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Original Article

Obstructive Sleep Apnea Prevalence, Upper Airway Dimensions, and Sleep Parameters in Skeletal Class III Malocclusion Patients Undergoing Orthognathic Surgery with Different Vertical Skeletal Patterns

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Abstract

Background: Craniofacial morphology's relationship with airway dimensions has been extensively studied. Despite this, evidence regarding obstructive sleep apnea (OSA) prevalence and differences in airway dimensions among vertical skeletal patterns in skeletal Class III malocclusion patients undergoing orthognathic surgery is limited. **Objective:** To determine the prevalence of OSA and compare upper airway dimensions and sleep parameters among skeletal Class III patients with different vertical skeletal patterns. **Materials and methods:** The study involved 98 adult patients (39 male and 59 female) with skeletal Class III malocclusions undergoing orthognathic surgery. Patients were divided into three groups according to vertical skeletal patterns: high-angle (SN-GoGn > 33°; 47 patients), low-angle (SN-GoGn < 25°; 20 patients), and normal-angle (SN-GoGn 25-33°; 31 patients) groups. OSA prevalence and sleep parameters, including the apnea-hypopnea index and lowest oxygen saturation, were assessed using a portable level III polysomnography device. Cone beam computed tomography was performed, and upper airway dimensions, including nasopharyngeal, oropharyngeal, hypopharyngeal, and total upper airway volumes and minimum cross-sectional area, were measured using Dolphin Imaging software. Group differences were analyzed using ANOVA and post hoc Tukey tests ($P < 0.05$). **Results:** The prevalence of OSA among skeletal Class III malocclusion patients was 11 of 98 (11.22 %). Upper airway dimensions and sleep parameters did not differ significantly among vertical skeletal pattern groups. **Conclusion:** Despite a comparable OSA prevalence in skeletal Class III patients, screening for OSA is crucial in those with Class III malocclusion undergoing mandibular setback surgery, irrespective of vertical patterns.

Keywords: Class III malocclusion, Obstructive sleep apnea, Sleep parameters, Upper airway, Vertical skeletal patterns

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Introduction

Skeletal Class III malocclusion is characterized by the presence of mandibular prognathism, maxillary retrognathism, or a combination of both. For non-growing patients with moderate to severe skeletal Class III malocclusion, a combination of orthodontic treatment and orthognathic surgery is preferred.[1] Orthognathic surgery that moves maxillomandibular structures can affect skeletal structures and related soft tissues, including the soft palate, tongue, and epiglottis. Two systematic reviews of airway changes after mandibular setback surgery have shown a significant decrease in the upper airway volume.[2,3] Moreover, some recent studies have reported that patients with a large mandibular setback can develop obstructive sleep apnea (OSA).[4,5]

OSA is the most common sleep breathing disorder and is characterized by repeated episodes of partial or complete obstructions in the upper airway during sleep, resulting in reduced oxygen saturation (SpO_2). OSA is associated with increased morbidity and mortality.[6,7] Polysomnography (PSG), which simultaneously monitors various sleep and respiratory parameters, is used to diagnose OSA and assess its severity. One parameter measured is the apnea-hypopnea index (AHI), which assesses the mean number of apneas and hypopneas per hour of sleep. Adult OSA can be categorized as mild (AHI from 5 to < 15 events/hour), moderate (AHI from 15 to < 30 events/hour), or severe (AHI $\geq$ 30 events/hour).[7] The anatomical structure of the upper airway and craniofacial region plays an important role in OSA development.[8,9] Craniofacial morphologies, including retrognathia, long and narrow faces, dolichocephalic facial type, narrow and deep palate, steep mandibular plane angle, anterior open bite, midface deficiency, and lower hyoid position, are predisposing factors for OSA.[10]

Among adults in the general population, the prevalence of OSA varies from 9 % to 38 %.[11] The prevalence of OSA in the Thai population is 11.40 %.[12] Positive correlations of increased age, male gender, and increased body mass index (BMI) with the occurrence of OSA were confirmed by a systematic review.[11] Among patients with OSA, one study found that the most frequent sagittal skeletal classification was Class II at 57.20 % and that the least frequent was Class III at 10.50 %, while the most frequent vertical classification was high angle at 54 %, and the least frequent was low angle at 19.30 %.[13] Nevertheless, there is a lack of data required to determine the frequency of OSA in patients with skeletal Class III malocclusion undergoing orthognathic surgery.

The relationship between craniofacial morphology and airway dimensions has been studied for decades. Numerous articles have analyzed the dimensions of the upper airway in patients with different sagittal and vertical skeletal facial morphologies. Cephalometric radiographs have historically been used to measure upper airway dimensions, but this method has some drawbacks, including distortion, low reproducibility due to challenges in identifying landmarks, variation in magnification, superimposition of bilateral craniofacial structures, and a two-dimensional (2D) anteroposterior linear dimension.[14] Airway examination improved with the introduction of cone beam computed tomography (CBCT), which produces more accurate and reliable images, generating more comprehensive data than 2D radiography.[15] Previous CBCT studies of sagittal relationships found that upper airway dimensions were smaller in Class II than in Class I and Class III patients, especially at the oropharyngeal level.[16-19] The results of the previous CBCT studies of the vertical relationship are still controversial. Grauer et al.[16] found no differences in airway volumes related to vertical skeletal patterns. Another study reported that the oropharyngeal and total airway volumes were highest in the low-angle group and lowest in the high-angle group in skeletal Class I patients.[20] However, there is a lack of data on differences in upper airway dimensions and sleep parameters among skeletal Class III patients with differing vertical skeletal patterns.

The aims of the study were as follows: 1) to determine the prevalence of OSA in skeletal Class III malocclusion patients undergoing orthognathic surgery and 2) to compare upper airway dimensions and sleep parameters among skeletal Class III patients undergoing orthognathic surgery with different vertical skeletal patterns.

Materials and methods

Study design and sample

This study was designed and implemented as an ambispective cohort study. The participants included skeletal Class III malocclusion patients requiring combined orthodontics and orthognathic surgery. Procedures involved both one-jaw, mandibular setback surgery, and two-jaw surgery, which comprised maxillary advancement and/or maxillary posterior impaction combined with mandibular setback from July 2019 to December 2023 at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chiang Mai University, Thailand. Participants were included according to the following criteria: Thai nationality; age 18 years or older; skeletal Class III malocclusion (ANB < 1.80 degrees; normal 3.80 ± 2.00 degrees);[21] undergoing combined orthodontics and orthognathic surgery; and good general health, according to the American Society of Anesthesiologists (ASA), at either ASA I or ASA II. Individuals were excluded if they had craniofacial syndromes, trauma, or pharyngeal or nasal pathology. The selected patients were divided into three groups based on vertical skeletal patterns using the SN-GoGn angle (high angle > 33 degrees, low angle < 25 degrees, and normal angle 25-33 degrees).[21] The Ethics Committee for Research Involving Human Experimentation Committee of the Faculty of Dentistry, Chiang Mai University, reviewed and approved the present study (No. 55/2022). All patients signed an informed consent form allowing use of their data for scientific purposes.

A pilot study was conducted to determine the minimum sample size. G*Power software version 3.1.9.4 (University of Kiel, Kiel, Germany) was used to calculate the sample size. Considering a power of 90 %, $P < 0.05$, and an effect size of 0.52, the final sample included 17 participants in each group.

CBCT image acquisition and upper airway volume assessment

Before orthognathic surgery, CBCT images were obtained using a mobile CBCT scanner, MobiiScan (NSTDA, Bangkok, Thailand), at 90 kV, 8 mA, 22 cm x 18 cm field of view, and 0.40 mm voxel size. Patients were scanned in a supine position. Before CBCT scan acquisition, patients were instructed to bite with maximum intercuspation, to place the tongue against the hard palate, to breathe normally, and not to swallow. The mean timeframe for pre-surgery CBCT scans was 29 days, with variations ranging from 1 to 95 days before the surgery date. The images were stored in Digital Imaging and Communications in Medicine (DICOM) format. To simulate 2D lateral cephalometry from CBCT images and to measure upper airway dimensions, Dolphin Imaging software version 11.90 (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) was utilized. All CBCT scans were taken and evaluated by a single examiner.

From the CBCT scan of each patient, the plane orientation was conducted manually using the method previously described by Guijarro-Martínez and Swennen.[22] 2D lateral cephalometry was simulated from three-dimensional (3D) CBCT. Linear and angular measurements, including SNA, SNB, ANB, SN-GoGn, and FMA angles, were recorded. The upper airway dimensions, including nasopharyngeal volume, oropharyngeal volume, hypopharyngeal volume, total upper airway volume, and minimum cross-sectional area, were measured using the method of Guijarro-Martínez and Swennen.[22] A threshold value of the upper airway morphology was manually adjusted until the pharyngeal airway was adequately depicted, with an average threshold of 60 (range 53-68). The software automatically calculated the upper airway volume of each component and the total upper airway volume in mm^3 (Figure 1).

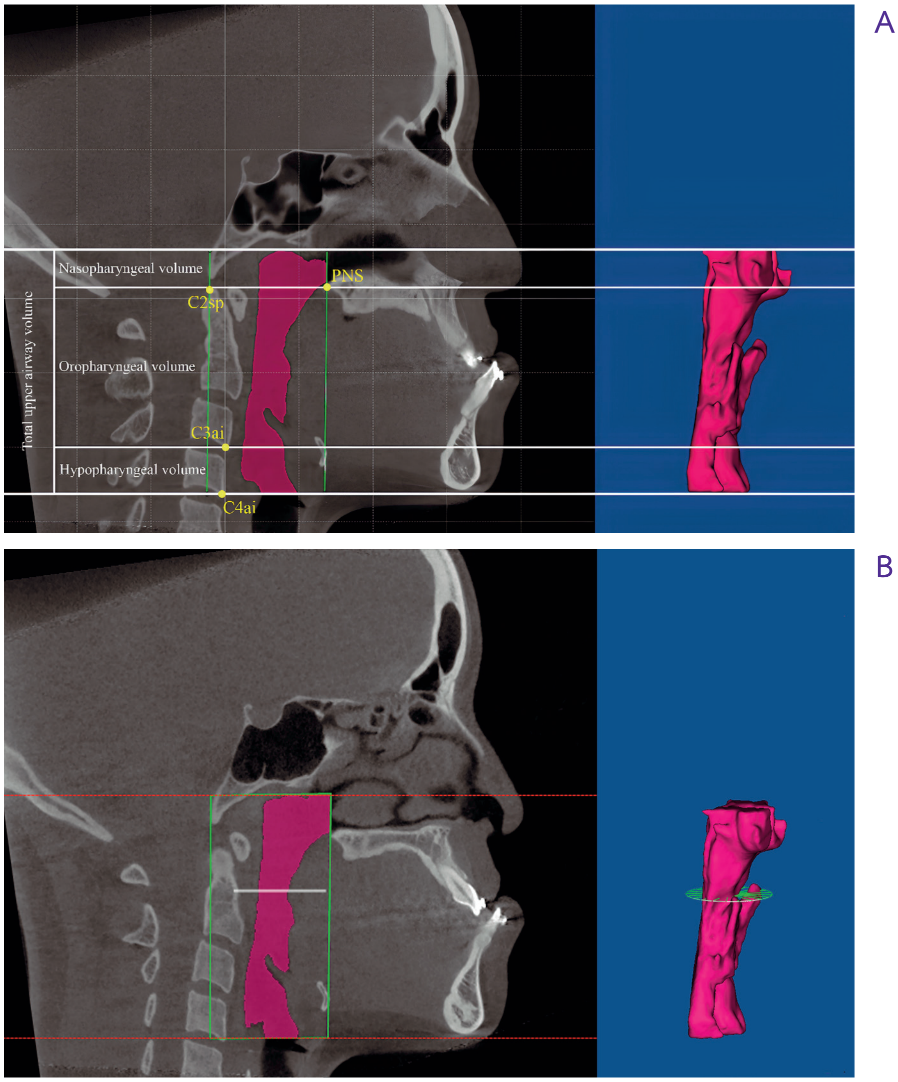

Figure 1 The boundaries of the upper airway dimensions. (A) Nasopharyngeal, oropharyngeal, hypopharyngeal, and total upper airway volume landmarks: posterior nasal spine (PNS), most superoposterior point of the second cervical vertebra (C2sp), most anteroinferior aspect of the third cervical vertebrae (C3ai), and most anteroinferior aspect of the fourth cervical vertebra (C4ai). (B) Minimum cross-sectional area.

Polysomnography evaluation

Before orthognathic surgery, patients were assessed for the sleep parameters monitored by overnight PSG, including AHI and lowest SpO_2, which were measured using a portable level III PSG device, namely, SOMNOlab 2 (Weinmann GmbH, Hamburg, Germany). The average duration for pre-surgery overnight PSG evaluation was 35 days, with a range from 1 to 168 days before the date of surgery. All sleep parameters were interpreted by an experienced otorhinolaryngologist.

Statistical analysis

To determine the intraobserver variability and reproducibility, 10 DICOM files were randomly selected, and upper airway volume was evaluated twice at an interval of 4 weeks by a single inspector. The resulting intraclass correlation coefficient more than 0.90 indicated high reliability. The Statistical Package for the Social Sciences (SPSS) version 24.0 for Windows (SPSS Inc., Chicago, IL, USA) was used to implement all statistical analyses. Descriptive statistics included the means and standard deviations of variables in all groups. Because the Shapiro-Wilk normality test confirmed a normal distribution of the data, comparisons between the groups were made using parametric tests. The distributions of the gender in each group were analyzed with a χ^2 test, and whether groups differed in chronological age or BMI was tested by one-way analysis of variance (ANOVA). One-way ANOVA was performed to test for potential differences in upper airway volume and sleep parameters among groups, and a post hoc Tukey honestly significant difference test was employed to evaluate individual differences. The results were considered statistically significant if $P < 0.05$.

Results

The overall sample included 98 patients who met the inclusion but not the exclusion criteria. The following demographic characteristics of the sample population were observed: there were 47 patients in the high-angle group (mean age: 22.79 ± 3.77 years; 20 males and 27 females; BMI: 21.09 ± 2.95 kg/m^2), 20 patients in the low-angle group (mean age: 22.50 ± 4.80 years; 11 males and 9 females; BMI: 22.22 ± 3.20 kg/m^2), and 31 patients in the normal-angle group (mean age: 24.71 ± 7.09 years; 8 males and 23 females; BMI: 20.94 ± 3.24 kg/m^2). The comparison of demographic characteristics, (Table 1) including age and BMI, of the sample population in three vertical skeletal patterns showed no significant differences ($P > 0.05$). One cephalometric measurement, ANB angle, showed no significant differences among groups. However, the significant differences ($P < 0.05$) in SNA, SNB, SN-GoGn, and FMA angles were found among groups (Table 1).

The prevalence of OSA severity among skeletal Class III malocclusion patients was 11 of 98 (11.22 %), with 8 (7.14 %) classified as mild severity and 3 (3.06 %) as moderate severity. There were 2 (4.25 %) and 2 (4.25 %) patients with mild and moderate OSA

Table 1 Demographic characteristics and cephalometric measurements in three vertical skeletal patterns.

Mean (SD)	High angle (n = 47)	Low angle (n = 20)	Normal angle (n = 31)	*P* value
Gender (n)				0.101
Male	20	11	8	
Female	27	9	23	
Age (years)	22.79 (3.77)	22.50 (4.80)	24.71 (7.09)	0.211
BMI (kg/m^2)	21.09 (2.96)	22.22 (3.20)	20.94 (3.24)	0.308
SNA (degrees)	81.46 (2.74)	85.55 (3.99)	84.89 (3.99)	0.000
SNB (degrees)	84.09 (2.86)	88.95 (5.47)	87.10 (3.45)	0.000
ANB (degrees)	−2.64 (2.16)	−3.42 (3.09)	−2.73 (2.97)	0.526
SN-GoGn (degrees)	37.02 (2.84)	22.39 (2.28)	30.11 (1.93)	0.000
FMA (degrees)	28.43 (3.92)	17.35 (4.36)	23.45 (3.56)	0.000

Table 2 Frequencies and percentages of OSA severity in three vertical skeletal patterns.

