SLEEP-DISORDERED BREATHING AND MALOCCLUSION IN ASYMPTOMATIC ADOLESCENTS

By

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Dedication

بسم الله الرحمن الرحيم

To my parents, Mosleh and Dalal, the foundation of everything I am and everything I strive to be.

To my beloved wife, Mayyadah, my greatest supporter and partner in life’s many adventures.

To my son, Ibrahim, who reminds me daily of the joy and purpose life holds.

To my siblings, whose presence has filled my life with laughter, support, and lifelong memories.

To my younger self, for believing in the journey even when the path was unclear.

To reach higher, to live fully, to lead with purpose, and to give back to those who come after me. This achievement is not mine alone.

You are all my inspiration.

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ABSTRACT

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Introduction:

Sleep-disordered breathing (SDB) has been linked to craniofacial morphology. While orthodontists are uniquely positioned to screen for SDB using tools like the Pediatric Sleep Questionnaire (PSQ), few studies have explored associations between malocclusion severity and SDB in asymptomatic adolescents.

Methods:

This observational cross-sectional study included 45 asymptomatic adolescents aged 7–18 years seeking orthodontic treatment at an academic clinic. Malocclusion severity was assessed using ABO-DI, IOTN-DHC, and IOTN-AC. Sleep-disordered breathing was evaluated via auto-scored home sleep apnea testing (Nox-T3s™) with results expressed as Apnea-Hypopnea Index (AHI). Pearson and Spearman correlations were used to assess relationships between indices and AHI.

Results:

Descriptive statistics revealed a mean AHI of 2.71 events/hour, ABO-DI = 17.53, IOTN-DHC = 3.04, and IOTN-AC = 5.20. Correlation analyses showed no statistically significant relationships between any of the malocclusion indices and AHI: ABO-DI vs. AHI ($r = –0.065$, $p \leq 0.62$), IOTN-DHC vs. AHI ($\rho = 0.034$, $p \leq 0.817$), and IOTN-AC vs. AHI ($\rho = 0.068$, $p \leq 0.653$), indicating no correlation between malocclusion severity and SDB.

Conclusions:

In this sample of asymptomatic adolescents, no meaningful association was found between malocclusion severity and SDB as measured by AHI. These findings suggest that orthodontic indices alone cannot reliably predict subclinical SDB risk. Further research involving larger cohorts and polysomnography is needed before malocclusion can be meaningfully linked to airway compromise.

Table of contents

DEDICATION 2

ACKNOWLEDGMENTS 3

ABSTRACT 4

REVIEW OF THE LITERATURE 6

Introduction 6
Prevalence of Obstructive Sleep Apnea in Children 8
Diagnostic Approaches to Pediatric Sleep-Disordered Breathing 10
Home Sleep-Apnea Testing 12
SDB and the Craniofacial Complex 15
Orthodontic Indices in Malocclusion Assessment 17
The Pediatric Sleep Questionnaire 21
Literature Review References 22

STATEMENT OF THESIS 31

MANUSCRIPT 32

Introduction 33
Materials and Methods 36
Statistical Analysis 38
Results 38
Discussion 40
Limitations 43
Conclusion 44
References 45

APPENDICES 48

Appendix A: IRB Approval 48
Appendix B: Abbreviation Key 49
Appendix C: Data Tables 50
Appendix D: Scatter Plots 51

REVIEW OF THE LITERATURE

Introduction

Sleep-disordered breathing (SDB), particularly obstructive sleep apnea (OSA), has been increasingly recognized as a significant contributor to craniofacial anomalies and dental malocclusions in children, such as a high-arched palate (Kang et al., 2022; Park et al., 2011). OSA is characterized by repeated episodes of partial or complete upper airway obstruction during sleep, which leads to intermittent hypoxemia, fragmented sleep, and altered respiratory mechanics(Gould et al., 1988; Guilleminault et al., 1976; Sateia, 2014; Thorpy, 1990). These disturbances have wide-ranging effects on a child's physical, cognitive, and emotional development (Hansen et al., 2022; Liu et al., 2023).

Emerging evidence supports a causal relationship between chronic SDB and the development of malocclusion, particularly Class II malocclusion, crossbite, and open bite. Structural abnormalities such as mandibular retrognathia, steep mandibular plane angle, and excessive anterior overjet are not only contributors to the development of SDB but can also be exacerbated by it (Liu et al., 2023). For instance, persistent mouth breathing associated with SDB can alter the growth and development of the facial skeleton, leading to further structural anomalies over time, such as a narrowed airway and more pronounced mandibular retrognathia (Katz & D'Ambrosio, 2008; Pirila-Parkkinen et al., 2009). This reciprocal relationship underscores the importance of early

intervention in managing SDB to prevent these craniofacial changes, which can further exacerbate the severity of OSA in affected children.

Children with SDB presented more frequently with malocclusions such as crossbite, open bite, increased overjet or mandibular retrognathia, making orthodontic assessment a crucial component in the early identification and management of OSA (Carvalho et al., 2014; Sauer et al., 2012). Therefore, integrating craniofacial and dental assessments into the diagnostic process for pediatric OSA is essential.

This study aims to investigate whether malocclusion severity in asymptomatic adolescents is associated with SDB, as measured by the apnea-hypopnea index (AHI) obtained through home sleep apnea testing (HST). Malocclusion will be assessed using two standardized indices: the Index of Orthodontic Treatment Need – Dental Health Component (IOTN-DHC) and the American Board of Orthodontics Discrepancy Index (ABO-DI), which quantify traits such as overjet, sagittal jaw discrepancies (ANB angle), and maxillary constriction, features previously linked to airway compromise in children with diagnosed SDB. By applying these indices to a population not previously suspected of having SDB, this research seeks to determine whether undetected or mild respiratory disturbances during sleep are associated with underlying structural malocclusions.

The current literature predominantly focuses on children already diagnosed with SDB, limiting our understanding of how malocclusion may serve as a potential early indicator of compromised airway function. Few studies have integrated objective sleep data with standardized orthodontic scoring systems, resulting in a critical gap in identifying at-risk individuals outside of clinical populations. This pilot study addresses that gap by examining the correlation between malocclusion severity and AHI in otherwise healthy adolescents with no reported symptoms of SDB. Additionally, the IOTN-Aesthetic Component (IOTN-AC) will be used to assess the visual impact of craniofacial changes, offering further insight. The findings may support earlier interdisciplinary screening for SDB among orthodontic patients and encourage the integration of airway assessment into routine orthodontic evaluations.

