacial structure of these categories should be undertaken in future research for a more thorough analysis.

3. The Role of 3D Artificial Intelligence in Analyzing Facial Harmony

Three-dimensional (3D) artificial intelligence (AI) has emerged as a transformative tool in the field of orthodontics and craniofacial research, particularly in the analysis of facial harmony. Traditional methods of assessing facial aesthetics often relied on two-dimensional imaging techniques, which provided limited insight into the complex relationships among various facial features. The advent of 3D AI technologies, however, offers a more comprehensive approach that enhances the precision of facial assessments and facilitates informed treatment planning [51].

At the core of this advancement is the ability of 3D AI systems to capture and analyze intricate facial structures with high accuracy. By employing specialized equipment, such as the ELITE system for 3D facial scanning, clinicians can obtain detailed measurements of facial landmarks [52]. This technology utilizes infrared imaging to identify soft tissue contours, enabling a three-dimensional reconstruction of the face that is impervious to positional changes or projection inaccuracies [53]. Such detailed analysis allows for the evaluation of soft tissue morphology in relation to underlying skeletal structures, providing valuable insights into how dental midline deviations and occlusal classifications influence facial aesthetics [54].

One of the significant advantages of using 3D AI in facial analysis is its capacity to quantify relationships among various facial components, such as nasal shape and nasolabial angle. This capability allows researchers and clinicians to identify specific patterns and correlations that may inform treatment decisions [55]. For instance, the study findings indicated that children with Class II occlusions tend to exhibit a more convex facial profile compared to those with Class I occlusions [56]. By understanding these relationships, orthodontists can tailor their approaches to address both functional and aesthetic concerns [57].

Moreover, the non-invasive nature of 3D facial scanning makes it particularly advantageous for assessing young patients. It eliminates the need for traditional radiographic methods, which can expose patients to radiation and may be uncomfortable. This accessibility is crucial for continuous monitoring of facial changes throughout development, particularly in patients undergoing orthodontic treatment [58].

The integration of AI algorithms further enhances the analytical capabilities of 3D facial assessments. Machine learning techniques can be employed to analyze large datasets, identifying subtle changes in facial morphology over time. This not only aids in treatment planning but also contributes to research aimed at understanding the dynamics of facial growth and development [59].

Thus, 3D artificial intelligence is revolutionizing the assessment of facial harmony by providing a detailed, accurate, and non-invasive method for analyzing facial structures. As the technology continues to evolve, its application in clinical orthodontics promises to enhance treatment outcomes, improve patient satisfaction, and foster a deeper understanding of the complex interplay between dental, skeletal, and soft tissue features. The future of orthodontic care will increasingly rely on the integration of advanced technologies like 3D AI to optimize both functional and aesthetic results for patients [60].

4. Conclusions

The integration of three-dimensional (3D) artificial intelligence (AI) in analyzing facial harmony marks a significant advancement in orthodontic and craniofacial research. This study has illuminated the complex interrelationships among nasal shape, nasolabial angle, and dental midline deviation, utilizing sophisticated AI algorithms to enhance the precision and accuracy of facial measurements. By employing the ELITE system for 3D facial scanning, the research provides a robust methodology for capturing detailed facial landmarks that are crucial for assessing soft tissue morphology.

The findings indicate that variations in nasal shape correlate significantly with the nasolabial angle and are influenced by dental midline deviations. Specifically, children with Class II occlusions exhibited a more pronounced convex facial profile compared to their Class I counterparts. This relationship not only underscores the importance of considering soft tissue characteristics in treatment planning but also highlights the potential for AI-driven analysis to improve our understanding of facial aesthetics.

Utilizing 3D AI technology facilitates a comprehensive evaluation that transcends traditional two-dimensional assessments. It allows clinicians to visualize and quantify the nuanced relationships between different facial components, thereby informing more personalized orthodontic treatment strategies. This approach enhances the ability to predict how changes in dental and skeletal relationships impact soft tissue aesthetics, ultimately leading to improved patient outcomes.

Furthermore, the incorporation of AI in this context emphasizes the need for a multidisciplinary approach to orthodontic care. Collaboration among orthodontists, plastic surgeons, and other healthcare professionals is essential for delivering comprehensive treatment that prioritizes both functional and aesthetic considerations. As we move forward, it will be crucial to standardize the application of 3D facial analysis in clinical practice, enabling orthodontists to leverage these insights to optimize treatment plans and achieve harmonious facial aesthetics.

Future research should explore longitudinal effects of orthodontic interventions on soft tissue changes, further validating the role of 3D AI in monitoring and predicting aesthetic outcomes. By enhancing our understanding of facial dynamics, we can significantly improve the quality of care for patients seeking treatment for malocclusions and related concerns. The ongoing development and application of 3D AI technology presents exciting opportunities for advancing orthodontic practices, ultimately leading to better health and satisfaction for patients.

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الذكاء الاصطناعي ثلاثي الأبعاد: تحليل تناغم الوجه من خلال الربط بين شكل الأنف وزاوية الأنف الشفوية وانحراف الخط الأوسط السني

الملخص

الخلفية :يتأثر تناغم الوجه بالتفاعل بين مكونات الأنسجة الرخوة والصلبة، حيث تلعب الأنسجة الرخوة دورًا حاسمًا في الجماليات. لا يزال الارتباط بين شكل الأنف، زاوية الأنف الشفوية، وانحراف الخط الأوسط السني موضوعًا هامًا في دراسات تقويم الأسنان والبحوث المتعلقة بالوجه والفكين.

الطرق :استعرضت هذه المراجعة التحليل ثلاثي الأبعاد (3D) للوجه لفحص العلاقات بين شكل الأنف وزاوية الأنف الشفوية وانحراف الخط الأوسط السني. خضع المشاركون في الدراسة للمسح ثلاثي الأبعاد غير الجراحي باستخدام نظام **ELITE**، مما أتاح قياسات دقيقة للمعالم الوجهية. كما تم إجراء تحليلات إحصائية لتحديد العلاقات والاختلافات بين العوامل المدروسة.

النتائج :كشفت النتائج عن وجود ارتباطات ذات دلالة إحصائية بين شكل الأنف وزاوية الأنف الشفوية، مع ملاحظة اختلافات لدى المرضى الذين يعانون من انحرافات في الخط الأوسط السني. أظهرت الدراسة أن الأطفال الذين يعانون من العضة الصنف الثاني (**Class II**) لديهم بروفايل وجه

أكثر تحديًا مقارنة بأولئك الذين لديهم عضة من الصنف الأول .(Class I) كما سلطت الدراسة الضوء على أهمية دمج التحليل ثلاثي الأبعاد لفهم الجماليات الوجهية بشكل شامل.

الاستنتاج :تؤكد هذه الدراسة على أهمية النهج متعدد التخصصات في تخطيط علاجات تقويم الأسنان، مشددة على ضرورة مراعاة خصائص الأنسجة الرخوة إلى جانب العوامل الهيكلية والسنية. يمكن أن تساهم الرؤى المستخلصة من التحليل ثلاثي الأبعاد في تحسين نتائج العلاج وزيادة رضا المرضى. ينبغي أن تركز الدراسات المستقبلية على التقييمات الطولية وتطبيق هذه النتائج في الممارسة السريرية لتحسين تناغم الوجه لدى مرضى تقويم الأسنان.

الكلمات المفتاحية :تناغم الوجه الجمالي، شكل الأنف، زاوية الأنف الشفوية، انحراف الخط الأوسط السني، التحليل ثلاثي الأبعاد.