OSA severity	High angle (*n* = 47)		Low angle (*n* = 20)		Normal angle (*n* = 31)	
	n	%	*n*	%	*n*	%
Normal	43	91.50	17	85.00	27	87.10
Mild	2	4.25	3	15.00	3	9.68
Moderate	2	4.25	-	-	1	3.22
Severe	-	-	-	-	-	-
Total	47	100	20	100	31	100

Table 3 Comparisons of airway dimensions and sleep parameters in the vertical skeletal patterns.

Mean (SD)	High angle (*n* = 47)	Low angle (*n* = 20)	Normal angle (*n* = 31)	*P* value
Nasopharyngeal volume (mm^3)	7,537.53 (2,461.09)	7,516.65 (2,667.04)	7,141.77 (2,325.74)	0.767
Oropharyngeal volume (mm^3)	15,574.47 (5,767.83)	14,180.05 (4,815.44)	12,993.42 (4,771.49)	0.109
Hypopharyngeal volume (mm^3)	4,743.91 (1,666.41)	5,181.65 (2,060.76)	4,153.32 (1,602.06)	0.108
Total upper airway volume (mm^3)	27,787.30 (8,439.69)	26,878.35 (8,333.62)	24,288.52 (7,185.84)	0.172
Minimum cross-sectional area (mm^2)	85.83 (50.73)	92.80 (61.55)	87.55 (47.15)	0.881
AHI (events/hour)	1.68 (3.77)	1.85 (2.23)	2.18 (3.85)	0.829
Lowest SpO_2	86.91 (5.44)	84.40 (7.30)	86.80 (5.10)	0.236

severity, respectively, in the high-angle group. In the low-angle group, 3 patients (15 %) had mild OSA severity. In the normal-angle group, 3 patients (9.68 %) exhibited mild OSA severity, while 1 (3.22 %) had moderate OSA severity (Table 2).

Table 3 compared airway dimensions and sleep parameters in three vertical skeletal patterns. No statistically significant differences were observed in the nasopharyngeal volume, oropharyngeal volume, hypopharyngeal volume, total upper airway volume, or minimum cross-sectional area across patients with various vertical skeletal patterns ($P > 0.05$). Likewise, there were no statistically significant differences in the AHI or lowest SpO_2 among patients with different vertical skeletal patterns ($P > 0.05$).

Table 4 Comparisons of oropharyngeal and hypopharyngeal volumes between the genders and groups

Mean (SD)	Oropharyngeal volume (mm^3)	*P* value	Hypopharyngeal volume (mm^3)	*P* value
High angle				
Male (*n* = 20)	17,935.85 (6,274.78)		5,740.40 (1,609.76)	
Female (n = 27)	13,825.30 (4,755.98)		4,005.78 (1,299.90)	
Low angle				
Male (*n* = 11)	16,425.18 (4,732.56)	0.003	6,460.09 (1,839.74)	0.000
Female (*n* = 9)	11,436.00 (3,416.75)		3,619.11 (927.99)	
Normal angle				
Male (*n* = 8)	15,000.00 (5,812.02)		5,798.88 (1,741.61)	
Female (*n* = 23)	12,295.48 (4,280.72)		3,580.95 (1,098.92)	

Comparisons of oropharyngeal and hypopharyngeal volumes between the genders are shown in Table 4. Male had higher oropharyngeal and hypopharyngeal volumes than female in all groups ($P < 0.05$). In contrast, there were no statistically significant differences in nasopharyngeal volume, total airway volume, minimum cross-sectional area, or sleep parameters between the genders ($P > 0.05$).

Discussion

The results of this study demonstrated that the overall prevalence of OSA in skeletal Class III malocclusion patients was 11.22 %, and 72.72 % of OSA patients had mild severity. The upper airway dimensions and sleep parameters of skeletal Class III malocclusion patients did not differ significantly among vertical skeletal pattern groups.

Combined orthodontic and orthognathic surgery has proven to be the most effective treatment for moderate to severe skeletal Class III malocclusion. Surgically correcting skeletal deformities in patients with Class III malocclusion involves displacing the maxilla and/or mandible. This surgical intervention changes the relationship between the bony structures and the soft tissues, including those closely associated with the upper airway anatomy.[23] In most studies, undergoing isolated mandibular setback surgery led to a decrease in the nasopharyngeal, oropharyngeal, hypopharyngeal, and total airway volumes.[24-26] Bimaxillary surgery, which includes mandibular setback, has been associated with a reduction in airway volume. However, it is noteworthy that the magnitude of this reduction tends to be less than that observed with isolated mandibular setback surgery.[24,25] The impact of the upper airway anatomy on airway obstruction is widely acknowledged. In individuals with sleep apnea, the upper oropharyngeal airway is typically smaller than in control participants without sleep disorders.[27] Furthermore, recent studies have indicated that a significant mandibular setback can contribute to the development of OSA.[4,5] This underscores the importance of investigating airway dimensions and sleep parameters in this particular group of patients.

Magnetic resonance imaging (MRI), cine-MRI, endoscopy, optical coherence tomography, cephalometry, conventional CT, and CBCT are among the imaging methods used to evaluate the upper airway.[28] Although MRI seems to be the best imaging method for measuring the upper airway, it has numerous disadvantages, such as high cost, limited access, weight restrictions, and difficulty of use in patients who have claustrophobia or metal devices implanted in the body. Since the 1990s, CBCT has been a generally accepted tool for diagnostic and treatment planning in orthodontics and oral and maxillofacial surgery. Compared to traditional CT, CBCT provides a few benefits, such as less radiation exposure, lower prices, higher accessibility, and faster acquisition times.[28] In numerous studies, CBCT also was shown to be precise and reliable for analysis of the upper airways.[28-30] Therefore, CBCT was used in the present study.

The current study focused on recording upper airway data when patients were in a resting supine position, which is considered to better simulate a patient's sleep posture than other positions. Additionally, the supine position often triggers symptoms of OSA. A study by Joosten et al.[31] highlighted that supine OSA is a major characteristic of the OSA syndrome, potentially explaining why the supine position is particularly conducive to upper airway collapse. This rationale supports the decision to conduct measurements while patients were in a supine body position.

The 3D software used in the present study, Dolphin Imaging, has been shown to be both accurate and reliable in the measurement of upper airway dimensions.[28,32] Among its advantages are the abilities for the user to manually change the threshold values and to evaluate reconstructions in three dimensions (axial, coronal, and sagittal). However, the high cost of the software and the incompatibility of its sensitivity threshold with other image software options are limitations.[32]

In this study, level III PSG was employed to measure sleep parameters. Level III PSG relies on a portable device to monitor at least four parameters.[33] This option was introduced as a more accessible and less expensive alternative to in-laboratory PSG. Moreover, the examination is performed in a more relaxed and natural environment than in-laboratory PSG. According to a systematic review and meta-analysis, level III portable devices demonstrated good diagnostic performance in comparison to level I sleep tests in adult patients with a high pretest probability of moderate to severe OSA and no unstable comorbidities.[34]

Kim et al.[13] reported that, in OSA patients, the sagittal skeletal classification had a frequency distribution of 32.30 % for Class I, 57.20 % for Class II, and 10.50 % for Class III malocclusion. The distribution of vertical classification was 26.70 % for normodivergent, 54 % for hyperdivergent, and 19.30 % for hypodivergent types. Class II hyperdivergent patients have the highest chance of experiencing OSA. Moreover, when considering only the sagittal skeletal relationship, it becomes evident that Class III patients are less likely to have OSA. The current study discovered that the prevalence of OSA among skeletal Class III patients was 11.22 %, which does not differ from the rates observed in the general population (ranging from 9 % to 38 %)[11] or the general Thai population (11.40 %).[12]

Few studies have reported airway volume in patients with different vertical skeletal patterns. In individuals not classified by sagittal skeletal relationships, Grauer et al.[16] found that there were no significant differences in the nasopharyngeal, oropharyngeal, hypopharyngeal, or total airway volumes among the high-angle, normal-angle, and low-angle groups. It is evident from both past studies and the present study that different vertical skeletal patterns have diverse impacts on the upper airway within each group of patients categorized by sagittal skeletal relationships. Wang et al.[35] reported that, in individuals with a skeletal Class II relationship, the high-angle group had significantly lower glossopharynx volume than normal-angle and low-angle groups, respectively. In contrast, another study reported that, among skeletal Class I patients, oropharyngeal and total airway volumes were highest in the low-angle group and lowest in the high-angle group.[20] In the current study involving skeletal Class III patients, we found no significant differences in pharyngeal airway volume measurements among the groups with different vertical skeletal patterns.

Insufficient evidence exists to establish an association between sleep parameters and various craniofacial morphologies, including both sagittal and vertical skeletal relationships. The current study found that a variety of vertical skeletal patterns in Class III malocclusion patients did not impact sleep parameters, including AHI and lowest SpO_2. However, additional study is imperative to explore sleep parameters within groups of patients exhibiting diverse craniofacial structures.

In the current study, male with skeletal Class III malocclusion exhibited significantly larger oropharyngeal and hypopharyngeal volumes than female. This aligns with the findings of Chiang et al.,[36] who also identified a significant gender-related difference in airway volume. Another study[37] observed a noteworthy gender-related difference in airway volumes, specifically in the retropalatal and retroglossal regions within the Class III group, but no significant difference was noted in nasopharyngeal airway volumes. However, no significant gender differences in airway volumes were found in various other previous studies.[16,19,20] The observed variation in various characteristics among studies, such as differences in sample size, gender distribution, age distribution, and the utilization of distinct anatomical landmarks to define the airway, suggests that these factors could be contributing to the differences in results. These methodological distinctions may impact the interpretation and comparison of outcomes across studies.

Another noteworthy consideration is that previous research has highlighted disparities in the upper airway characteristics between individuals with and without OSA.[38] It would be intriguing to explore within-group differences between subjects with and without OSA in further studies. This comparative analysis could offer valuable insights into the distinct features of the upper airway associated with OSA.

In clinical practice, before commencing treatment for skeletal Class III malocclusion patients, particularly those necessitating mandibular setback surgery, it is essential to conduct screening for OSA. This is crucial in enabling orthodontists and maxillofacial surgeons to identify the most effective treatment approach that minimally impacts upper airway dimensions and preserves sleep quality.

Conclusion

The upper airway dimensions and sleep parameters of skeletal Class III malocclusion patients did not differ significantly among vertical skeletal pattern groups. However, despite the prevalence of OSA in skeletal Class III patients being 11.22 %, a figure not significantly different from rates observed in the general population, it remains crucial to conduct screening for OSA in skeletal Class III malocclusion patients undergoing mandibular setback surgery.

Author contributions

TK: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, and Visualization; NS: Conceptualization, Investigation, Resources, Writing-Review & Editing, and Supervision; KT: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Writing-Review & Editing, Visualization, Supervision, Project administration, and Funding acquisition.

Ethical statement

The research protocol was approved by the Ethics Committee of the Faculty of Dentistry, Chiang Mai University (No. 55/2022).

Disclosure statement

Authors have no the conflict of interest.

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Original Article

Comparison of Masticatory Muscle Effort when Chewing on an Anterior Bite Plane Fabricated from Hard and Soft Materials

Passakorn Wasinwasukul* Udom Thongudomporn** Methee Promsawat***

Abstract

Background: Different anterior bite plane materials may affect masticatory muscle effort (ME) differently. ME is defined in this study as the electrical activity used per unit of bite force. **Objective:** We aimed to compare the effects of a hard acrylic resin anterior bite plane (HARD) and a semi-soft thermoplastic anterior bite plane (SOFT) on ME over a 3-month period in children with deep bites. **Materials and methods:** Thirty-eight children with deep bites were randomly assigned to either the HARD or SOFT group (n = 19 each). Masseter and anterior temporalis activity along with maximum bite force (MBF) were measured during appliance placement. Anterior and posterior ME were calculated by dividing muscle activity by the anterior and posterior MBF, respectively. Data were collected at baseline (T0), at one month (T1), and at three months (T2). Within- and between-group comparisons were performed ($\alpha = 0.05$). **Results:** Neither significant intra-group nor between-group of ME was found throughout the study period ($P > 0.05$). **Conclusion:** Neither a hard nor soft anterior bite plane had a disadvantageous effect on ME as none of the ME values exceeded the baseline values during treatment.

Keywords: Bite force, Deep bite, Hardness, Masticatory muscles, Orthodontic appliances

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Introduction

Several parameters have been used to assess the changes in masticatory functions after orthodontic interventions. The changes can include maximum bite force, masticatory muscle activities, masticatory performance, muscle activity balance, and occlusal contact area,[1-5] all of which measure its own specific aspect of masticatory function. Another parameter namely masticatory muscle effort (ME) stands as a crucial parameter that has been extensively investigated.[6-8] It encompasses the effective completion of masticatory tasks by an oral apparatus without unnecessary time or energy consumption.[9] Various methodologies have been employed to explore this concept with the common goal of assessing the effort exerted by the masticatory system in achieving a unit of masticatory outcome.

ME has been characterized in various ways that range from assessing the effort needed for standardised comminution to measuring individual abilities to fragment foods within a specific time frame.[7] Studies have employed diverse metrics such as the ratio of electrical signals of masticatory muscles to maximum bite force (MBF),[10] work output by MBF divided by energy input via surface electromyography (sEMG),[11] or the slope of bite force/sEMG under assigned bite forces.[12] In this study, ME is defined as the electrical activity used per unit of bite force (EMG/BF ratio),[13,14] which implies that higher ME indicates increased activity of masticatory muscles in generating a unit of bite force.

Research suggests that occlusal rehabilitation and correction of malocclusion can positively impact masticatory efficiency, or, in other words, improve ME. Vertical rehabilitation with complete dentures[6] and correction of retrognathic mandibles using functional jaw orthopedics[15] have demonstrated ME improvement. Conflicting results exist with certain studies that reported no significant change in ME among patients treated with fixed orthodontic appliances.[8]

A shift from posterior to anterior occlusion can impact function, as evidenced in a study involving adults with Class I malocclusion exhibiting normal overjet and overbite. This study demonstrated increased muscular effort during anterior biting, which indicated that alterations in occlusal patterns may influence masticatory muscle function.[16] The observed differences in vertical dimensional changes may be attributed to variations in muscle activity and bite force.[4] Notably, biting an object with the incisors requires a smaller mouth opening compared to biting on the molars.

According to a mechanical advantage study,[16] a reduced mouth opening correlates with higher masticatory muscle effort needed to generate a unit of bite force. We hypothesized that individuals with a deep bite may exhibit the opposite pattern. The excessive vertical overlap of the incisors in deep bite patients may necessitate a greater mouth opening when biting on the incisors than when biting on the molars. Consequently, muscle effort may differ from that observed in subjects with a normal overbite.

It is important to consider that the use of an anterior bite plane, commonly employed to address deep bites, further increases the required mouth opening beyond the normal range. However, the impact of a removable anterior bite plane on masticatory efficiency remains unexplored. Material hardness on the biting surface is another factor that may influence muscle effort by altering the proprioceptive feedback pathway. Studies indicated that softer thermoplastic materials for orthodontic appliances might have advantages in terms of aesthetics, comfort, and flexibility. However, a direct comparison of ME between hard acrylic resin and semi-soft thermoplastic materials, particularly in the context of anterior bite planes, is lacking.