Prevalence of Obstructive Sleep Apnea in Children

Obstructive sleep apnea affects an estimated 0.73–13% of children (Bixler et al., 2009; Kang et al., 2022; Magnusdottir & Hill, 2024; Rohra et al., 2018). Studies report wide variations in its prevalence, largely due to differences in diagnostic criteria, age groups studied, and methodologies used depending on whether diagnosis was based on parental reporting, clinical signs, or objective measures such as polysomnography PSG.

Higher prevalence rates are typically observed in children with identifiable risk factors such as adenotonsillar hypertrophy, obesity, or craniofacial anomalies (Andersen et al., 2019; Sauer et al., 2012). A cross-sectional study by Andersen et al. (2019) found that 44.6% of overweight and obese children and adolescents aged 7–18 years met the diagnostic threshold for OSA (AHI ≥ 2/hour), compared to just 9.1% in a normal-weight control group, highlighting a strong association between elevated BMI and increased risk of OSA. The study also reported that each one-unit increase in Body Mass Index Standard Deviation Score (BMI SDS) significantly increased the likelihood of OSA by 92%, independent of other variables.

A study by Rohra et al. (2018) aimed to evaluate the prevalence of high-risk factors for SDB in a sample of 303 healthy children aged 9 to 17 years seeking orthodontic care at Case Western Reserve University (CWRU) (Rohra et al., 2018). Using the PSQ, a validated 22-item screening tool (Chervin et al., 2000), participants were classified as high risk for SDB if they had 33% or more "yes" responses, indicating significant sleep-related symptoms such as snoring, daytime sleepiness, and behavioral disturbances. The results revealed that 7.3% (n=22) of the orthodontic patients were categorized as high risk for SDB, with no significant differences observed based on sex, age, or race. This study highlights the feasibility of incorporating SDB screening into routine orthodontic evaluations, suggesting that orthodontists can play a key role in identifying

asymptomatic adolescents at risk for undiagnosed SDB, facilitating early referrals for further sleep assessment and intervention.

Despite growing awareness, OSA remains underrecognized due to nonspecific clinical manifestations such as irritability, poor academic performance, and behavioral disturbances, symptoms often misattributed to attention-deficit/hyperactivity disorder (ADHD) or developmental issues (Gozal, 1998; Schwengel et al., 2014). This diagnostic ambiguity contributes to delayed treatment and misses opportunities for early intervention, particularly during critical stages of growth and learning.

Methodological inconsistencies across studies further complicate accurate estimation of OSA prevalence in children. Many rely on parent-reported questionnaires, such as the Pediatric Sleep Questionnaire (PSQ) (Chervin et al., 2000), rather than objective assessment. Additionally, definitions of abnormal breathing events vary across studies, leading to discrepancies in reported prevalence rates. These inconsistencies introduce variability in results and hinder the ability to compare findings across studies (Carol Lynn Rosen, 1996; Kang et al., 2022).

Diagnostic Approaches to Pediatric Sleep-Disordered Breathing

Polysomnography (PSG) emerged as a cornerstone of sleep research and remains the gold standard for diagnosing OSA. It allows for the simultaneous

measurement of multiple physiological parameters, including brain activity (EEG), eye movement (EOG), muscle tone (EMG), heart rhythm, and respiratory effort, providing a comprehensive assessment of sleep quality and breathing patterns during sleep (Allan Rechtschaffen and Anthony Kales, 1968; Berger, 1929; Caton, 1970).

Its development was rooted in foundational discoveries such as Hans Berger's invention of the electroencephalogram (Berger, 1929), which enabled the objective measurement of brain function during sleep. Alfred Loomis and colleagues later identified distinct EEG wave patterns associated with different stages of sleep, laying the groundwork for modern sleep staging systems (Loomis et al., 1937). The formal classification of sleep architecture into rapid eye movement (REM) and non-REM (NREM) phases by Aserinsky and Kleitman (1953) and Dement and Kleitman (1957) further refined the diagnostic power of PSG (Aserinsky & Kleitman, 1953; Dement & Kleitman, 1957).

In the context of SDB, PSG has been instrumental in identifying the types and severity of apneic events. Gastaut et al. (1965) introduced airflow measurements, distinguishing between obstructive, central, and mixed apneas, a breakthrough that improved both diagnosis and treatment planning (Gastaut, 1965; Sidney Burwell et al., 1956). Patients who underwent tracheostomy for severe OSA experienced significant symptom relief, underscoring the critical role of airway mechanics in SDB (Camacho et al., 2014).

The American Academy of Sleep Medicine (AASM) played a central role in standardizing sleep diagnostics. With each updated version of The AASM Manual for the Scoring of Sleep and Associated Events, the accuracy and consistency of sleep disorder diagnoses have improved (Iber, 2007; Troester et al., 2023).

However, despite its diagnostic superiority, PSG presents several limitations, especially in pediatric populations. It is resource-intensive, requiring specialized equipment and trained personnel, and is often difficult to access due to high costs and limited availability of sleep laboratories (Kang et al., 2022; Schwengel et al., 2014). Additionally, the unfamiliar lab environment can disrupt normal sleep behavior, affecting data reliability.

Home Sleep-Apnea Testing

The American Academy of Sleep Medicine (AASM) recognizes home sleep test (HST) as a valid diagnostic tool for adult patients with a high pretest probability of moderate-to-severe OSA (Carol Lynn Rosen, 1996). According to the AASM position statement, HST should be interpreted by a physician board-certified in sleep medicine or under their supervision, and results must be evaluated in the context of the patient's clinical history. The use of Type III HST devices, those measuring airflow, respiratory effort, and oxygen saturation, is supported for unattended testing in adults when performed appropriately.

Despite this endorsement, the application of HST in pediatric populations remains more limited and less standardized. Unlike adults, children present with different symptom profiles, and OSA may manifest with behavioral issues, learning difficulties, or growth delays rather than classic symptoms like daytime sleepiness (Lumeng & Chervin, 2008). Moreover, pediatric sleep architecture and breathing patterns differ significantly from those of adults, necessitating tailored scoring criteria and interpretation methods.

Bhattacharjee et al. (2021) evaluated the accuracy of the ResMed ApneaLink Air, a portable sleep monitor, for diagnosing OSA in adolescents aged 12–18 years. The study included 20 participants who underwent both in-laboratory PSG and portable monitoring, once at home, and once during PSG (Bhattacharjee et al., 2021).

The results showed that HST generally aligned with PSG findings, with 80% diagnostic agreement using a pediatric-adapted method of comparison. However, the device tended to underestimate the AHI, likely due to longer total recording time at home compared to actual sleep time captured during PSG. Agreement improved when testing was supervised in the lab, reaching 95%, suggesting that proper setup and technical support can improve reliability. Signal loss, especially in nasal airflow monitoring, was more frequent during unsupervised home testing, contributing to lower success rates (75% for HST vs.

89% in lab). Despite these limitations, most participants found the portable device easy to use and preferred it over the in-lab sleep study.

These findings are consistent with other studies evaluating portable monitors like the Watch-PAT and MediByte in adolescent populations, which have also shown promising results but highlight the importance of signal quality and appropriate use conditions (Choi et al., 2018; Masoud et al., 2019).

Validation studies have also examined the Nox-T3, another Type III portable monitor used in both adult and pediatric sleep studies. In adult populations, Cairns et al. reported high sensitivity and specificity for moderate-to-severe OSA, with good agreement for AHI scoring (Cairns et al., 2014). Similarly, Xu et al. found that the Nox-T3 demonstrated 92% sensitivity and 87% specificity for diagnosing OSA in Chinese adults, supporting its utility in certain clinical contexts where access to PSG may be limited (Xu et al., 2017).

A meta-analysis by Certal et al. highlights the effectiveness of unattended sleep using type 3 monitoring devices. Their analysis included 10 studies with a total of 724 children, showing a pooled sensitivity and specificity of 76% and an area under the curve (AUC) of 0.88. When using an AHI cutoff greater than 1, sensitivity increased to 88%, suggesting that these devices are effective for detecting mild-to-moderate OSA, especially when in-lab sleep studies are not practical (Certal et al., 2015).

However, evidence regarding the accuracy of the Nox-T3 in pediatric populations is more limited and less consistent. Valério et al. evaluated the device's scoring algorithm and noted variability across software versions, raising concerns about reproducibility and consistency across institutions (Valério et al., 2021). Additionally, while some studies report acceptable agreement between Nox-T3 and PSG under controlled conditions, others caution against its use in mild cases without confirmatory testing (Chang et al., 2019). These inconsistencies highlight the need for careful interpretation when applying portable monitoring device.

These findings suggest that portable monitoring tools can serve as valuable screening tools, particularly in resource-limited settings or for initial assessment of SDB. However, they should not replace PSG for definitive diagnosis or differential evaluation of central versus obstructive apneas (Valério et al., 2021; Xu et al., 2017). Their current role appears best suited for preliminary identification of SDB, followed by PSG confirmation when indicated.

SDB and the Craniofacial Complex

Chronic SDB in children has been increasingly suggested that it may be associated with certain alterations in craniofacial morphology, particularly during developmental years when growth can be affected. One of the most widely supported explanations is that persistent oral breathing due to nasal obstruction alters normal orofacial muscle function and tongue posture,

disrupting the balance between intraoral and extraoral forces. This shift can influence dental arch development and overall facial growth, potentially leading to malocclusions such as maxillary constriction and mandibular retrognathia (Carvalho et al., 2014; Pirila-Parkkinen et al., 2009).

The authors also link OSA to craniofacial changes, suggesting that chronic mouth breathing and altered posture may contribute to malocclusion. While insightful for orthodontic and sleep medicine fields, the paper does not propose clear diagnostic or treatment guidelines, nor does it address variability in clinical presentation. Still, it provides a valuable basis for understanding OSA's developmental impact and supports early, interdisciplinary intervention.

A recent systematic review and meta-analysis examined the dental and craniofacial characteristics associated with OSA in pediatric populations, revealing that children diagnosed with OSA are more likely to exhibit specific craniofacial features compared to healthy controls (Liu et al., 2023). These features include mandibular retrognathia, an increased mandibular plane angle, excessive anterior overjet, and reduced maxillary dimensions. The findings align with prior research suggesting that chronic upper airway obstruction may influence orofacial development through altered breathing patterns, neuromuscular function, and growth dynamics. The authors propose that these craniofacial traits could potentially serve as indicators of increased OSA risk;

however, they note that the observed effect sizes were relatively small, limiting their clinical significance.

It is important to consider the limitations of this review. While the differences identified were statistically significant, they generally fell within normal population ranges, raising questions about their practical relevance. Furthermore, the overall certainty of the evidence was rated as low or very low due to substantial heterogeneity across studies, methodological shortcomings, and potential biases in the included data. Importantly, the review does not establish causality or directionality—whether these craniofacial features predispose individuals to OSA, arise as a consequence of long-term respiratory disturbances, or simply coexist without a direct causal link remains unclear. Therefore, while this study offers a valuable synthesis of current evidence, it underscores the need for further high-quality longitudinal research to better understand the complex relationship between craniofacial morphology and pediatric obstructive sleep apnea. (Liu et al., 2023).

Orthodontic Indices in Malocclusion Assessment

The American Board of Orthodontics Discrepancy Index (ABO-DI) is an objective tool used to assess orthodontic case complexity based on measurable deviations from accepted norms. It evaluates pretreatment records such as dental casts and cephalometric radiographs, assigning points for malocclusion traits including overjet, overbite, crowding, posterior crossbites, and skeletal

relationships. Higher total scores indicate greater case complexity. The ABO-DI was developed to provide a standardized and reproducible method for evaluating clinical submissions during the ABO certification process, supplementing traditional case categories with a more objective measure of difficulty (Cangialosi et al., 2004).

Dragstrem et al. (2015) compared digital scoring using OrthoCAD and Ortho Insight 3D with manual measurements on plaster models, which were considered the gold standard. The results showed that OrthoCAD produced DI scores that were not significantly different from manual measurements, making it a clinically acceptable alternative. However, Ortho Insight 3D showed statistically significant differences in some categories, particularly overjet, open bite, and occlusal relationships, suggesting that while its automation offers efficiency, manual verification is still necessary to ensure accuracy for certification purposes (Dragstrem et al., 2015). The ABO DI remains a valid and valuable tool for assessing pretreatment complexity, and its adaptation to digital workflows enhances its utility in modern orthodontic education, certification, and clinical audits.

The Index of Orthodontic Treatment Need (IOTN) was developed by Brook and Shaw (1989) as a standardized tool for assessing orthodontic treatment need. It consists of two components: the Dental Health Component (DHC) and the Aesthetic Component (AC). The DHC evaluates occlusal traits such as

overjet, overbite, crowding, displacement of contact points, posterior crossbites, impeded eruption of teeth, and increased overbite with trauma. These traits are scored individually, and the most severe trait determines the overall DHC grade, which ranges from Grade 1 (no treatment needed) to Grade 5 (urgent treatment needed). The AC uses a set of 10 standardized photographs to assess dental aesthetics, with scores ranging from Grade 1 (most attractive) to Grade 10 (least attractive)(Brook & Shaw, 1989).