This randomised clinical study aimed to address this gap by comparing the effects of a hard acrylic resin anterior bite plane (HARD) and a semi-soft thermoplastic anterior bite plane (SOFT) on ME over a three-month period in children with a deep bite. The hypothesis posited no significant difference in ME between subjects wearing either the HARD or the SOFT.

Materials and methods

Study design

This study was a blind secondary data analysis from a previous randomized controlled trial[1] conducted at the Dental Hospital, Faculty of Dentistry, Prince of Songkla University with an equal allocation ratio. The intention-to-treat protocol was applied under the authorization of the human experimental ethics committee of the Faculty of Dentistry, Prince of Songkla University (Ethical Approval Number: EC6305-019) and submitted to the Thai Clinical Trial Registry (TCTR20210330002).

Sample size calculation

The sample size was calculated based on a study that investigated jaw-muscle mechanical advantage and activities during isometric bites in normal adults[16] using the G*power program version 3.1.[17] Using an effect size of 0.84, α = 0.05, and β = 0.80, at least 19 samples were needed per group.

Participants, eligibility, and setting

Healthy subjects aged 9-13 years with late mixed dentition who attended the Dental Hospital of the Faculty of Dentistry, Prince of Songkhla University in previous study were randomly recruited into this study. All individuals and their parents provided written informed consent prior to participation in the study.

Before enrollment in the study, all volunteers underwent a dental examination by one examiner to determine the degrees of overjet and overbite with reference to the occlusal plane. The most vertical and horizontal overlapping of the maxilla and mandibular central incisors (overbite and overjet) were evaluated using a periodontal probe. Lateral cephalometric radiographs were taken following the same protocol and using the same machine to determine the vertical and horizontal skeletal relationships. An investigator analysed the cephalometric data using Dolphin Imaging software version 11.9 (Dolphin Imaging and Management Solutions, Chatsworth, CA, USA).

The inclusion criteria included participants with (1) maxillary incisal edges that vertically covered more than 40 % of the clinical crown height of the mandibular incisors, (2) an overjet range of 1 to 5 mm, (3) skeletal Class I or mild Class II (ANB = 1-9°), (4) normodivergent or hypodivergent pattern (SN-MP < 35°), (5) angle Class I or II molar relationship, (6) no history of trauma to the lower or upper anterior teeth, (7) no signs and symptoms of a temporomandibular disorder or parafunctional habits, and (8) no prior history of orthodontic treatment.

Subjects were not enrolled if they had (1) incomplete root formation of the mandibular incisors on panoramic radiographic imaging, (2) clinical absence of the mandibular incisors or first molars, (3) insufficient tooth number or insufficient clinical crown height to provide retention of an appliance, (4) craniofacial anomalies, systemic diseases, or neuromuscular disorders, (5) long-term use of anti-inflammatory drugs, immunosuppressive medications, or neuromuscular-targeting medications, or (6) an inability to co-operate with the trial.

Randomization and blinding

The recruited subjects were consecutively randomly assigned by computer-generated numbers into the two types of anterior bite planes (n = 19 each) (www.random.org). The participants were treated by two orthodontists and the data collection and measurements were performed by one investigator. Blinding of both subjects and operators to the appliance materials was not feasible. Therefore, a single-blind approach was implemented at the level of the statistician.

Interventions

The HARD appliance was anchored with Adam's clasps around the upper first molars accompanied by a labial bow and a baseplate featuring a front bite surface made of polymethyl methacrylate (PMMA). The labial bow was extended to preserve space for the permanent canine in case of uneruption or

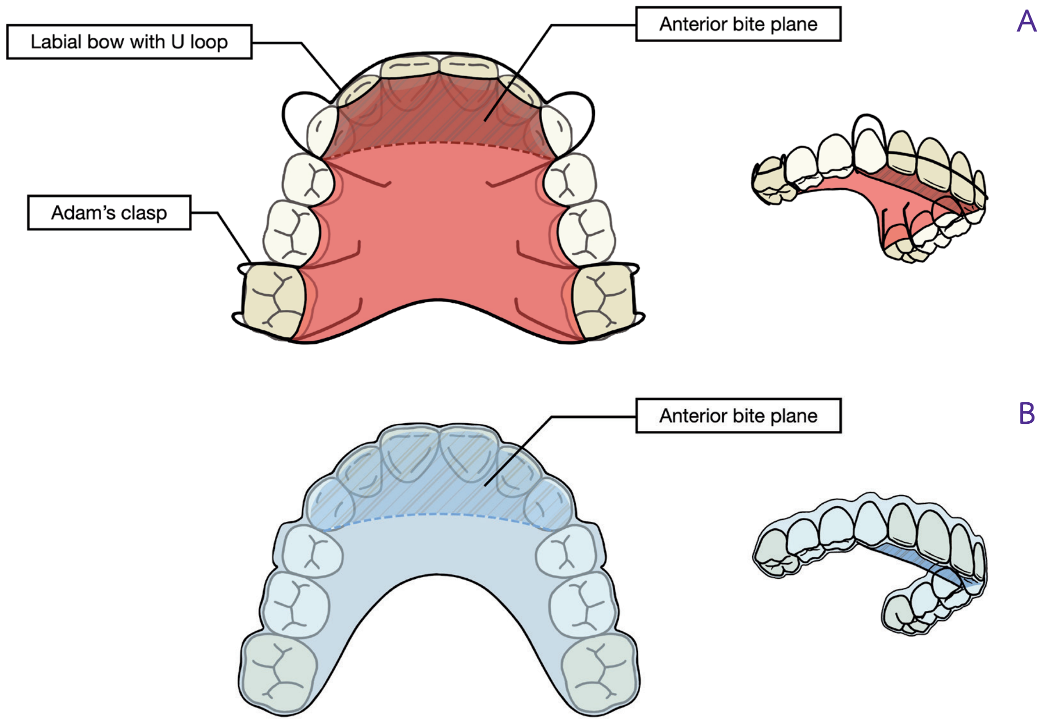


Figure 1 Occlusal view and the components of the HARD (A) and SOFT (B)

partial eruption. This configuration was positioned in the articulated dental model at the centric relation while maintaining a 2-mm separation between the first permanent molars. (Figure 1A). Four mandibular incisors were consistently occluded on the bite plane. The SOFT appliance was made from 1.80-mm-thick thermoplastic bi-laminate composed of polyethylene terephthalate glycol copolyester and polyurethane (Durasoft® pd; Scheu-Dental, Iserlohn, Germany). An anterior bite plane was prepared on the palatal surface of the maxillary incisors with plaster on the working model. The models were articulated the same as the HARD appliance, except that the first permanent molars were 2.50 mm vertically separated to compensate for the 0.30-0.50 mm shrinkage of the material thickness during the heated vacuum forming process. This ensured that both groups had an equal amount of bite opening. The margin of the SOFT appliance was then trimmed apically 2-3 mm beyond the gingival margin (Figure 1B).

The participants were instructed to wear the appliance at all times. Daily reminders were sent to the participants via a smartphone text application to enhance compliance. The participants were scheduled for follow-up every month after receiving the appliance. If an appliance broke or was lost, it was repaired or refabricated as quickly as possible.

Electromyographic examination

Surface electromyography (sEMG) was performed using an 8-channel BioEMG III and BioPAK Measurement System (BioResearch, Inc., Milwaukee, WI, USA) to evaluate the muscle activity of the masseter and anterior temporalis muscles. The data were recorded in microvolts (μV) following the Surface Electromyography for the Non-Invasive Assessment of Muscles guidelines.[18]

The participants sat relaxed in a chair with unsupported head for 5 minutes prior to the examination in a quiet environment without interruptions. The superficial skin of the target muscles was scrubbed with 70 % alcohol and dried before electrode placement. Bipolar surface electrodes (BioFLEX, BioResearch Associates, Inc., Brown Deer, WI, USA) with fixed distances of 20 mm were positioned on the target muscles and confirmed by the modified template by Castroflorio et al.[19] According to Ferrario et al.,[20] electrodes for the anterior temporalis muscles were placed vertically along the anterior muscular margin over the coronal suture. The electrodes for the masseter muscles were aligned parallel to the muscle fibres. The upper pole of the electrode was located at the intersection between the tragus-labial commissure and the exocanthion-gonion lines. Ground electrodes were attached on the most prominent part of the cervical spine on the posterior neck.[21]

Participants were instructed on the measurement procedures and allowed to practice to attain reproducibility. With the appliance in place, the subjects were instructed to clench their teeth as hard as possible for 3 seconds on 10-mm-thick cotton rolls placed on both sides of the posterior teeth. The highest value was set as 100 % as a reference point to standardise the subsequent data across the subject and timing. Following this, with the appliance still in the mouth, the participants followed the instruction to produced five series of 3 seconds of maximal clenching and 3 seconds relaxing. The average values were calculated as the percentage of maximum voluntary clenching compared to the reference value (% MVC). Data were collected at four time points: pretreatment (T0), which served as the baseline data without the appliance in place; at 1 month (T1); and at 3 months (T2) after appliance delivery measured with the appliance intraorally.

Maximum bite force (MBF) recording

A 6-mm-thick custom-made bite force meter with a force-sensing resistor was used to assess the anterior and the right and left posterior MBF. The sensor was calibrated with a Universal Testing Machine (Lloyd instruments, Model LRX-Plus, AMETEK Lloyd Instrument Ltd., Hamphshire, United Kingdom), in increments of 50 Newtons (N) from 0 to 800 N. The validity and reliability were confirmed with a Pearson's correlation of 0.99 and an intraclass correlation of 0.99. The components of the bite force recording device and measurement procedure were previously published[1,2] (Figure 2).

The MBF was recorded subsequent to the sEMG recording with 15 minutes of rest. Subjects were asked to sit upright without head support and rest for 5 minutes before the measurement. The bite force recording device was sterilized and covered with a piece of disposable latex sheet.

The centre of the device's sensor was placed on the maxillary central incisors area for the anterior MBF measurement, and on each permanent maxillary first molar to record the right and left MBF. With the appliance in place, subjects were requested to bite as hard as possible without pain for 3 seconds with 30 second intervals to avoid muscle fatigue. The MBF

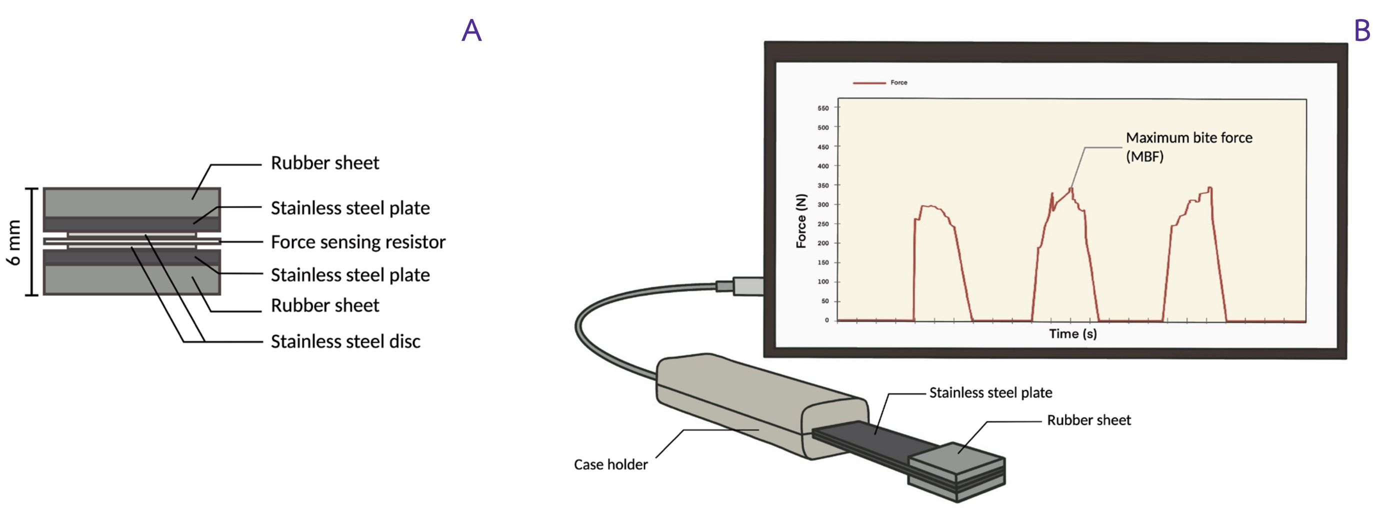


Figure 2 Composition of the custom-made bite force meter (A) and measuring program (B)

was automatically calculated and displayed in N. Three replicates were performed, and the maximum values were averaged. The posterior MBF was calculated as the average of the right and left MBF. Data were gathered at four time points following the same schedule as the sEMG measurements.

Masticatory muscle effort (ME)

The ME, which was defined as the ratio of energy input to work output, was derived from the division of the % MVC by the anterior or posterior MBF while wearing the appliance regarding each muscle (% MVC/ MBF). The anterior and posterior ME of the masseter and temporalis muscles were calculated.

Statistical analysis

The results were analysed by SPSS program version 17 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test signified the normal distribution of age and cephalometric values, while non-normal distribution was presented in other parameters. Thus, the student *t*-test was used to analyse the differences of age and cephalometric values between groups. Non-parametric statistical tests were applied due to large variations among subjects as follows: Chi-square test for gender ratio evaluation, Mann-Whitney *U* test to compare % MVC, MBF, and ME between the two treatment groups and assess similarity across the sides of MBF and % MVC, and Friedman's tests with pairwise comparisons and the Bonferroni correction for within-group comparison across the session of % MVC, MBF, and ME. The level of significance was set at $P < 0.05$.

The repeatability of the dentoskeletal evaluation and muscle activity was re-examined after 15 minutes in 10 random subjects by the same protocol and examiner. The intraclass correlation coefficient (ICC) presented acceptable reproducibility (ICC = 0.93-0.97 for lateral cephalometric variables, 0.65-0.79 for sEMG variables, and 0.55-0.85 for MBF). Dahlberg's formula indicated acceptable random error (0.50° for angular variables, 0.50 mm for linear variables, 19.83 μV for muscle activity, 15.99 N for anterior MBF, and 75.18 N for posterior MBF).