A longitudinal study by Cooper et al. (2000) investigated whether IOTN scores remain stable between ages 11 and 19 in untreated individuals. The results showed that the DHC remained relatively consistent, despite changes in individual occlusal traits such as overjet and overbite over time (Cooper et al., 2000). For example, overjet decreased significantly between 11 and 19 years, especially between 11 and 15 years, likely due to facial growth during puberty. However, the overall DHC score, based on the worst trait, did not change significantly for most individuals. This suggests that an IOTN DHC score assigned at age 11 is unlikely to change significantly by age 19, making it a reliable index for long-term treatment planning and resource allocation.

In contrast, the Aesthetic Component (AC) generally improved over time. Many individuals who had higher AC scores at age 11 showed improvement by age 19. This indicates that early aesthetic concerns may resolve naturally without intervention. However, some subjects with high AC scores at 11 years

may have already undergone treatment before reaching 19 years, potentially affecting the representativeness of the sample. Despite this, the observed trend supports cautious decision-making when considering early aesthetic treatments.

In a separate study by Üçüncü & Ertugay (2001), the IOTN was used to assess orthodontic treatment need in a Turkish school population (ages 11–14) and a referred patient group of the same age range. Among schoolchildren, 38.8% were classified as having great need based on DHC, while only 4.8% showed great aesthetic need (AC). In the referred group, 83.2% were categorized as having great need (DHC) and 36.8% showed great aesthetic concern (AC). Notably, Grade 8 (ectopic canines) accounted for 28.8% of the great aesthetic need cases, indicating that canine position strongly influences patients' motivation for treatment (Üçüncü & Ertugay, 2001).

Both studies confirm that the IOTN is a valid and reliable index, particularly the DHC, which remains stable over time. This makes it valuable for public health planning and treatment prioritization. The AC, while more subjective, provides insight into patient-perceived need and helps identify cases driven primarily by aesthetic concerns, especially among referred patients. Together, both components support informed clinical decisions and equitable distribution of orthodontic care.

The Pediatric Sleep Questionnaire

The Pediatric Sleep Questionnaire (PSQ) is a widely utilized instrument in pediatric sleep research and clinical screening, specifically designed to assess sleep-related issues in children. Its development and application have been extensively discussed in literature, particularly in the review article by Spruyt and Gozal (2011) , which evaluates various sleep questionnaires for their psychometric properties and suitability as diagnostic or epidemiological tools (Spruyt & Gozal, 2011).

The PSQ was developed with a clear focus on measuring SDB, snoring, daytime sleepiness, and associated behavioral problems in children (Spruyt & Gozal, 2011). The questionnaire comprises 22 items rated on a 7-point Likert scale, focusing on the frequency of specific sleep behaviors over the past six months. The tool's design emphasizes reliability and validity , ensuring it meets psychometric standards necessary for clinical and research use (Chervin et al., 2000).

Initial validation studies demonstrated the PSQ's internal consistency, test-retest reliability, and construct validity (Chervin et al., 2000, 2007). These studies indicated that the PSQ is not only reliable but also valid in identifying children at risk for OSA and other sleep disturbances. The PSQ has since been adapted into multiple languages and applied in diverse cultural contexts, further establishing its utility across different populations (Ferreira et al., 2009).

Despite these strengths, some limitations persist. While the PSQ effectively measures the frequency of sleep problems, it does not address severity, which could be critical in clinical settings. Moreover, although the tool has been translated and used internationally, there remains a need for more standardized norms across different age groups and cultures (Lumeng & Chervin, 2008).

Clinically, the PSQ aids in screening for SDB and related symptoms, enabling early intervention and management strategies. In research, the PSQ has contributed significantly to understanding the prevalence and impact of sleep disorders on children's health and academic performance (Goodwin et al., 2003).

Additionally, there is a growing interest in integrating the PSQ with objective measures like polysomnography to enhance diagnostic accuracy (Montgomery-Downs et al., 2004).

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STATEMENT OF THESIS

The purpose of this study is to investigate whether a correlation exists between sleep-disordered breathing (SDB), as measured by the Apnea Hypopnea Index (AHI) using at-home polysomnography, and malocclusion severity, as assessed by the American Board of Orthodontics Discrepancy Index (ABO-DI) and the Index of Orthodontic Treatment Need (IOTN), in asymptomatic adolescents seeking orthodontic treatment.

SLEEP-DISORDERED BREATHING AND MALOCCLUSION IN ASYMPTOMATIC ADOLESCENTS

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ABSTRACT

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Introduction:

Sleep-disordered breathing (SDB) has been linked to craniofacial morphology. While orthodontists are uniquely positioned to screen for SDB using tools like the Pediatric Sleep Questionnaire (PSQ), few studies have explored associations between malocclusion severity and SDB in asymptomatic adolescents.

Methods:

This observational cross-sectional study included 45 asymptomatic adolescents aged 7–18 years seeking orthodontic treatment at an academic clinic. Malocclusion severity was assessed using ABO-DI, IOTN-DHC, and IOTN-AC. Sleep-disordered breathing was evaluated via auto-scored home sleep apnea testing (Nox-T3s™) with results expressed as Apnea-Hypopnea Index (AHI). Pearson and Spearman correlations were used to assess relationships between indices and AHI.

Results:

Descriptive statistics revealed a mean AHI of 2.71 events/hour, ABO-DI = 17.53, IOTN-DHC = 3.04, and IOTN-AC = 5.20. Correlation analyses showed no statistically significant relationships between any of the malocclusion indices and AHI: ABO-DI vs. AHI ($r = –0.065$, $p \leq 0.62$), IOTN-DHC vs. AHI ($\rho = 0.034$, $p \leq 0.817$), and IOTN-AC vs. AHI ($\rho = 0.068$, $p \leq 0.653$), indicating no correlation between malocclusion severity and SDB.

Conclusions:

In this sample of asymptomatic adolescents, no meaningful association was found between malocclusion severity and SDB as measured by AHI. These findings suggest that orthodontic indices alone cannot reliably predict subclinical SDB risk. Further research involving larger cohorts and polysomnography is needed before malocclusion can be meaningfully linked to airway compromise.

Introduction

Sleep-disordered breathing (SDB), particularly obstructive sleep apnea (OSA), has gained increasing attention for its role in influencing craniofacial development and dental occlusion in children and adolescents [1–3]. OSA is characterized by recurrent episodes of partial or complete upper airway obstruction during sleep, leading to intermittent hypoxemia, disrupted sleep architecture, and altered respiratory mechanics [4–7]. These disturbances have been linked not only to neurocognitive and behavioral impairments but also to morphological changes in the developing craniofacial complex, including maxillary narrowing, mandibular retrognathia, increased overjet, and open bite formation [2,8,9].

Emerging evidence suggests potential associations between sleep-disordered breathing (SDB) and malocclusion, with some studies proposing certain craniofacial features, such as Class II relationships, posterior crossbites, and vertical discrepancies, may contribute to airway vulnerability. Concurrently, chronic mouth breathing and altered neuromuscular function associated with SDB may influence orofacial development and exacerbate dental anomalies [9–11]. For instance, children diagnosed with SDB have been found to exhibit a higher prevalence of these malocclusions compared to non-snoring controls. However, many of these findings are based on small effect sizes and are not consistently supported across studies. Moreover, most of the existing literature

focuses on clinically diagnosed populations, limiting our understanding of whether similar patterns exist among asymptomatic individuals who are otherwise healthy and seeking routine orthodontic treatment.

Orthodontists are uniquely positioned to identify early signs of compromised airway function through routine clinical assessments. Standardized tools such as the American Board of Orthodontics Discrepancy Index (ABO-DI) and the Index of Orthodontic Treatment Need (IOTN) offer objective, quantifiable measures of malocclusion severity and treatment urgency [12–14]. Despite their widespread use in orthodontic education and certification, these indices have rarely been integrated with objective sleep data in pediatric or adolescent populations without known SDB symptoms.

This pilot study aims to explore the potential correlation between sleep-disordered breathing, as measured by the Apnea-Hypopnea Index (AHI) obtained via home sleep testing (HST), and malocclusion severity assessed using the ABO-DI and IOTN-Dental Health Component (DHC) in asymptomatic adolescents. Additionally, the IOTN-Aesthetic Component (AC) will be used to evaluate the visual impact of craniofacial traits associated with SDB. By examining these relationships in a population not previously suspected of having SDB, this study seeks to contribute to the growing body of evidence supporting interdisciplinary screening for airway-related disorders in orthodontic practice.

Ultimately, identifying subtle yet significant associations between malocclusion features and undiagnosed SDB could inform earlier intervention strategies, improve patient outcomes, and enhance collaboration between orthodontists and sleep medicine specialists.

Materials and Methods

This observational cross-sectional study was approved by the Institutional Review Board (IRB) at Case Western Reserve University (CWRU) (IRB#STUDY20181067). Written informed consent was obtained from all parents or legal guardians prior to participation. Written assent was also obtained from participants in accordance with IRB guidelines.

Participants were recruited consecutively from patients seeking orthodontic treatment at the Department of Orthodontics, CWRU. Inclusion criteria required that participants be asymptomatic for sleep-disordered breathing (SDB), as determined by clinical history and parent-reported scores on the Pediatric Sleep Questionnaire (PSQ; <33% affirmative responses) [15]. Participants had no prior diagnosis or treatment for obstructive sleep apnea (OSA), no craniofacial anomalies or syndromes, and no history of orthodontic intervention. Those unable to complete home sleep apnea testing due to technical difficulties or noncompliance were excluded.

Sleep-disordered breathing was assessed using a Type III portable monitoring device (Nox-T3s™, Nox Medical, Reykjavik, Iceland). The device records nasal airflow, thoracic and abdominal respiratory effort, oxygen saturation, body position, snoring intensity, and heart rate. Participants completed one night of unsupervised home sleep apnea testing following standardized instructions provided by trained personnel.

Data from the Nox-T3s™ device were automatically scored using the built-in analysis software. The Apnea-Hypopnea Index (AHI), defined as the number of apneas and hypopneas per hour of sleep, was calculated based on these auto-generated results. An AHI ≥ 1 event/hour was considered abnormal, based on pediatric definitions of SDB.

Malocclusion severity was assessed using two validated orthodontic indices: the American Board of Orthodontics Discrepancy Index (ABO-DI) and the Index of Orthodontic Treatment Need – Dental Health Component (IOTN-DHC) [13,16]. These indices were manually scored by a single calibrated orthodontist to ensure consistency and reduce inter-examiner variability. Digital dental models were scored using OrthoCAD® software. Cephalometric measurements were derived from cone-beam computed tomography (CBCT) scans using Dolphin Imaging software. These values were then applied in the ABO-DI scoring process.

In addition, the IOTN-Aesthetic Component (IOTN-AC) was evaluated using standardized intraoral photographs. Participants were rated from Grade 1 (most attractive) to Grade 10 (least attractive) based on comparison to reference images by the same examiner, who remained blinded to the sleep test results.

All data were de-identified and stored securely in compliance with HIPAA regulations.

Statistical Analysis

All statistical analyses were performed using Python 3.10. Descriptive statistics were calculated to summarize participant demographics, and all clinical variables.

To assess the relationship between malocclusion severity and SDB, Pearson correlation was used to evaluate associations between continuous variables ABO-DI and AHI. Spearman's rank correlation was used for ordinal variables IOTN-DHC and IOTN-AC vs AHI. Correlation coefficients (r or ρ) and corresponding p -values were reported. The significance level was set at $p < 0.05$.

Results

A total of 53 adolescents aged 7–18 years were initially enrolled in the study. Eight participants were excluded due to missing data, resulting in a final

sample of 45 participants (25 males, 20 females), with a mean age of 13.55± 2.2 years **(Table I)**.

All participants were confirmed to be asymptomatic for SDB, based on clinical history and parent-reported responses on the PSQ, with less than 33% affirmative responses. None had a prior diagnosis or treatment for OSA, craniofacial anomalies, or a history of orthodontic intervention.

SDB was assessed using HST via the Nox-T3s™ device, with results expressed as the AHI. The mean AHI of 2.71 events/hour (SD =1.63), with values ranging from 0.10 to 5.90 events/hour. The mean oxygen desaturation index (ODI) of 3.15 events/hour (SD=2.58), with values ranging from 0.4-12.00.

Malocclusion assessment revealed ABO-DI mean score was 17.53 ± 11.12. IOTN-DHC mean score was 3.04 ± 1.43 while the IOTN-AC mean score was 5.20 ± 2.65 **(Table I)**.

Table I: Descriptive Statistics

Variable	Mean	Range
Age (y)	13.55±2.2	9.00–17.92
BMI	22.5±7.45	13.65–44.59
AHI	2.71±1.63	0.10–5.90
ODI	3.15±2.58	0.40–12.00
ABO-DI	17.53±11.12	2–44
IOTN-DHC	3.04±1.43	1–5
IOTN-AC	5.2±2.65	1–10

Correlation analyses revealed no statistically significant relationships between malocclusion severity indices and SDB severity as measured by AHI. The ABO-DI showed a negligible negative correlation with AHI (r = –0.07, p-value = 0.62). Similarly, the IOTN-DHC and IOTN-AC demonstrated very weak positive correlations with AHI (ρ = 0.034, p-value = 0.817 and ρ = 0.069, p-value = 0.653, respectively). All 95% confidence intervals were wide and included zero, indicating uncertainty in the direction and magnitude of these associations. See **(TableII)** for full correlation results.