Results

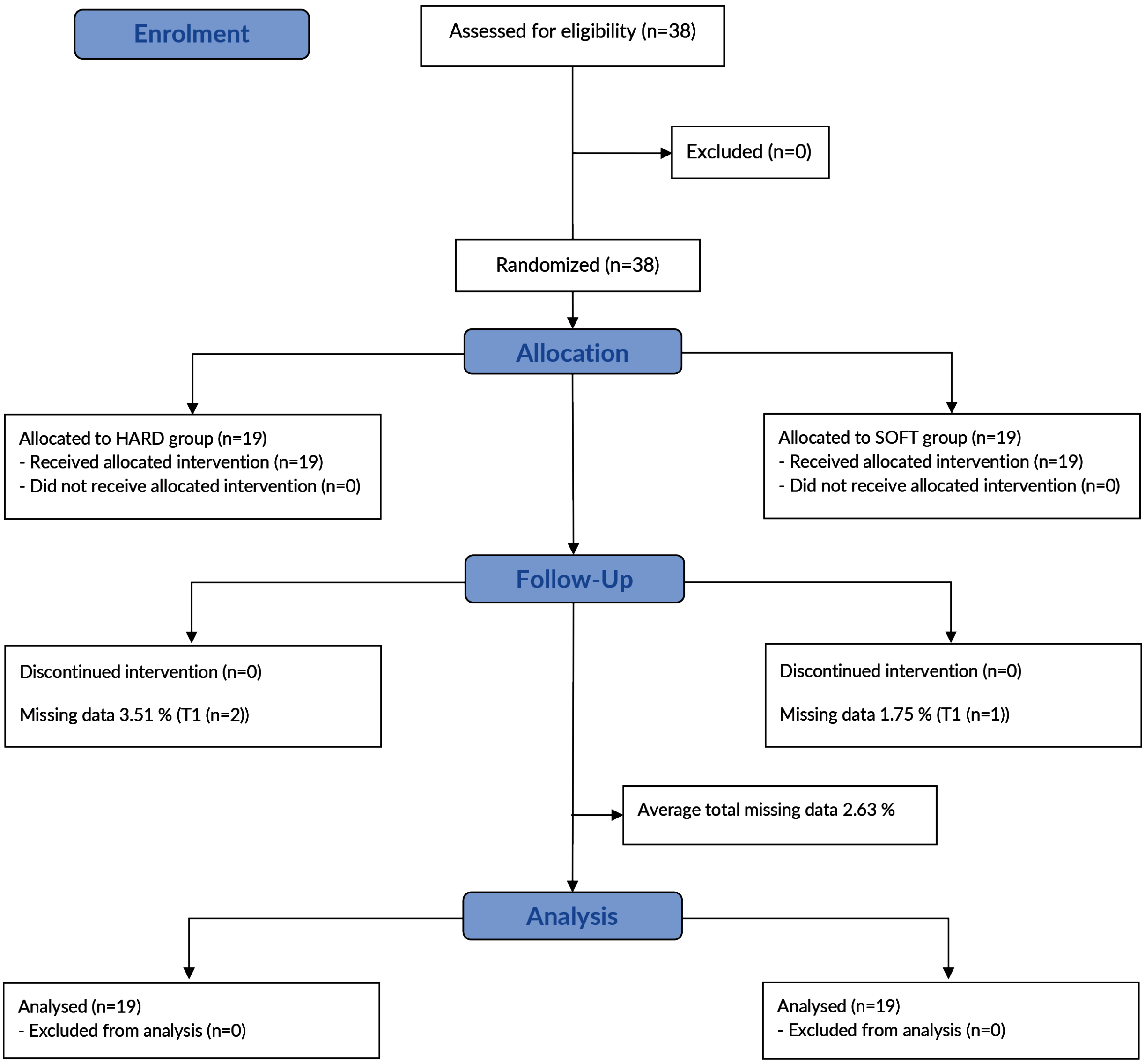
The CONSORT diagram of the patient assessment and enrolment process shows the recruitment of 38 children. 21 boys and 17 girls were consecutively randomised into two treatment groups. During the trial, no volunteers were harmed or dropped out. Since the study was conducted during the outbreak of the COVID-19 pandemic, some individuals were absent at some time points, which accounted for 2.63 % of missing data. The missing values were replaced via a simple imputation procedure based on the mean of the individual variables[22] (Figure 3).

At pretreatment, no statistically significant differences ($P > 0.05$) between the two groups in gender, age, or vertical and horizontal dental and skeletal relationships were found (Table 1). Since there were no significant differences ($P > 0.05$) between the right and left posterior MBF, % MVC of the masseter muscle, and % MVC of the temporalis muscle, the values for each parameter from the right and left sides were combined and averaged to represent the subject's posterior MBF, % MVC of the masseter muscle, and % MVC of the temporalis muscle. At T0, all parameters of the two groups were not statistically significantly different ($P > 0.05$) (Table 2).

In terms of intra-group comparisons at different time points, both the HARD and SOFT groups exhibited similar patterns of masticatory function changes. At one month (T1), % MVC of the temporalis muscles significantly decreased ($P < 0.05$), while the % MVC of the masseter muscles, anterior MBF, and posterior MBF were insignificantly changed ($P > 0.05$). All masticatory function parameters were not significantly different from the baseline (T0) at the third month (T2) ($P > 0.05$).

Inter-group comparison, it was observed that only the % MVC of the temporalis muscle in the HARD group was significantly higher than the SOFT group at one month (T1) ($P < 0.05$).

The anterior and posterior ME of the masseter and temporalis muscles did not show significant differences ($P > 0.05$) in both intra- and inter-groups comparisons (Table 3).



Abbreviations:
HARD, anterior bite plane fabricated from acrylic resin; SOFT, anterior bite plane fabricated form bi-laminate thermoplastic;
T0, pre-treatment; T1, 1 month after appliance placement, T2; 3 months after appliance placement

Figure 3 CONSORT flow diagram of the study

Table 1 Pretreatment gender ratio and median (interquartile range) of pretreatment characteristics

Variables (Median (IQR))	HARD (n = 19)	SOFT (n = 19)	*P* value
Boy:girl ratio	10:9	11:8	0.744†
Age (year)	12.03 (1.38)	11.04 (2.21)	0.124‡
SN-MP (°)	29.70 (8.40)	31.00 (7.20)	0.876‡
ANB (°)	3.20 (2.40)	5.00 (1.60)	0.179‡
Overbite (mm)	4.00 (1.50)	4.50 (3.00)	0.603§

Abbreviations: HARD, anterior bite plane fabricated from acrylic resin; SOFT, anterior bite plane fabricated from bi-laminate thermoplastic.
† *P* values for Chi-square test. ‡ *P* values for Student *t*-test. § *P* values for Mann-Whitney *U* test. * $P < 0.05$

Table 2 Comparisons of muscle activity between HARD and SOFT in different time points.

Index	Group	Examination time point (Median (IQR))			*P* value ‡ (Within-group comparison)
		T0	T1	T2	
% MVC temporalis	HARD	126.59 (54.27)[a]	95.98 (45.46)[b]	111.40 (36.48)[a]	0.017*
	SOFT	107.97 (18.27)[a]	62.11 (40.93)[b]	95.65 (18.05)[a]	0.002*
	P value† (Between-group comparison)	0.339	0.012*	0.085	
% MVC masseter	HARD	102.50 (64.07)[a]	73.65 (53.43)[a]	107.29 (62.88)[a]	0.058
	SOFT	97.03 (59.66)[a]	73.02 (66.65)[a]	107.23 (43.83)[a]	0.060
	P value† (Between-group comparison)	0.884	0.865	0.772	
Anterior MBF (N)	HARD	129.86 (40.34)[a]	109.59 (24.10)[a]	117.39 (13.38)[a]	0.422
	SOFT	128.57 (36.89)[a]	109.56 (23.85)[a]	115.18 (21.04)[a]	0.244
	P value† (Between-group comparison)	0.398	0.981	0.888	
Posterior MBF (N)	HARD	334.85 (78.88)[a]	307.43 (123.48)[a]	313.12 (73.36)[a]	0.186
	SOFT	360.88 (84.59)[a]	315.26 (113.06)[a]	312.16 (100)[a]	0.554
	P value† (Between-group comparison)	0.453	0.869	0.851	

Abbreviations: HARD, anterior bite plane fabricated from acrylic resin; SOFT, anterior bite plane fabricated from bi-laminate thermoplastic; % MVC, percentage of maximum voluntary clenching; MBF, maximum bite force; T0, pre-treatment; T1, 1 month after appliance placement; T2, 3 months after appliance placement; IQR = Interquartile range.

† *P* values for between-group comparisons at the same time-point (Mann-Whitney *U* test).

‡ *P* values for within-group comparisons between time-points (related sample Friedman's test), significance value was adjusted by the Bonferroni correction for Dunn's pairwise comparisons between time points within group.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.005$

Values with the same lower-case letters were not significantly different in post-hoc and pairwise comparisons between time points.

Discussion

The % MVC of temporalis muscles was temporally decrease after appliance insertion. It was returned to baseline at 3 months of treatment. In contrast, the % MVC of masseter muscles and MBF did not show the different from the baseline. The results were conformed with the previous study presenting the adaptation ability of muscles after appliance insertion.[1]

The within-group comparison of muscle effort in both the HARD and SOFT groups did not follow the

Table 3 Comparisons of anterior and posterior masticatory muscle effort (ME) between HARD and SOFT in different time points.

Index	Group	Examination time point (Median (IQR))			*P* value ‡ (Within-group comparison)
		T0	T1	T2	
Anterior ME Temporalis	HARD	0.94 (0.68)[a]	0.72 (0.42)[a]	0.87 (0.32)[a]	0.113
	SOFT	0.93 (0.28)[a]	0.62 (0.31)[a]	0.78 (0.28)[a]	0.095
	P value † (Between-group comparison)	0.690	0.222	0.231	
Anterior ME Masseter	HARD	0.76 (0.66)[a]	0.70 (0.57)[a]	0.97 (0.56)[a]	0.098
	SOFT	0.80 (0.41)[a]	0.64 (0.43)[a]	0.90 (0.78)[a]	0.186
	P value † (Between-group comparison)	0.589	0.778	0.778	
Posterior ME Temporalis	HARD	0.33 (0.18)[a]	0.31 (0.15)[a]	0.33 (0.16)[a]	0.170
	SOFT	0.30 (0.07)[a]	0.28 (0.13)[a]	0.30 (0.14)[a]	0.195
	P value † (Between-group comparison)	0.385	0.415	0.260	
Posterior ME Masseter	HARD	0.29 (0.16)[a]	0.23 (0.15)[a]	0.34 (0.15)[a]	0.082
	SOFT	0.28 (0.12)[a]	0.24 (0.17)[a]	0.30 (0.21)[a]	0.195
	P value † (Between-group comparison)	0.291	0.425	0.253	

Abbreviations: HARD, anterior bite plane fabricated from acrylic resin; SOFT, anterior bite plane fabricated form bi-laminate thermoplastic; ME, masticatory muscle effort; T0, pretreatment; T1, 1 month after appliance placement; T2, 3 months after appliance placement; IQR = Interquartile range.

† *P* values for between-group comparisons at the same time-point (Mann-Whitney *U* test).

‡ *P* values for within-group comparisons between time-points (related sample Friedman's test), significance value was adjusted by the Bonferroni correction for Dunn's pairwise comparisons between time points within group.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.005$

Values with the same lower-case letters were not significantly different in post-hoc and pairwise comparisons between time points.

trend of the change in % MVC of temporalis muscles. The decreasing of temporalis muscles activity, while the insignificantly changed of the posterior ME and the posterior MBF at T1, suggests that it had no impact on the production of posterior bite force. It could be inferred from the result that the masticatory muscle effort depends on the masseter. Many studies agree that the masseter is the crucial affected muscle from the changes of intraoral environment by an interocclusal appliances.[23,24]

The insignificantly differences of muscle effort to baseline levels after one month of treatment suggests that the subjects quickly adapted to the anterior bite plane regardless of the type of materials used. A study was confirmed by using functional magnetic resonance imaging (fMRI) after prosthodontic treatment and found that there was a neuroplastic adaptation after 3 months.[25]

In terms of practical application, both the HARD and SOFT can be equally chosen in terms of the MBF and muscle effort, as they both exhibited no difference after one month of appliance insertion. However, a SOFT may be more preferable due to its association with less mandibular root volume loss.[26]

This study has some limitations. First, the results can only be generalised to growing patients whose muscle activities and bite force may be different from adults. Second, masticatory function parameters were recorded with the appliance in place at T1 and T2 that follows the recommendation that the appliance should be worn during meals. Consequently, the interpretation of the results may not be generalised to the alternate recommendation that the appliance may be removed during meals. Comparing masticatory function under both conditions could provide valuable insights for establishing suitable appliance-wearing protocols to preserve normal masticatory function. Third, muscle activity and bite force were not simultaneously recorded, although both parameters were measured immediately and subsequently under the same conditions. Designing a real-time synchronizing integrated system for bite force and the recording of muscle activity would yield more accurate data on masticatory muscle effort. Fourth, non-parametric statistical analysis was chosen because of large variations among subjects and the non-normal distribution of data. Efforts were made to normalise and standardise the data, as mentioned earlier, to facilitate comparisons across subjects and over time. Increasing the sample size in future studies may improve the chances of achieving normal data distribution. Lastly, the study applied an intention-to-treat protocol, reflecting practical outcomes in clinical situations. However, this approach may obscure the true effect of the intervention if subjects strictly adhere to the study protocol.

Conclusion

Within the study's limitations, both the hard and soft anterior bite planes demonstrated no disadvantageous effects on masticatory muscle effort, as none of the values exceed the baseline during treatment.

Author contributions

PW: Conceptualization, Methodology, Software, Validation, Investigation, Data curation, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization, and Project administration; UT: Conceptualization, Methodology, Data curation, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization, Supervision, and Project administration; MP: Conceptualization, Software, Writing-Original draft preparation, Writing-Reviewing and Editing, Visualization, Supervision, and Project administration.

Ethical statement

This study was applied under the approval of the human experimental ethics committee of the Faculty of Dentistry, Prince of Songkla University (Ethical Approval Number: EC6305-019) and submitted to the Thai Clinical Trial Registry (TCTR20210330002).

Disclosure statement

Authors have no the conflicts of interest.

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Original Article

Effect of Predrilling Diameter on Orthodontic Miniscrew Primary Stability

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Abstract

Background: Predrilling diameter is a factor that is associated with miniscrew primary stability. However, no studies have reported on the relationship between predrilling sizes and shear force loaded as anchorage during orthodontic treatment. **Objective:** The purpose of this study was to evaluate the effect of 0.70, 0.80, 0.90, 1.00, 1.10, and 1.20 mm predrilling sizes on insertion torque and shear test using 1.30-mm diameter miniscrews in 1-mm thick synthetic cortical bone. **Materials and methods:** Insertion torque was recorded using a torque driver. The shear test was performed using a universal testing machine by loading a tangential force perpendicularly to the miniscrew at 1 mm/min until it was displaced by 0.50 mm. **Results:** Overall, the insertion torque tended to significantly decrease as the predrilling diameters increased. The exceptions were in the 0.70 and 0.80 mm groups that had insertion torque values lower than those in the 0.90 mm and 1.00 mm groups. Regarding the shear test, although there were no significant differences among the groups, the 1.20-mm predrilling diameter group demonstrated a much lower value, suggesting that it might be easier to dislodge after receiving an orthodontic force. **Conclusion:** Predrilling diameter size up to 77 % of the 1.30-mm outer diameter miniscrew can be used to achieve optimal orthodontic miniscrew primary stability.

Keywords: Insertion torque, Miniscrew, Predrilling diameter, Primary stability, Shear test

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Introduction

Orthodontic anchorage, defined as resistance to undesirable tooth movement,[1] has previously been achieved using teeth, intra-oral appliances and extra-oral appliances.[2] However, temporary anchorage devices have become widely used to obtain absolute anchorage, especially miniscrews, because of their advantages, e.g., smaller size, acceptable cost, simple insertion, less trauma, and do not require patient compliance.[3,4] However, miniscrew failure has been found to be ~13 %-20 %.[5]

Primary stability is important for miniscrew success due to the immediate loading that is applied on them, prior to osseointegration.[6,7] It is a mechanical interlock between the miniscrew surface and surrounding bone.[8] Several factors affect this initial stability, e.g., placement site characteristics, miniscrew characteristics, root proximity, and insertion methods.[7] Different techniques have been used to assess miniscrew stability, including a histological test (bone-to-implant contact) and mechanical tests (insertion torque, removal torque, pull-out strength, shear test, and percussion test).[9,10]

Miniscrew stability is most frequently evaluated by measuring the insertion torque, which represents the amount of torque required to overcome the bone resistance during miniscrew placement.[11] To achieve an acceptable success rate for typical orthodontic treatment, an insertion torque value ranging from 5-10 Ncm has been recommended.[12] In some situations, miniscrews need to resist much higher forces than usual, such as miniscrew-supported temporary pontics,[13] miniscrew-assisted rapid palatal expanders,[14] or molar distalizers.[15] To evaluate the miniscrew strength in these cases, a pull-out test is previously used to measure the maximum tensile force applied along the longitudinal axis of the screw to cause bone failure.[7,16,17] However, to exactly mimic the clinical use of miniscrews, a tangential force oriented perpendicularly to the screw should also be measured for more advantage, i.e., a shear test.[17] There were some studies evaluated miniscrew stability using shear force loaded to miniscrew head to examine the orientation for failure resistance[17] and the effect of miniscrew diameter,[10] but there is no report regarding the relationship between insertion torque and shear test.

There are various types of orthodontic miniscrews, divided into self-drilling and self-tapping procedures. Although the self-drilling type is easier to use and produces greater torque, it also creates more microdamage to the surrounding cortical bone,[18,19] Excessive amounts of damage can decrease the stiffness and strength of the cortical bone, leading to adverse complications, e.g., less stability and screw loosening.[19,20] Thus, one solution to reduce microdamage is to predrill through the cortical bone before miniscrew insertion. The recommended predrilling diameter has been previously reported, ranging from 69 %-77 %.[21,22] However, little is known about the relationship between predrilling size and shear force, which closely imitates the clinical procedure to evaluate primary stability.

Therefore, the objective of this study was to estimate the optimal predrilling diameter, varying in size of 0.70, 0.80, 0.90, 1.00, 1.10, and 1.20 mm, to evaluate the 1.30-mm miniscrew primary stability by measuring insertion torque and shear force. The null hypothesis was that there is no significant difference among the different predrilling sizes.

Materials and methods

1. Specimens

Sample size estimation was calculated using power analysis and a total of 30 has been decided for total sample size. Thirty titanium alloy miniscrews (1.30 mm diameter and 6 mm long, Jeil Medical Corporation, Seoul, Korea) were used in this study. Artificial cortical bone (1 mm thick) was prepared as a specimen (Sawbones, Vashon, WA, USA) to place the miniscrews in. The bone was cut into thirty 14-mm square pieces, using a low-speed precision cutter

Table 1 Physical and mechanical properties of the artificial cortical bone

Properties	Units
Density	1.70 g/mL
Ultimate tensile strength	90.00 MPa
Modulus of elasticity	12.40 GPa
Compressive yield strength	120.00 MPa
Compressive modulus	7.60 GPa

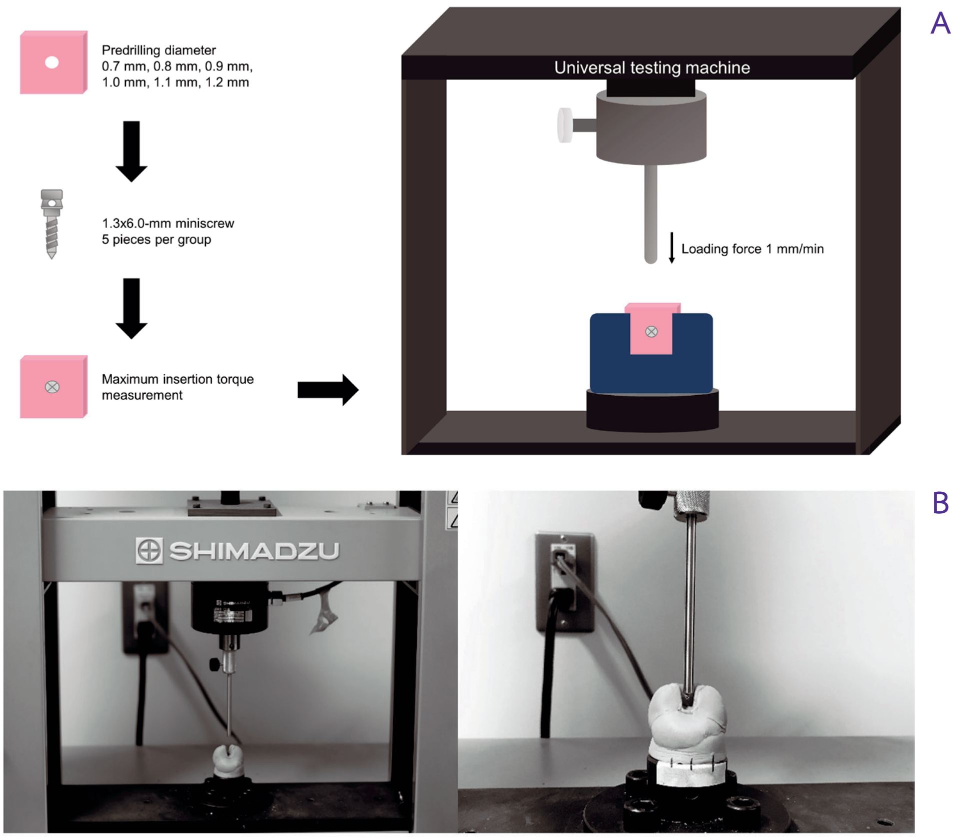

Figure 1 Images of the experiment; (A) Schematic image of the experiment process and (B) Image when a bone piece with the miniscrew was fixed with a customized silicone jig and a cylindrical rod connected to the universal testing machine was used to transfer the force

(IsoMet, Buehler, IL, USA). The physical and mechanical properties of the artificial bone are presented in Table 1.

2. Predrilling procedure

The thirty bone pieces were randomly divided into six groups (n = 5), one group each for miniscrews with a predrilling diameter of 0.70, 0.80, 0.90, 1.00, 1.10, and 1.20 mm. The center point of each piece of bone was marked with a pencil, and secured in a vice. The predrilling hole was drilled dry, perpendicular to the bone, with a cylindrical carbide bur in a micromotor. The holes were measured to confirm their accuracy using a light microscope (Nikon Instruments Inc., NY, USA) and NIS elements imaging software (Nikon Instruments Inc., NY, USA).

3. Miniscrew insertion

The bone piece was secured in the vice and a miniscrew was inserted into the predrilled hole manually by one examiner using a hand torque driver (Tohnichi, Tokyo, Japan) until the neck part was reached, approximately 1 mm under the head part. The maximum insertion torque was recorded.

4. Shear test

The shear test was performed using a universal testing machine (Shimadzu, Kyoto, Japan). The bone piece with the miniscrew was fixed with a customized silicone jig at the base of the machine to confirm its exact position. A cylindrical rod (5 mm diameter), connected to the machine was used to transfer the force and was set at the screw-bone interface before testing. A tangential force was loaded perpendicularly to the screw with a crosshead speed of 1 mm per minute. The procedure is illustrated in Figure 1. The miniscrews were displaced by 0.50 mm, which had been previously reported to not cause slippage.[10] The load-displacement data were recorded.

5. Statistical analysis

The pairwise Wilcoxon rank sum test adjusted with the Hochberg method ("R" software (version 4.2.3, http://www.r-project.org/, accessed on 5 July 2023)) was used to examine the effect of the predrilling diameter on the insertion torque value and shear force. P values < 0.05 were considered significant.

Results

The maximum insertion torque ranged from 2.00-8.90 Ncm. The mean insertion torque from 0.70 mm to 1.20 mm predrilling diameters was 7.46, 6.74, 8.70, 8.02, 4.32, and 2.12 Ncm, respectively. Screws with larger predrilling diameters had significantly (P < 0.05) lower insertion torques compared with those from 0.90 mm to 1.20 mm. However, the 0.70 mm and 0.80 mm predrilling size groups demonstrated

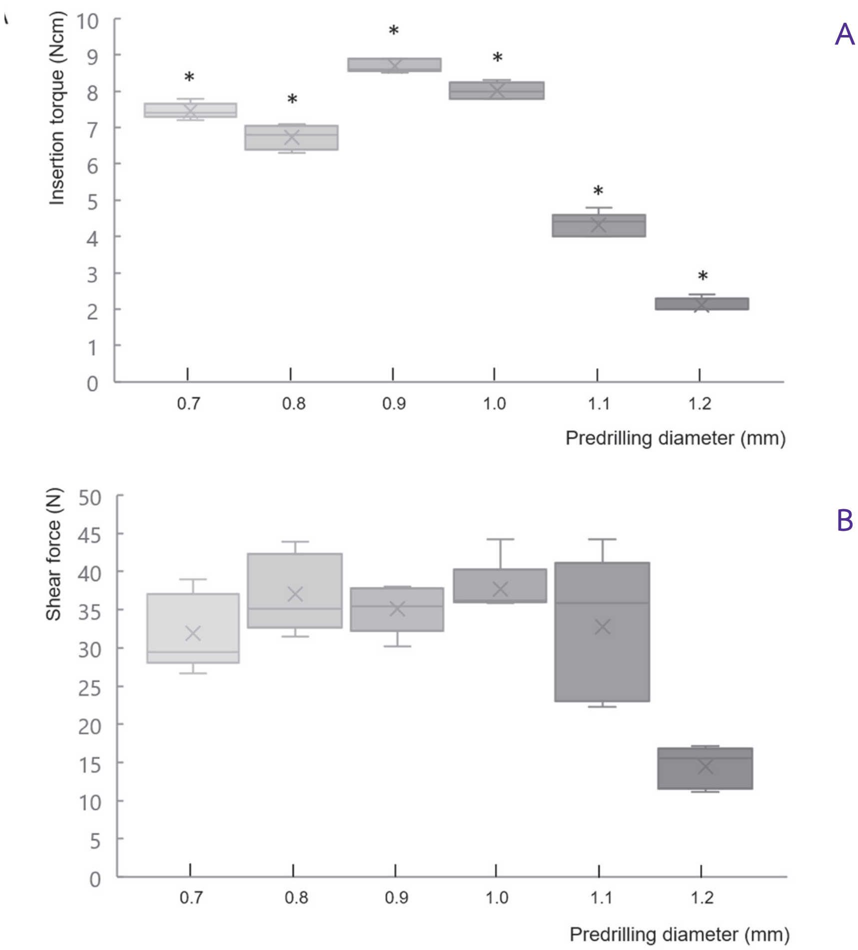

Figure 2 Box-plot graphs of (A) insertion torque test and (B) shear test. The asterisk represents significant differences among all groups (P < 0.05)

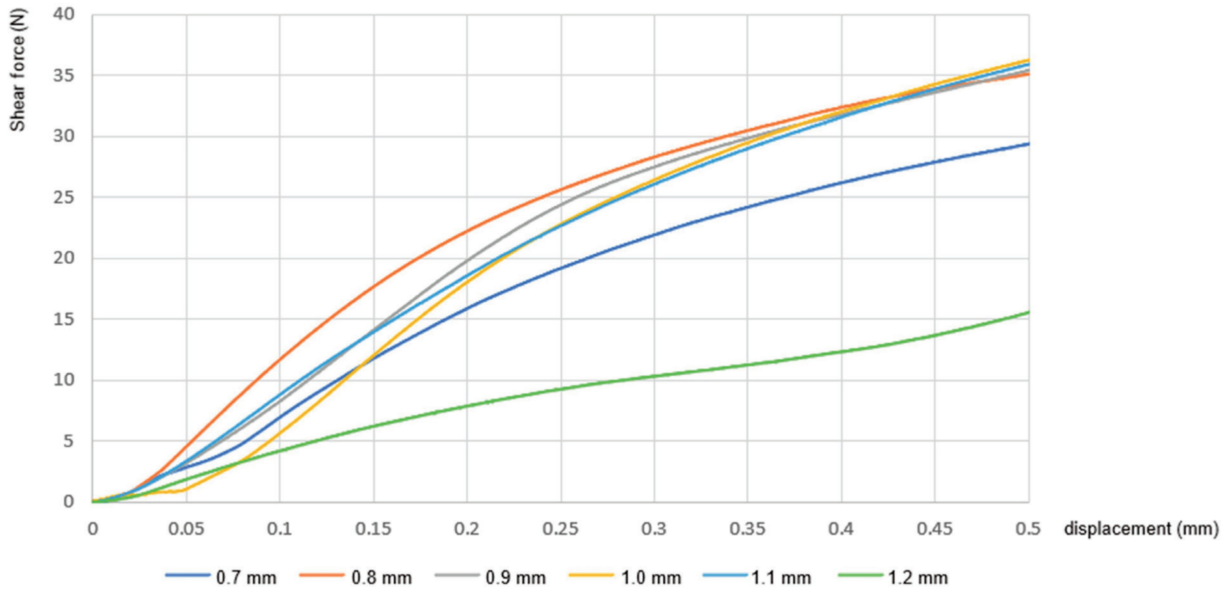

Figure 3 Mean shear force values vs. miniscrew displacement of the six predrilling diameters.

significantly lower insertion torque than that of the 0.90 mm predrilling diameter group (Figure 2A).

Regarding the force loaded at 0.50 mm screw displacement, the statistical analysis found no significant differences among the six groups. The mean shear force value in the 0.70 mm to 1.20 mm predrilling diameter group was 31.90, 36.99, 35.11, 37.69, 32.80, and 14.46 N, respectively (Figure 2B). A similar trend was shown in all groups when the screws were displaced up to 0.50 mm. However, the 1.20-mm predrilling diameter group presented a much lower force load to move the miniscrews 0.50 mm than the other groups (P = 0.087) (Figure 3).

Discussion

This study was to evaluate the relationship between miniscrew predrilling diameters, insertion torque and shear test. Even though there are several articles published about the influence of miniscrew insertion torque on primary stability, the sizes of miniscrew were quite large when planning to use between roots.[12,23,24] The reason for choosing 1.30 mm diameter miniscrews as a testing material is that small screws have been increasingly used to avoid tooth root contact due to the root proximity when inserted inter-radicularly, causing root damage and miniscrew failure.[25,26] Furthermore, large diameter miniscrews can produce more microdamage to the surrounding cortical bone, which can compromise their stability.[27] However, miniscrews that are too small tend to fracture more easily during placement and removal.[28] Based on their results, Poggio et al[29] recommended to use miniscrews ranging from 1.20-1.50 mm in diameter when inserted inter-radicularly.

Most previous studies have determined that the insertion torque value was influenced by the predrilling size, finding that the larger the predrilling diameter, the lower the insertion torque.[30,31] This is because less bone needs to be displaced during miniscrew insertion when using a larger predrilling size. However, the present study revealed that the insertion torque values when the predrilling diameter was 0.70 mm and 0.80 mm were lower than those of 0.90 mm and 1.00 mm, while a 0.70 mm predrilling size caused a larger insertion torque than for the 0.80-mm size. Several previous studies also reported this unexpected result. Wilmes et al[31] reported that the insertion torque of a 2-mm diameter miniscrew was higher when inserted into a larger pilot hole. The authors claimed that a smaller predrilling size may result in miniscrew fracture. Another result from Battula's study,[32] using bone screws for rigid fixation, also showed that the highest insertion torque value was not from the smallest predrilling diameter with no further discussion.

One factor that may explain these results is the effect of the cutting flute, which is a recessed area usually placed at the tip of the miniscrew. Adding this flute results in decreased miniscrew surface area, leading to decreased friction and insertion torque because the flute can clear more bone debris accumulated around the threads if it is wide enough.[33,34] According to a previous study using micro-CT to examine the cross-sectional view of the cutting flute of a 1.30-mm miniscrew, it found that the cutting flute area was larger at 0.70-mm cross-sectional diameter and almost gone at 0.90-mm cross-sectional diameter. This can cause lower insertion torque values in 0.70-mm and 0.80-mm predrilling groups than that of 0.90-mm group. Additionally, the flute also produced more plastic deformation with an 0.80-mm predrilling diameter, causing smaller insertion torque values of this group.[21]

Regarding holding power, previous studies mainly evaluated the effect of predrilling size using pull-out strength to measure the maximum vertical force that miniscrew can resist. Hung et al[30] found that there was a significant decrease in the pull-out force when predrilled with a larger diameter because of less thread-cortical bone engagement. Furthermore, they also suggested using pull-out strength rather than insertion torque for measuring primary stability because the insertion torque method produced greater variation. However, both methods had a strong correlation, thus they can still be used effectively.[7,30] But in our experiment, we focused on the shear force, oriented perpendicularly to the screw, to imitate the clinical situation. Shear force was found to be lower compared with the pull-out force due to the thread axis that provides maximum resistance when there is a force perpendicular to them.[17] Although no significant differences of shear test among the predrilling size groups were found in this study, the 1.20-mm predrilling diameter group demonstrated less loaded force to move the miniscrews than others, which may cause easier screw loosening clinically.