Table II: Correlation Analysis of Orthodontic Indices VS AHI			
Variables	**Correlation**	**95% CI**	***p-value***
ABO-DI VS AHI *(r)*	–0.0654	[-0.36, 0.23]	0.62
IOTN-DHC VS AHI (ρ)	0.0345	[-0.21,0.28]	0.817
IOTN-AC VS AHI (ρ)	0.0682	[-0.18,0.31]	0.653

Discussion

This study investigated whether malocclusion severity is associated with SDB in asymptomatic adolescents. The results revealed no statistically significant correlations between any orthodontic index—ABO-DI, IOTN-DHC, or IOTN-AC and SDB severity as measured by the AHI **(Table II)**. These findings indicate that structural malocclusion features alone cannot reliably predict subclinical or undiagnosed SDB in otherwise healthy adolescents seeking orthodontic treatment.

Malocclusion assessments showed that most participants fell within the moderate severity range according to standardized indices. The ABO-DI mean

score was 17.53 ± 11.12, with over 70% scoring above 10, indicating typical levels of dental misalignment seen in general orthodontic practice. The IOTN-DHC mean score of 3.04 ± 1.43 suggests mild-to-moderate treatment need, primarily in Grades 2–3. The IOTN-AC mean score of 5.20 ± 2.65 indicates mild-to-moderate aesthetic concerns. These distributions reflect a sample representative of routine orthodontic patients rather than those with severe occlusal or aesthetic deviations.

Although 64.4% of participants had an AHI ≥1 event/hour, a threshold considered abnormal by pediatric standards [17], the overall ODI remained low at 3.15 events/hour. Given that all participants were confirmed asymptomatic for SDB based on clinical history and PSQ scores, these elevated AHI values likely represent isolated or non-pathological respiratory events rather than clinically meaningful SDB.

The relationship between craniofacial structure and upper airway patency has been frequently discussed in the literature [1–3,11], particularly in pediatric populations where anatomical variations have been proposed to influence breathing during sleep. Some studies suggest that structural features such as maxillary hypoplasia, mandibular retrognathia, and increased lower facial height are often associated with reduced pharyngeal airway dimensions and may predispose individuals to obstructive events during sleep. However, this study found that while these morphological characteristics may contribute to airway vulnerability in some cases, they do not necessarily equate to

measurable airway dysfunction in asymptomatic individuals. This aligns with previous evidence indicating that airway function is influenced by a complex interplay of anatomical, neuromuscular, and ventilatory control mechanisms, rather than being determined solely by dental alignment or occlusal traits.

The AAO White Paper [18] emphasizes that orthodontists are uniquely positioned to identify craniofacial patterns associated with potential airway compromise but are not primary providers for diagnosing or managing OSA. Our findings support this stance, showing that orthodontic records are valuable for assessing occlusal and aesthetic traits but lack the sensitivity and specificity to serve as standalone indicators of airway function in children.

While certain malocclusion types, such as Class II relationships or maxillary constriction, are often associated with retrognathic mandibles and narrow airways [11], these morphological associations do not necessarily equate to clinically meaningful airway compromise unless supported by objective evidence of disturbed breathing during sleep. In fact, Rohra et al. (2018) reported that approximately 7% of orthodontic patients may be at risk for SDB based on PSQ scores [15]; however, in our sample, participants were specifically selected to exclude those with high-risk PSQ scores, resulting in a group where malocclusion traits are not associated with functional airway disturbances.

Therefore, orthodontists should continue to use validated screening tools to identify at-risk individuals and ensure timely referrals to sleep medicine specialists for formal evaluation via PSG or HST.

Limitations

One limitation of this study is its relatively small sample size (n = 45), which may have limited statistical power to detect weak correlations. A power analysis indicated that the study had 80% power to detect correlations of r = 0.4 or greater, but weaker associations—below this threshold—may have gone undetected. However, such small correlations are unlikely to be clinically meaningful, suggesting that the absence of significant findings likely reflects a true lack of a strong relationship.

Additional limitations include the use of auto-scored HST with the Nox-T3s™ device, which may not capture the full complexity of obstructive events compared to manually scored PSG. Furthermore, all participants were asymptomatic for SDB based on clinical history and standardized screening tools PSQ, limiting generalizability to higher-risk populations.

Finally, the reliance on a single night of unsupervised HST may not fully reflect the typical sleep and breathing patterns of participants, given known night-to-night variability in respiratory events during sleep.

These limitations highlight the need for future studies employing larger, more diverse cohorts; standardized, manually scored PSG; and advanced imaging

modalities to further clarify the relationship between craniofacial morphology and airway function in children.

Conclusion

This study found no statistically significant or clinically meaningful association between malocclusion severity and sleep-disordered breathing (SDB) in asymptomatic adolescents seeking orthodontic care. The results suggest that structural dental anomalies alone are insufficient to predict airway dysfunction in this population.

These findings support the view that while orthodontists play an important role in identifying craniofacial patterns associated with potential airway compromise, malocclusion indices such as the ABO-DI and IOTN are not reliable screening tools for subclinical SDB in the absence of symptoms.

Future research involving larger, more diverse cohorts and objective sleep assessments is needed to further clarify the relationship between craniofacial development and airway function. In the meantime, orthodontists should continue using validated screening tools and collaborate with sleep medicine specialists when SDB is suspected.

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Appendices

Appendix A: IRB Approval



IRB Administration Offices
UH IRB Phone: 216.844.1529
CWRU IRB Phone: 216.368.6925

INITIAL APPROVAL

Principal Investigator:	Mark Hans
Title:	Longitudinal Study of Sleep Behavior in Healthy Children and Adolescents
Submission Number:	STUDY20181067
IRB Office:	CWRU IRB
Approval Date:	3/12/2019
Effective Date:	3/12/2019
Approval End Date	N/A
Type of Submission:	Initial Study
Type of Review:	Expedited
Documents Reviewed:	• Health Adolescent Sleep , Category: IRB Protocol; • Hans - AAOF General Application (1).pdf, Category: Sponsor Attachment; • Health Adolescent Sleep Assent Form, Category: Consent Form; • Health Adolescent Sleep Informed Consent Parent/Guardian, Category: Consent Form;

The IRB has reviewed this submission.