Considering the optimal predrilling diameter, there is a recommended insertion torque value.[12] Our results indicated that the insertion torque that matches the recommendation of 5-10 Ncm is obtained from 0.70-mm, 0.80-mm, 0.90-mm, and 1.00-mm diameter predrilling sizes. Furthermore, there is also a recommended ratio of the predrilling diameter to achieve miniscrew stability. It is suggested that the drill diameter should be less than 80 % of the screw's external diameter, based on pull-out strength testing,[35] or should be between 69 % and 77 % of the outer diameter for a 1.30-mm miniscrew when assessing by the bone-to-implant contact ratio.[22] A recent study evaluating the microdamage of the cortical bone also suggested a ratio of 77 % to obtain the greatest primary stability.[21] Our results supported these studies by showing that predrilling from 0.70-1.00 mm, which are 53.80 % -76.90 % respectively, should be performed to obtain optimal insertion torque value and shear force resistance. Hence, regarding all aspects, 77 % is the most appropriate size of predrilling diameter to enhance miniscrew primary stability.

The major limitation of this study is the difference between synthetic and living cortical bone. Although synthetic bone is the most appropriate material for biomechanical testing due to its availability and uniformity, the results cannot be directly transferred into clinical situations. Further research using animal or cadaver bone, as well as clinical study is still needed to achieve the most advantage of using orthodontic miniscrews.

Conclusion

The appropriate predrilling size ranges from 57 to 77 % of 1.30-mm diameter miniscrews when insertion torque and shear force were examined to acquire greater primary stability, indicating less mobility and failure of orthodontic miniscrew.

Author contribution

CT: Conceptualization, Methodology, Software, Formal analysis, Resources, Data curation, Writing-Original draft preparation, and Visualization; MU: Conceptualization, Software, Validation, Investigation, Resources, Writing-Review and Editing, and Supervision; PT: Supervision, and Project administration; KM: Supervision, and Project administration; CT and MU have made an equal contribution to this study; All authors have read and agreed to the published version of the manuscript.

Disclosure statement

Authors have no the conflicts of interest.

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Thai Journal of Orthodontics

Original Article

Factors Influencing Orthodontic Patient Compliance with Removable Retainers

Lalita Jeamkatanyoo* Supanee Suntornlohanakul** Sukanya Tianviwat**

Abstract

Background: Maintaining the results of orthodontic therapy requires adherence to the use of removable retainers. However, compliance-related variables remain debatable. **Objective:** This study aimed to measure patient compliance in wearing a retainer and explore the factors that affect compliance. **Materials and methods:** Random sampling was conducted on 1,078 patients who had completed full-fixed appliance therapy from 2019 to 2022. The selected patients were stratified by the number of years (1 to 2, > 2 to 3, and > 3 to 4 years) after debonding. A telephone questionnaire consisted of four parts: patient characteristics, retainer utilization, knowledge, and attitude factors related to compliance. Descriptive statistics and binary logistic regression were used for the analysis. **Results:** There were 295 patients participating in this study. The response rate was 97 %. The percentage of compliance in wearing retainers for 1 to 2, > 2 to 3, and > 3 to 4 years after debonding were 64.30, 64.70, and 60, respectively. There were 5 factors significantly associated with patient compliance in wearing a removable retainer. Patients with scores of 8-10 in self-assessment of compliance had significantly more compliance than patients with scores of 0-7 (odds ratio = 20.40, 95 % CI 10.25-40.61). **Conclusion:** The percentage of compliance in wearing a retainer during four years after debonding was 63.10. Factors significantly associated with compliance in wearing a retainer were age, number of recall visits, loss of retainer, self-assessed level of compliance in wearing a retainer, and knowledge of the frequency of wearing a retainer.

Keywords: Compliance, Orthodontic, Retainer, Retention phase

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Introduction

A previous study reported that 72 % of orthodontic patients exhibited dental relationships that were outside of the ideal range.[1] Also, 40 % to 90 % of orthodontic patients had unacceptable dental alignment 10 years after retention.[2] Therefore, in order to achieve successful orthodontic treatment, it is imperative for patients to consistently use a retainer.

The posttreatment retention phase has a crucial role in preserving the alignment of teeth as the periodontal tissues undergo remodeling. Using a retention device also prevents change the natural process of occlusion aging, including the transitional changes in growth, dentoalveolar development, and muscular adaptation, all of which persist until adulthood.[2-4] Removable retainers are most commonly used as retention appliances. Consequently, patient cooperation and compliance are essential to realize good outcomes.[5]

There are numerous guidelines available regarding retainer usage. From 2003 to 2018, many studies attempted to compare different regimens for wearing a retainer. Wearing a retainer either part-time or full-time remains controversial.[6-9] Some studies reported that full-time wearing of a retainer has a better effect than part-time.[10,11] But one part of a systematic review in 2020[12] reported no statistically significant difference between part-time and full-time retainer use in either maxillary or mandibular arches. However, the retention protocol in terms of frequency nowadays tends to be more part-time. Similarly, the appropriate duration for wearing the retainer remains inconclusive. The best advice for patients is to continue wearing the retainer as long as it can be monitored on a regular basis by an orthodontist or a general practitioner or both.[3]

Compliance on the wearing of an orthodontic retainer has been reported. Kacer et al.[13] measured the cooperation of patients wearing a retainer based on remembering the orthodontist's instructions and following them. They found that the compliance rates in the periods of 0 to 3, 7 to 9, and 19 to 24 months were 69 %, 55 %, and 45 %, respectively. These results demonstrated a trend of decreasing cooperation in wearing the retainer as time passed but was not statistically significant. On the other hand, Pratt et al.[14] found that as time increased after debonding, the decrease in cooperation was statistically significant. In addition, Banabilh and Almuqbil[15] reported that 44 % of patients cooperated in wearing the retainers over a period of 4 months to 8 years after debonding, and a statistically significant difference existed in compliance levels that was related to the length of time following debonding.

Research into the factors affecting compliance in wearing a retainer revealed that certain variables did have an impact on compliance (amount of time out of braces,[14,15] parents' attitudes,[16] method of orthodontist instructions[17] etc.), while others had no effect (esthetic concern,[14] BMI,[18] treatment location, living place, parents' educational degrees, ethnicity[16] etc.) and still others produced inconclusive results (age,[13,14,19-21] gender,[13,14,16,19-22] type of retainer[13,14,16,20,23,24] etc.). Furthermore, little research seems to be available on the factors associated with patient compliance in wearing a retainer. Other interesting factors related to patient compliance in wearing an orthodontic retainer include the reason for requiring treatment, number of recall visits, knowledge and attitude of wearing an orthodontic retainer, access to service when the retainer had a problem, and patient self-assessment level of compliance. Therefore, the purposes of this study were to measure patient compliance and to explore the possible factors that affect compliance in wearing a retainer.

Materials and methods

Part 1: Questionnaire design and quality control

This project was approved by the Human Research Ethics Committee of the Faculty of Dentistry at Prince of Songkla University (EC6406-039). After reviewing the literature and conducting a pilot interview in December 2022 with 18 patients who had completed fixed orthodontic appliance therapy, were able to communicate in Thai language, and were willing to voluntarily supply information.

To refine questions and assess reliability before gathering real data, a pilot telephone survey was conducted in December 2022, utilizing accidental sampling. Following the rule of thumb,[25] a minimum of 15 subjects per variable was advised, with 19 factors identified as relevant. Consequently, the sample population required at least 285 subjects. During data collection totally 295 were recruited.

The inclusion criteria were patients who had completed fixed appliance therapy at the Orthodontic Clinic, Faculty of Dentistry at Prince of Songkla University from 2019 to 2022 and had the debonding for at least one year. The exclusion criteria were patients with incomplete information, cleft lip/palate or syndromic patients, patients who received a fixed retainer, a dentist, a dental student, and patients who were not available by telephone.

The content validity of the telephone questionnaire with 19 factors of interest was tested by three orthodontists using the index of item-objective congruence (IOC). The IOC scores for each question ranged between 0.50 and 1.00, which were acceptable. Eleven items were revised and one item was deleted that ultimately became the complete questionnaire. All variables except attitude were assessed for reliability using the test-retest method, and the Kappa coefficient was used for analysis. The Cronbach's alpha coefficient was employed to assess the attitude for internal consistency in the first interview. The Kappa was 0.63-1.00 and the Cronbach's coefficient was 0.71, both of which were high values.[26,27] The questionnaire was attached in annex.

Part 2: Collecting data

Between January 2022 and April 2023, a cross-sectional study was conducted via telephone survey using a structured questionnaire. The sampling method employed was a disproportionate stratified random sampling, facilitated through https://www.random.org, based on the year of brace removal. Patients were briefed on the study's invitation and particulars. Prior to the telephone interview, all participants provided verbal informed consent. Patients had the right to withdraw from research at any time. To prevent participants' identities from being revealed, all interview materials were anonymized. And the received information did not have any impact on future treatment.

In the event that the patient was not available for the interview at that time, the telephone interview will be rescheduled for a later date. If the researchers were unable to reach the patients via telephone more than twice, they were to attempt to contact the next randomly selected patient. When the patient reestablished communication and expressed consent to participate in the study, the researchers proceeded with the data collection and interview process.

The researcher (L) and a standardized research assistant (non-dentist) conducted 190 and 95 interviews, respectively. Approximately 20 to 30 minutes are required per person. The same interview approach was used throughout the process the desired sample size of 285 patients was achieved.

The following were the prescribed guidelines for assistant training: Firstly, the patients were interviewed by the researcher (L) until thorough interview methods were obtained. This training based on the recruited subjects. Secondly, the research assistant received training on interview methods, which included instructions on introducing themselves, requesting permission, and conducting the questionnaire in its entirety across all formats, along with a demonstration of data collection. Subsequently, engage in an understanding-gaining discussion with the research assistant. Lastly, the research assistant rehearses the interview and records findings only based on the patients' words. Afterwards, the research assistant was responsible for interviewing 95 patients.

Dependent and independent variables of the questionnaire

The complete questionnaire covered 19 factors of interest. The patient factors were age (at interview date), gender, length of time since debonding, the number of recall visits to the orthodontist after starting use of a retainer, motivation for orthodontic treatment, reasons for receiving orthodontic treatment, and sponsorship of orthodontic treatment expenses.

The retainer usage factors were experience in losing or breaking the retainer, how the patient managed after losing or breaking the retainer, knowing the location of services for a new retainer, difficulties in traveling to dental service clinics for a new retainer, difficulty in obtaining a new retainer, the method of giving instructions by the orthodontist, and self-assessment level of compliance in wearing the retainer.

The knowledge factors included the retainer can maintain tooth position, the retainer must be worn every day, and the teeth may misalign if a retainer is not worn. The attitude factors were related to the importance of the retainer and possible tooth relapse.

The independent variables related to patient compliance in wearing the retainer were divided into two groups (Compliance and Noncompliance) as shown in Table 1.

Table 1 Dependent and independent variables

Dependent variables	Independent variables
Patient factors • Age • Gender • Length of time after debonding • Number of orthodontist recall visits after starting retainer use • Motivation for orthodontic treatment • Reasons for receiving orthodontic treatment • Sponsorship of orthodontic treatment expenses	Compliance Patients who have a retainer that properly holds the teeth and wear the retainer at least every night.
Retainer using factors • Experience in losing or breaking the retainer • How the patient managed after losing or breaking a retainer • Knowing the location of services for a new retainer • Difficulties in traveling to dental service clinics for a new retainer • Difficulty obtaining a new retainer • Method of orthodontist instructions • Self-assessment level of compliance in wearing the retainer	Noncompliance Patients who did not wear a retainer or wear a retainer less than every night, or used the retainer for reasons not related to orthodontic maintenance, such as using them to replace missing teeth.
Knowledge factors • Retainer can maintain tooth position • Retainer must be worn every day • Teeth may misalign if a retainer is not worn	
Attitude factors • Importance of the retainer • Tooth relapse	

Statistical analysis

Participant demographic data and compliance in wearing the retainer are presented as descriptive statistics. Binary logistic regression was used to analyze the statistics for factors affecting compliance in wearing the retainer using the SPSS software version IBM 29.0.0.0 (241). The level of significance (α) was set at $P < 0.05$. Detail of retrieving the effective rates was shown in Supplementary Table 4 (Available at https://kb.psu.ac.th/psukb/bitstream/2016/19405/1/Supplementary-Table-4.pdf)

Results

Initially, 697 patients were randomly selected from a total of 1,078 (which were the patients who had completed fixed appliance therapy at the Orthodontic Clinic, Faculty of Dentistry at Prince of Songkla University from 2019 to 2022). Then, 393 were excluded. Therefore, 304 patients were included in the study, but 9 patients refused to participate. Finally, 295 patients participated in this study for a response rate of 97 %. The demographic characteristics of the patients were summarized in Table 2. The percentages of school-age patients and working-age patients were 37.30 % and 62.70 %, respectively.

The compliance group consisted of 63.10 % of patients. The percentages of patients who wore the retainer every day and night and patients who wore the retainer every night were 13.60 % and 49.50 %, respectively. The noncompliant group consisted of 36.90 % of patients. The percentages of patients who wore the retainer on some days and patients who stopped wearing the retainer over a period of four years were 22 % and 14.60 %, respectively (Table 3).

Table 2 Frequency and percentages of the general characteristics (n = 295)

General characteristics	n (%)
Age (mean age 26.50 ± 8.60 years old)	
School-age (< 23 years old)	110 (37.30)
Working-age (≥ 23 years old)	185 (62.70)
Gender	
Male	75 (25.40)
Female	220 (74.60)
Length of time after debonding	
1 to 2 years	98 (33.20)
> 2 years to 3 years	97 (32.90)
> 3 years to 4 years	100 (33.90)
Number of recall visits	
0 time	175 (59.30)
1 time	79 (26.80)
2 times	26 (8.80)
≥ 3 times	15 (5.10)
Experience in losing or breaking a retainer	
Yes	83 (28.10)
No	212 (71.90)
Self-assessment level of compliance in wearing the retainer	
0-7	108 (36.60)
8-10	187 (63.40)

Table 3 Percentages of compliant and non-compliant respondents in wearing the retainers by length of time after debonding.

Length of time after debonding (years)	Assessments of compliance in wearing the retainer (n = 295)							Total
	Compliant (n (%)) (n = 186)			Non-compliant (n (%)) (n = 109)				
	Every day and night	Every night	Total	Some days	Not wearing	Other	Total	
1 to 2	20 (20.40)	43 (43.90)	63 (64.30)	23 (23.50)	11 (11.20)	1 (1.00)	35 (35.70)	98 (100.00)
> 2 to 3	10 (10.30)	53 (54.60)	63 (64.90)	18 (18.60)	16 (16.50)	0 (0.00)	34 (35.10)	97 (100.00)
> 3 to 4	10 (10.00)	50 (50.00)	60 (60.00)	24 (24.00)	16 (16.00)	0 (0.00)	40 (40.00)	100 (100.00)
Total	40 (13.60)	146 (49.50)	186 (63.10)	65 (22.00)	43 (14.60)	1 (0.30)	109 (36.90)	295 (100.00)

Table 4 Prediction of the relationship of various factors with compliance in wearing the retainer using binary logistic regression (enter method).