- Per Federal regulation, changes MAY NOT be made to any element of the current research without prior IRB approval, except to eliminate an immediate and apparent hazard to subjects enrolled in the study.

***Approval by the IRB does NOT mean that you have permission to start your study. Prior to starting your study, you may be required to obtain (1) a coverage analysis for studies that involve patient care, regardless of source of funding, and/or (2) a contract with the Sponsor of your study or an agreement with any third-party collaborator that may receive UH or CWRU patient information in any format. Please ensure that all required approvals are obtained before initiation of research activity. ***

The UH IRB operates under HHS Federalwide Assurance (FWA) number 00003937 and IRB registration numbers 00000684, 00001691 and 00008600. The CWRU IRB operates under DHHS FWA00004428 and IRB registration number 00000683.

Appendix B: Abbreviation Key

ABO-DI: American Board of Orthodontics Discrepancy Index

ANB: Angle-Nasion-B point angle

AHI: Apnea-Hypopnea Index

BMI: Body Mass Index

CBCT: Cone-Beam Computed Tomography

HST: Home Sleep Apnea Testing

IOTN-AC: Index of Orthodontic Treatment Need – Aesthetic Component

IOTN-DHC: Index of Orthodontic Treatment Need – Dental Health Component

NOX-T3s™: Nox T3s™ Sleep Monitoring Device

ODI: Oxygen Desaturation Index

OSA: Obstructive Sleep Apnea

PSG: Polysomnography

PSQ: Pediatric Sleep Questionnaire

RME: Rapid Maxillary Expansion

SDB: Sleep-Disordered Breathing

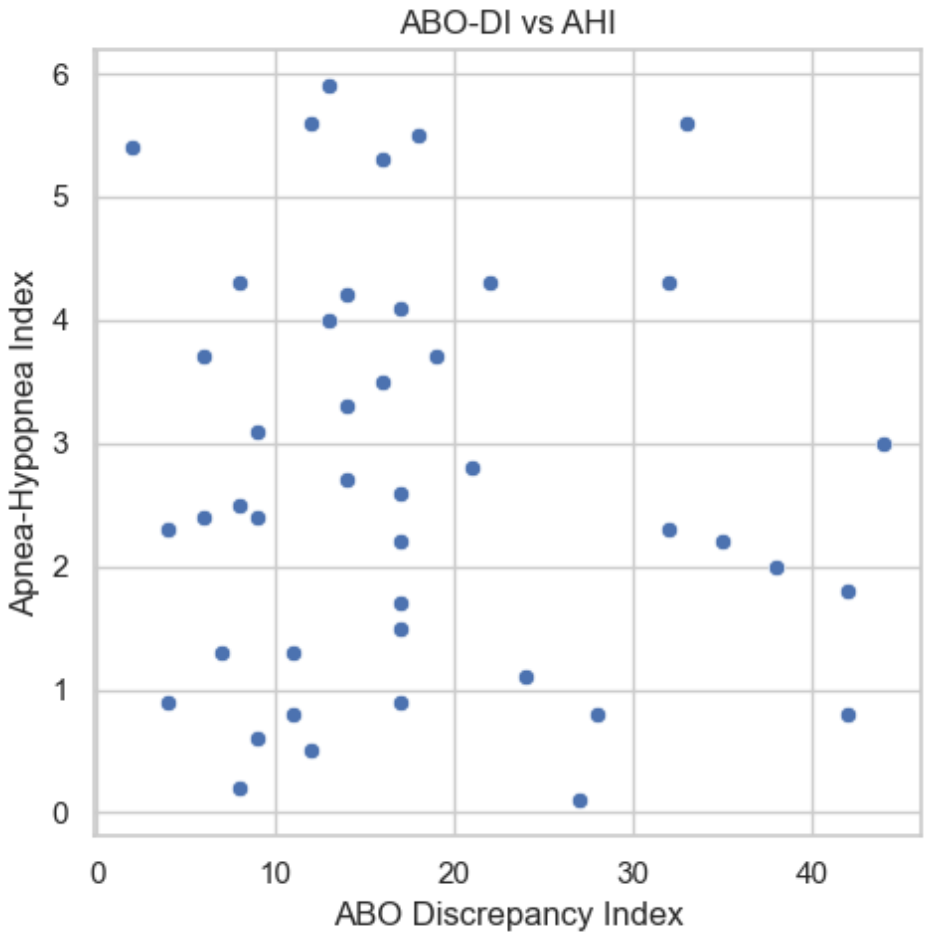
SPSS: Statistical Package for the Social Sciences