Variable (ref)	Crude OR	Adjusted OR (95 % CI)	*P* value
Age (ref: working-age group)	1.74 (1.05-2.88)	2.93 (1.28-6.73)	0.011
Number of recall visits (ref: 0 time)			
1 time	1.14 (0.65-1.99)	2.40 (1.12-5.16)	0.025
2 times	1.12 (0.47-2.65)	3.09 (0.91-10.46)	0.070
More than 3 times	0.52 (0.18-1.49)	1.01 (0.25-4.03)	0.986
Experience in losing or breaking a retainer (ref: no)	1.56 (0.93-2.63)	2.83 (1.38-5.79)	0.004
Self-assessment level of compliance in wearing the retainer (ref: 0-7 score)	13.08 (7.39-23.16)	20.40 (10.25-40.61)	< 0.001
Knowledge on frequency of wearing the retainer (ref: did not know)	1.61 (0.66-3.92)	4.61 (1.41-15.03)	0.011

OR = odds ratio, CI = confidence interval, Supplementary Table 4 (Available at https://kb.psu.ac.th/psukb/bitstream/2016/19405/1/Supplementary-Table-4.pdf)

Table 4 showed that 5 of the 19 factors were significantly associated with compliance: age ($P = 0.011$), number of recall visits ($P = 0.025$), experience in losing or breaking a retainer ($P = 0.004$), self-assessment level of compliance in wearing the retainer ($P < 0.001$), and knowledge on the frequency of wearing the retainer ($P = 0.011$). The factor with the most predictability was the self-assessment level of compliance in wearing the retainer. Also, patients who assessed themselves to be compliant in wearing their retainer with scores of 8-10 had a 20.40 times greater opportunity to wear the retainer than the patients who assessed themselves at scores of 0-7 (odds ratio = 20.40, $P < 0.001$).

Discussion

The objectives of this research were to assess patient compliance and the factors that influenced compliance to wearing the retainer using telephone interviews. The response rate was 97 % which is considered to be at a good level.[28] Only 60 % of patients continued to wear their retainers four years after the completion of orthodontic treatment. The results of the telephone interviews revealed that up to 16 % of patients discontinued the use of their retainer by the end of four years. It is information from Table 3. Additionally, five factors were associated with the level of compliance.

There is a difference between ‘ideal definition’ and ‘operational definition’ of patient compliance. Ideally, patient compliance measured by observing the patient’s adherence to the dentist’s instructions. However, there are two major problems: firstly, a variety of retention protocols from different orthodontists, and secondly incomplete data regarding orthodontist instruction in the chart record. Hence, operational definition in this study was wearing a retainer at least every nighttime. According to the study, using a retainer for a minimum of 10 hours per day is enough to preserve the proper position of the teeth.[29] Moreover, a systematic review in 2020 found no statistically significant difference in outcomes between patients who wore retainers full-time versus part-time.[12]

The compliance rate in this study, measured more than 2 years to 3 years after debonding, was 64.90 %. This outcome approximates the findings of a research conducted by Pratt et al.,[14] which had comparable criteria for compliance. According to their analysis, the percentage of patients who consistently wore their retainers every night after having their braces removed for a period of two years was within the range of 34-68 %.[14] From another study by Kacer et al.,[13] the compliance rate was 55 % at 7-9 months after debonding, which was lower than this current study at two years after debonding. The population in the Kacer et al. study was advised to wear the retainers for only 2 years; therefore, the compliance rate would be expected to decrease in the second year.

This current research revealed that school-age patients were more compliant than patients in the working-age group. The school-age group demonstrated a 2.93 times greater opportunity to cooperate in wearing the retainer than the working-age group. This was consistent with other research that indicated younger people were more compliant in wearing a retainer than older people.[14,20] Perhaps teenagers simply prefer to wear retainers, while working people pay more attention to their work. Nevertheless, some studies have shown that age does not have any influence on compliance in wearing a retainer.[13,19,21]

This research discovered new factors related to compliance in wearing a retainer. The new factors included the number of recall visits, experience in losing or breaking a retainer, self-assessment level of compliance in wearing the retainer, and knowledge on the frequency of wearing the retainer. These factors had different predictive values, with 95 % CI of odds ratios ranging from 2.40 to 20.40. The results of the self-assessment level of compliance in wearing the retainer factor can be applied to a follow-up screening question. If the patient’s score is 0-7, the orthodontist may spend more time motivating the patient to adhere to wearing the appliance and arrange for more recall appointments.

Furthermore, it is imperative for orthodontists to provide patients with information regarding the recommended frequency of wearing removable retainer. Education and raising awareness should not be done only at the end of fixed appliance treatment but also during the entire course of orthodontic therapy.

The strength of this research is the method of data collection by telephone interview, which resulted in a high response rate.[30,31] The use of the telephone allows interviewers to cover a greater geographic area[30-33] and provide greater flexibility for scheduling.[30,31,33] Even though the time-consuming,[30,31,34] the incapacity to react to visual cues, and the possible loss of contextual data are some of the most frequently expressed concerns regarding telephone interviews.[33] However, telephone interviews also have the advantage of reducing costs (compared with face to face interviews), increasing interviewer safety, perceiving anonymity, increasing privacy for respondents, and reducing distraction (for interviewees) or self-consciousness (for interviewers) when interviewers take notes during interviews.[35,36]

A limitation of the study was the measurement of dependent variables using subjective data collection. The validity of the data therefore depended on the ability of the interviewer to interpret and summarize the information. In general, patients will tend to overestimate the time spent wearing the retainer. As a result, the compliance rate may be exaggerated. The researcher designed additional questions to cross-check the answers. An additional limitation was that a number of patients were excluded because they could not be contacted by telephone.

Moreover, this study was conducted at the university dental hospital. To extrapolate the findings to other setting should be carefully considered. Future research on other populations should be recommended.

Conclusions

Within 4 years of observation after debonding. The factors found to be associated with compliance in wearing the retainer were the patient's age, number of recall visits, experience in losing or breaking a retainer, self-assessed level of compliance in wearing the retainer, and knowledge of the frequency of wearing the retainer.

Author contributions

LJ: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, and Project administration; SS: Conceptualization, Resources, Writing-Original Draft, Writing-Review & Editing, Visualization, and Supervision; ST: Methodology, Validation, Formal analysis, Writing-Original Draft, Writing-Review & Editing, Visualization, and Supervision.

Ethical statement

The research protocol was approved by the Ethics Committee Faculty of Dentistry, Prince of Songkla University (No. EC6406-039).

Disclosure statement

Authors have no the conflict of interest.

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Case Report

Correction of Severe Skeletal Class II Discrepancy with Orthodontic Treatment Combined with Bimaxillary Orthognathic Surgery: A Case Report

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Abstract

Background: A 53-year-old Thai female patient came to the orthodontic clinic with upper anterior teeth protrusion and insecurity while smiling as the chief complaints. Her expectation was to correct these problems. The examination showed severe skeletal Class II discrepancy with hyperdivergent facial pattern, orthognathic maxilla but retrognathic mandible, and anterior gummy smile. An orthodontic treatment combined with bimaxillary orthognathic surgery was planned. The treatment objectives were to correct the upper anterior teeth protrusion and gummy smile and improve the patient's skeletal, dental, and soft tissue morphology. The treatment duration was 34 months to achieve normal skeletal, dental, and soft tissue structure in the anteroposterior, vertical, and transverse dimensions. At 30 months after completing treatment, the patient was recalled. We found acceptable function, improved esthetic results, and stability. The patient was pleased with the treatment outcome.

Keywords: Gummy smile, Orthognathic surgery, Retrognathic mandible, Skeletal Class II

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Introduction

Class II malocclusion is one of the most prevalent developmental defects that affects 15 to 30 percent of most populations. This malocclusion is likely to have esthetic, psychological, and social consequences.[1,2] This dentofacial abnormality can be classified into maxillary excess, mandibular deficiency, or both. Because the ensuing abnormality can exhibit varying degrees of severity of Class II malocclusion in different ages, the chosen method of clinical therapy must be adapted accordingly.[3,4] In addition, a gummy smile is a significant esthetic problem for patients. This problem leads many patients to seek treatment to correct this issue. The etiology of a gummy smile is multifactorial that includes short upper lip length, hyperactivity of the upper lip, short clinical crown, altered passive eruption, gingival hyperplasia, dentoalveolar extrusion, and vertical maxillary excess. Correcting this problem can be achieved through various treatments that include dental, skeletal, or soft tissue alterations, or a combination of these approaches.[5,6]

In patients with a skeletal Class II relationship, the treatment options vary depending on the severity of the malocclusion, facial appearance, patient expectations, and the level of cooperation.[2,7] When dealing with growing patients, it is proper to use growth modification treatments that involve either removable or fixed functional appliances. Patient cooperation should be a primary focus in these treatments. When there are mild to moderate anteroposterior skeletal discrepancies in adult patients with acceptable vertical facial proportions and no transverse skeletal abnormalities, camouflage orthodontic treatment can be an option.[4] The primary component of camouflage treatment is upper incisor retraction. This is accomplished by either extracting the upper first premolars or performing whole maxillary arch distalization with temporary anchorage devices, and protraction of the lower incisors to obtain normal overjet.[3] In some cases, extractions of the mandibular second premolars are also performed to obtain a Class I molar relationship through lower molar mesialization. However, this treatment is restricted in its ability to compensate for underlying skeletal discrepancies because it relies on tooth movements. In severe cases, camouflage treatment means fitting teeth on improper skeletal bases, which can lead to possible periodontal problems such as gingival recession in the lower anterior area, root resorptions, worsening facial esthetics, and occlusal instability.[8,9] Therefore, orthodontic treatment combined with orthognathic surgery is the best treatment alternative to achieve the ideal results in terms of function, esthetics, and stability in patients who have severe anteroposterior skeletal discrepancies, transverse maxillary skeletal constriction, airway problems, and improper facial esthetics.[10] Orthodontic treatment combined with orthognathic surgery in a 53-year-old woman with skeletal Class II malocclusion related to retrognathic mandible and follow-up at 30 months were described in this case report.

Case report

A 53-year-old woman sought orthodontic treatment at the orthodontic clinic, dental hospital, Faculty of Dentistry, Prince of Songkla University with a chief complaint of upper incisor protrusion and a gummy smile. The patient reported no known underlying disease or allergy and was not taking any medication. The extraoral examination presented normal facial development. The frontal view showed a symmetrical dolichofacial type. In the rest position, the patient had incompetent lips. A high smile line was presented while smiling. The patient exhibited a convex facial profile and an acute nasolabial angle (Figure 1). The patient had no signs or symptoms of temporomandibular disorders.[11]

The intraoral examination found a large overjet (4 mm) and deep overbite (5 mm). According to Angle’s classification of malocclusion, the molars were Class I relationship and the canines were Class II relationship (5 mm on the right side and 2 mm on the left side). The upper dental midline coincided with the facial midline, and the lower dental midline deviated from the facial midline to the right by 1 mm. Space analysis demonstrated mild crowding of the upper arch (Figures 2 and 3). Neither dental interference nor functional shift was detected. The soft tissue presented normal oral soft tissue, mucosa, and adequate attached gingiva. The tongue size and position were normal. The periodontium was diagnosed with gingivitis on a reduced periodontium.

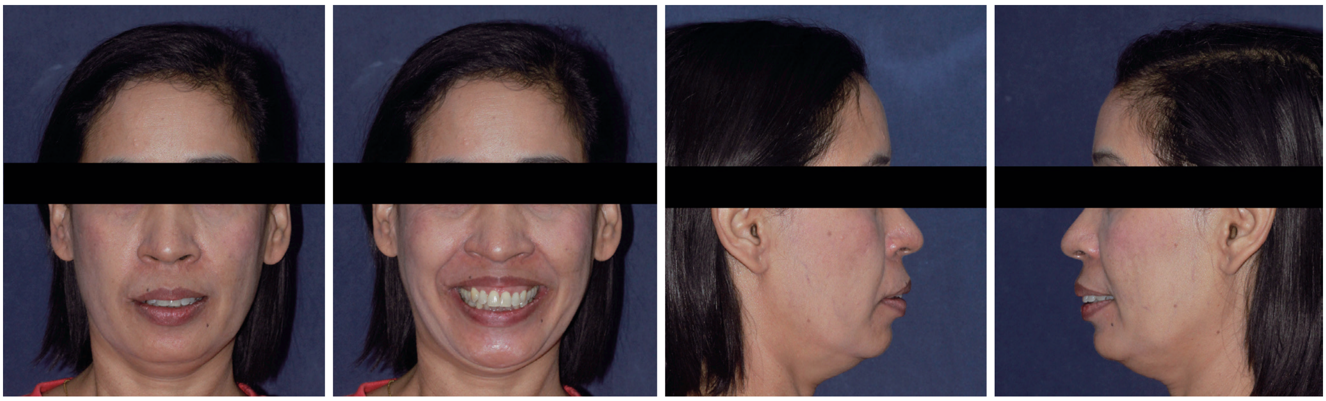

Figure 1 Pretreatment extraoral examination

Figure 2 Pretreatment intraoral examination

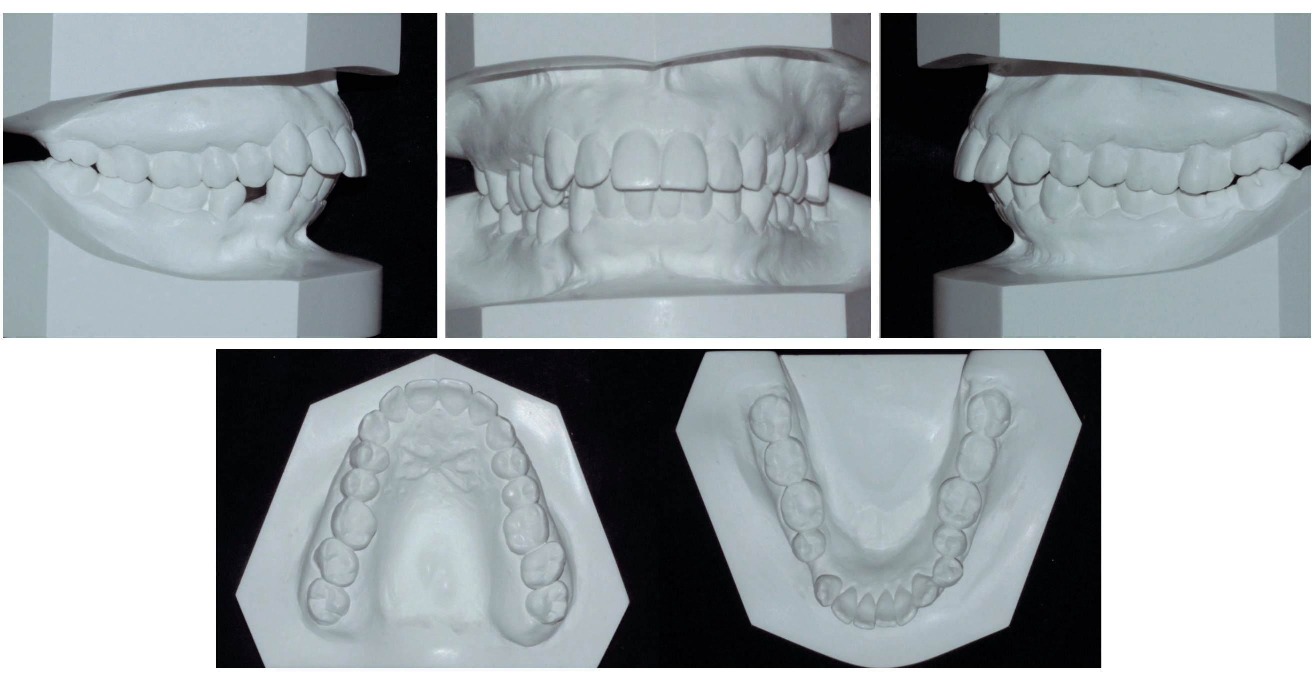

Figure 3 Pretreatment dental models

Table 1 Pretreatment Korkhaus's analysis

	Maxillary arch		Mandibular arch	
Type	Thai norm[12]	Pretreatment	Thai norm[12]	Pretreatment
Arch height (mm)	19.10 ± 2.40	19.00	17.3 ± 2.30	16.50
Anterior arch width (mm)	36.40 ± 1.90	31.50	36.2 ± 2.10	33.00
Posterior arch width (mm)	46.80 ± 2.20	41.00	45.7 ± 2.20	43.00

Figure 4 Pretreatment panoramic radiograph

Korkhaus's analysis showed that the lower anterior arch width (AAW) and posterior arch width (PAW) were wider than the upper AAW and PAW. Upper and lower AAW and PAW were narrower than standard value. The upper arch height (AH) was larger than the lower AH. Both upper and lower AH were larger than standard values (Table 1). Space analysis measurements revealed that the upper arch had a space deficiency of 1.50 mm.