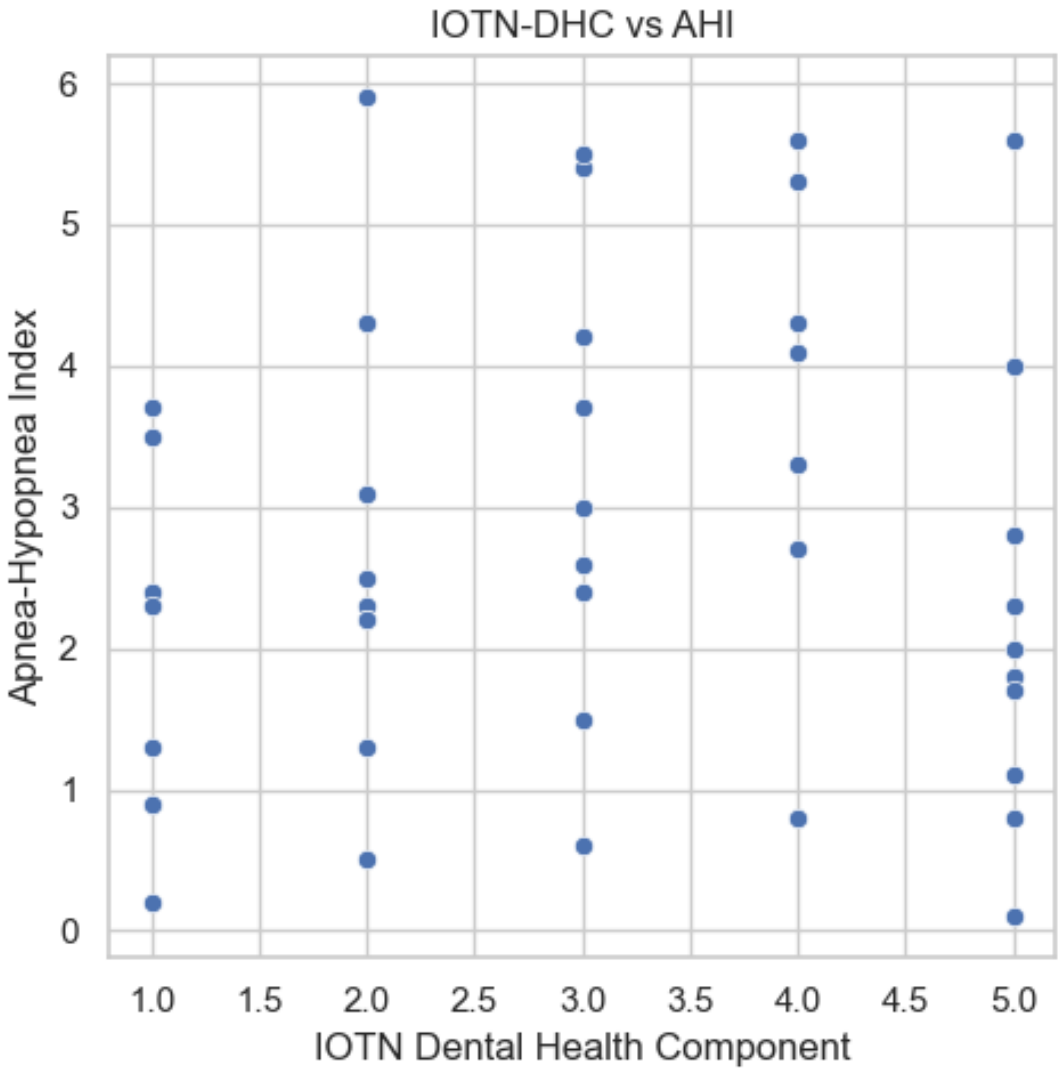
Appendix C: Data Tables

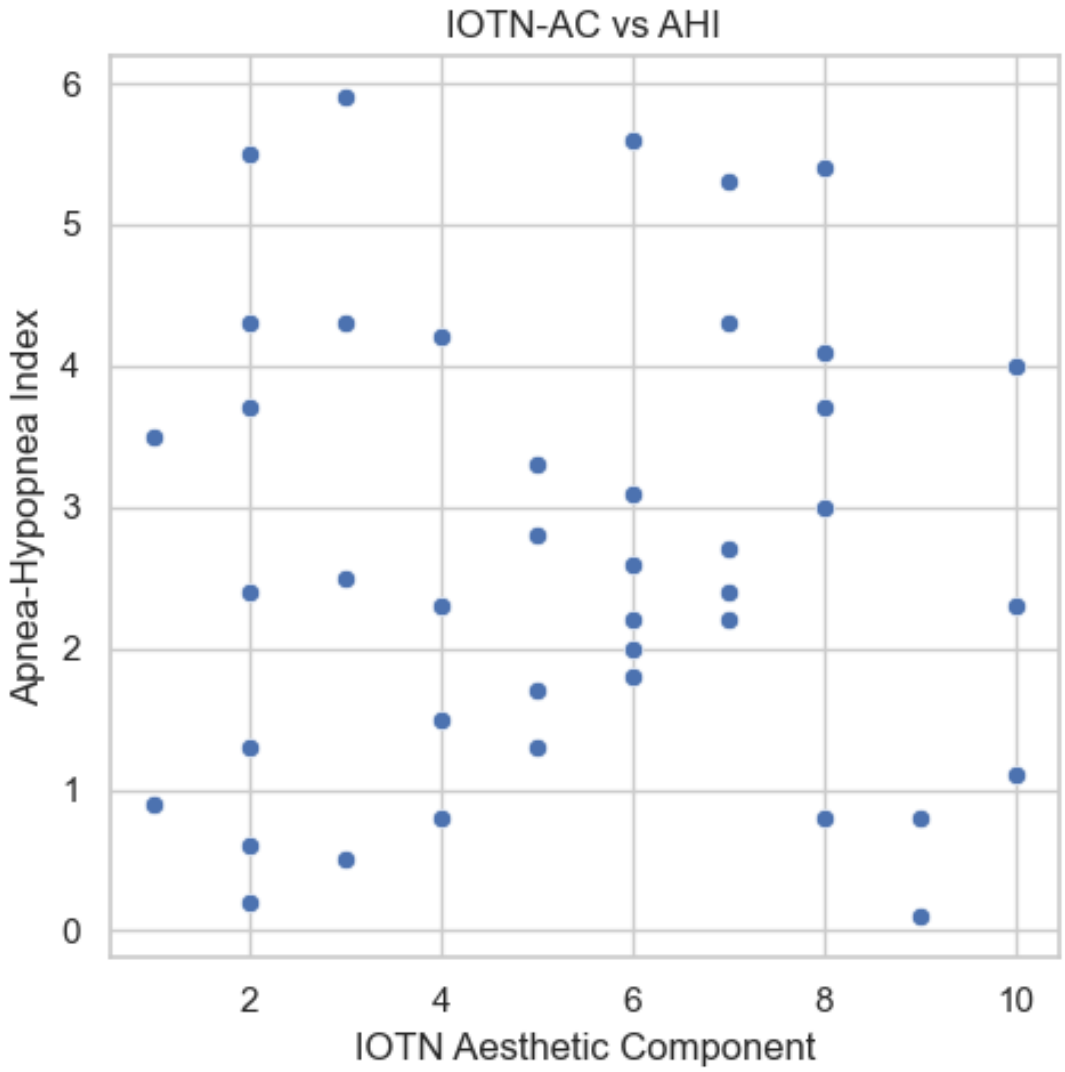
Table I: Descriptive Statistics		
Variable	**Mean**	**Range**
Age (y)	13.55±2.2	9.00–17.92
BMI	22.5±7.45	13.65–44.59
AHI	2.71±1.63	0.10–5.90
ODI	3.15±2.58	0.40–12.00
ABO-DI	17.53±11.12	2–44
IOTN-DHC	3.04±1.43	1–5
IOTN-AC	5.2±2.65	1–10

Table II: Correlation Analysis of Orthodontic Indices VS AHI			
Variables	**Correlation**	**95% CI**	***p-value***
ABO-DI VS AHI *(r)*	–0.0654	[-0.36, 0.23]	0.62
IOTN-DHC VS AHI (ρ)	0.0345	[-0.21,0.28]	0.817
IOTN-AC VS AHI (ρ)	0.0682	[-0.18,0.31]	0.653

Appendix D: Scatter Plots




IOTN-DHC vs AHI
Apnea-Hypopnea Index
0
1
2
3
4
5
6
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
IOTN Dental Health Component


IOTN-AC vs AHI
Apnea-Hypopnea Index
0
1
2
3
4
5
6
2
4
6
8
10
IOTN Aesthetic Component