Panoramic radiograph showed dental development at the permanent dentition stage with loss of the mandibular right first premolar due to dental caries (Figure 4). The maxillary nasal septum, bone density, and trabeculation were within normal limits with no other visible pathology; however, maxillary sinus pneumatization was at the 16 to 18 and 26 to 28 areas. Asymmetrical mandibular condyles were noted in that the right condyle was smaller than the left condyle. There were radiopaque masses size 2 x 3 mm at the base of the maxillary sinus apically to the right maxillary canine and left maxillary second molar.[13] Lateral cephalometric analysis[14] indicated a skeletal Class II hyperdivergent pattern with orthognathic maxilla and retrognathic mandible. Also observed were normally inclined but protruded upper incisors, proclined and protruded lower incisors, acute interincisal angle, protruded upper lip, normally positioned lower lip, and a normal nasolabial angle (Figure 5 and Table 2). The postero-anterior (PA) cephalometric analysis indicated that the right and left condyles were asymmetrical, and the left and right ramal heights were equal. The right body of the mandible was longer than the left side by 4 mm, maxillary plane canting by the left side was lower than the right side by 1 mm, and no occlusal plane canting was noted (Figure 6).

Figure 5 Pretreatment lateral cephalogram

Figure 6 Pretreatment postero-anterior cephalogram

Table 2 Pretreatment cephalometric analysis

Area		Measurement	Norm (Mean ± SD)	Pre treatment	Interpretation
Skeletal	Maxilla to cranial base	SNA (degree)[15]	84 ± 4	82	Orthognathic maxilla
		SN-PP (degree)[16]	9 ± 3	8	Normal inclination of maxilla
	Mandible to cranial base	SNB (degree)[15]	81 ± 4	75	Retrognathic mandible
		SN-MP (degree)[15]	29 ± 6	38	Hyperdivergent pattern
		SN-Pg (degree)[15]	82 ± 3	76	Retrognathic mandible
		NS-Gn (degree)[15]	68 ± 3	73	Hyperdivergent pattern
	Maxillo-mandibular	ANB (degree)[15]	3 ± 2	7	Skeletal Class II
		Wits (mm)[14]	-3 ± 2	3	Skeletal Class II
		MP-PP (degree)[15]	21 ± 5	30	Hyperdivergent pattern
		FMA (degree)[16]	23 ± 5	29	Hyperdivergent pattern
Dental	Maxillary dentition	$\overline{1}$ to NA (degree)[15]	22 ± 6	28	Normally inclined upper incisors
		$\overline{1}$ to NA (mm)[15]	5 ± 2	9	Protruded upper incisors
		$\overline{1}$ to SN (degree)[15]	108 ± 6	108	Normally inclined upper incisors
	Mandibular dentition	$\overline{1}$ to NB (degree)[15]	30 ± 6	42.50	Proclined lower incisors
		$\overline{1}$ to NB (mm)[15]	7 ± 2	14.50	Protruded lower incisors
		$\overline{1}$ to MP (degree)[14]	99 ± 5	109	Proclined lower incisors
	Maxillo-mandibular	$\underline{1}$ to $\overline{1}$ (degree)[15]	125 ± 8	103	Acute interincisal angle
Soft tissue	Soft tissue	E line U lip (mm)[16]	-1 ± 2	4	Protruded upper lip
		E line L lip (mm)[16]	2 ± 2	3	Normally positioned lower lip
		Nasolabial angle (degree)[14]	91 ± 8	84	Normal nasolabial angle
		H-angle (degree)[15]	14 ± 4	25	Protruded upper lip

The problem list in this patient included 1) skeletal problems (skeletal Class II relationship with retrognathic mandible and hyperdivergent pattern), 2) dental problems (dental Class II malocclusion, protruded upper incisors, mild crowding of the upper and lower anterior teeth, proclined and protruded lower incisors, and lower dental midline shift to the right by 1 mm), and 3) soft tissue problems (convex facial profile, protruded upper lip, and anterior gummy smile). Therefore, the treatment objectives were: 1) to improve the skeletal relationship to obtain normally inclined and positioned upper and lower incisors, 2) to obtain normal alignment and Class I canine and molar relationship, 3) to center the lower dental midline, 4) to improve the facial profile, and 5) to reduce the anterior gummy smile. The etiology of the malocclusion[4] was from hereditary factors. The chin retrognathism, gummy smile, and the tooth and arch size discrepancies were similar to her mother's. According to the collected information, the patient was diagnosed as Class II skeletal relationship with retrognathic mandible, dental Class II malocclusion with large overjet and deep overbite, convex facial profile, and protruded upper lip. An orthodontic treatment combined with orthognathic surgery (two-jaw surgical plan) was proposed. In the pre-orthodontic phase, the patient was referred for treatment of the gingivitis on reduced periodontium by full mouth scaling and polishing. During the presurgical orthodontic phase, dental decompensation was performed by repositioning the teeth into a correct position relative to the skeletal bases. This is the opposite of camouflage treatment. The patient was treated with a pre-adjusted edgewise appliance with a bidimensional bracket system (0.018-inch bracket slot at the anterior teeth and 0.022-inch bracket slot at the canine and posterior teeth) for leveling and aligning, and tooth decompensation. In this case, tooth decompensation was proposed for tooth aligning in normal alveolar bone before surgery. All teeth were leveled and aligned starting with 0.012-inch nickel-titanium (NiTi) followed by 0.014-inch and 0.016-inch NiTi wires, 0.016 x 0.016-inch and 0.016 x 0.022-inch stainless steel (SS) wires, respectively. The upper arch was expanded to coordinate the PAW with the lower arch. A dual occlusal plane of the lower arch was maintained using stainless steel wire with a curve of Spee.

In the surgical phase, rectangular 0.016 x 0.022-inch SS wires were used in both maxillary and mandibular arches. Tooth numbers 14, 24, and 34 were extracted in an operating room. The maxilla was corrected by anterior segmental osteotomy to retrocline and impact the anterior segment to correct the protruded upper incisors and gummy smile. The mandible had an improved facial profile and the lower incisor inclination was corrected by two surgical procedures: 1) bilateral sagittal split ramus osteotomy (BSSRO) advancement (4 mm) and 2) subapical osteotomy tilt back and retroclined lower incisors. After the surgical phase, the post-surgical finishing orthodontic phase was performed by correcting the dental inclination and angulation into a proper function, improved esthetics, and stability. Artistic wire bending was used in the upper and lower anterior teeth.

The total treatment time was 34 months and divided into the presurgical orthodontic phase (16 months), surgical phase (2 months), and post-surgical orthodontic phase (16 months). At the end of the treatment, the extra-oral and intra-oral examinations showed that the patient had an improved facial profile and a less convex facial profile. Furthermore, the examinations showed competent lips, decreased incisal show at rest, normal smile line, normal overjet and overbite, molar Class I relationship, improved canine relationship, and the upper and lower dental midline coincided with the facial midline (Figures 7-9). However, the nasolabial angle had increased. A panoramic radiograph showed mild apical root resorption but no other pathological finding (Figure 10). The lateral and PA cephalometric analysis showed successful outcomes and met the established treatment objectives, i.e., skeletal Class I normodivergent pattern

Figure 7 Posttreatment extraoral examination

Figure 8 Posttreatment intraoral examination

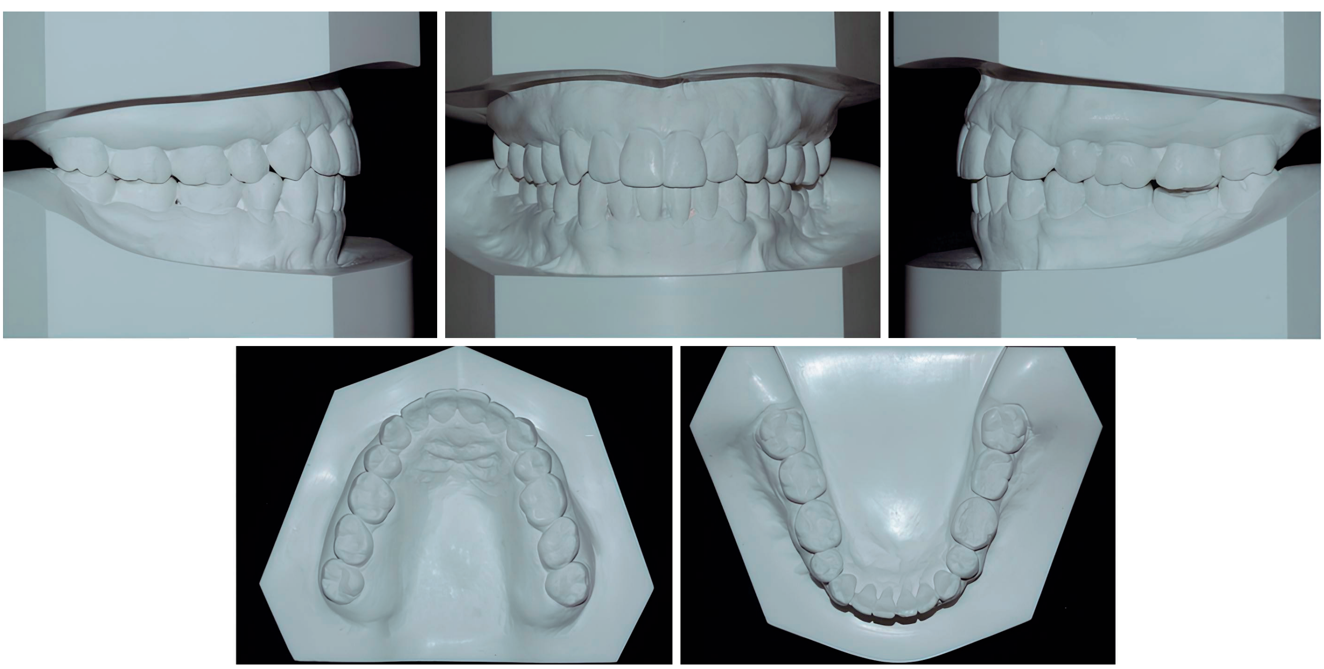

Figure 9 Posttreatment dental models

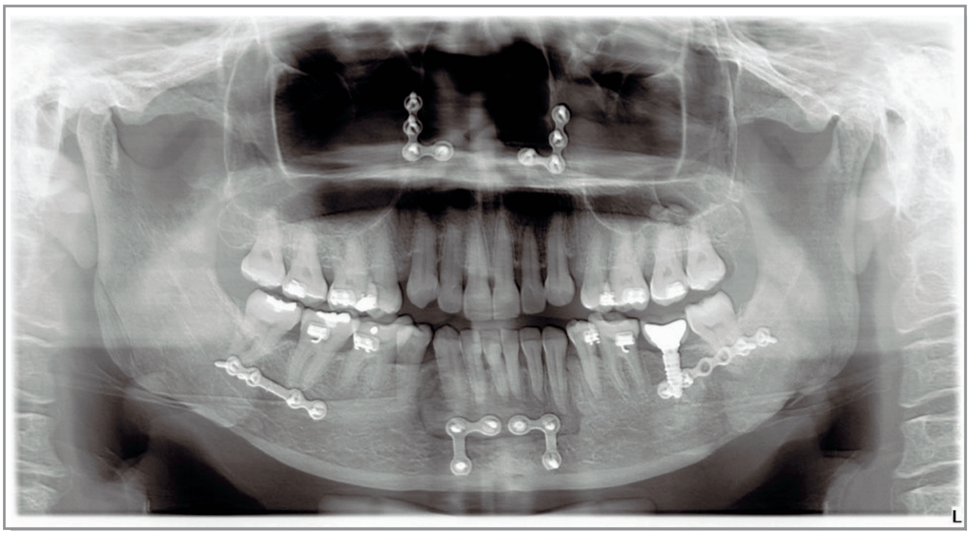

Figure 10 Posttreatment panoramic radiograph

Figure 11 Posttreatment lateral cephalogram

Figure 12 Posttreatment postero-anterior cephalogram

with orthognathic maxilla and mandible while maintaining maxillary plane canting without occlusal plane canting, and no chin deviation (Figures 11 and 12). Table 3 shows the results of the treatment: decreased SNA and increased SNB, improved divergent configuration, dental Class I normally inclined and positioned upper and lower incisors, normal interincisal angle, slightly convex facial profile, normally positioned upper lip but retruded lower lip, and normal nasolabial angle.

The pretreatment and posttreatment cephalometric superimposition tracings are shown in Figure 13. The changes observed were: position of the N point was maintained, the anterior maxilla moved inferiorly backward while the mandible moved forward, the upper and lower incisors had retroclined and retruded, and mesialization of the upper molars but the lower molars had distalized. Compared with pretreatment, the facial profile improved, the upper

Table 3 Comparison of pre and posttreatment cephalometric analyses

Area		Measurement	Norm (Mean ± SD)	Pre treatment	Post treatment	Differences
Skeletal	Maxilla to cranial base	SNA (degree)[15]	84 ± 4	82	80	-2
		SN-PP (degree)[16]	9 ± 3	8	9	+1
	Mandible to cranial base	SNB (degree)[15]	81 ± 4	75	77	+2
		SN-MP (degree)[15]	29 ± 6	38	34	-4
		SN-Pg (degree)[15]	82 ± 3	76	79	+3
		NS-Gn (degree)[15]	68 ± 3	73	70	-3
	Maxillo-mandibular	ANB (degree)[15]	3 ± 2	7	3	-4
		Wits (mm)[14]	-3 ± 2	3	-1	-4
		MP-PP (degree)[15]	21 ± 5	30	25	-5
		FMA (degree)[16]	23 ± 5	29	23	-6
Dental	Maxillary dentition	$\overline{1}$ to NA (degree)[15]	22 ± 6	28	21	-7
		$\overline{1}$ to NA (mm)[15]	5 ± 2	9	4	-5
		$\overline{1}$ to SN (degree)[15]	108 ± 6	108	102.50	-5.50
	Mandibular dentition	$\overline{1}$ to NB (degree)[15]	30 ± 6	42.50	26	-16.50
		$\overline{1}$ to NB (mm)[15]	7 ± 2	14.50	8	-6.50
		$\overline{1}$ to MP (degree)[14]	99 ± 5	109	93	-16
	Maxillo-mandibular	$\underline{1}$ to $\overline{1}$ (degree)[15]	125 ± 8	103	129	+26
Soft tissue	Soft tissue	E line U lip (mm)[16]	-1 ± 2	4	-3	-7
		E line L lip (mm)[16]	2 ± 2	3	-1	-4
		Nasolabial angle (degree)[14]	91 ± 8	84	89	+5
		H-angle (degree)[15]	14 ± 4	25	12.50	-12.50

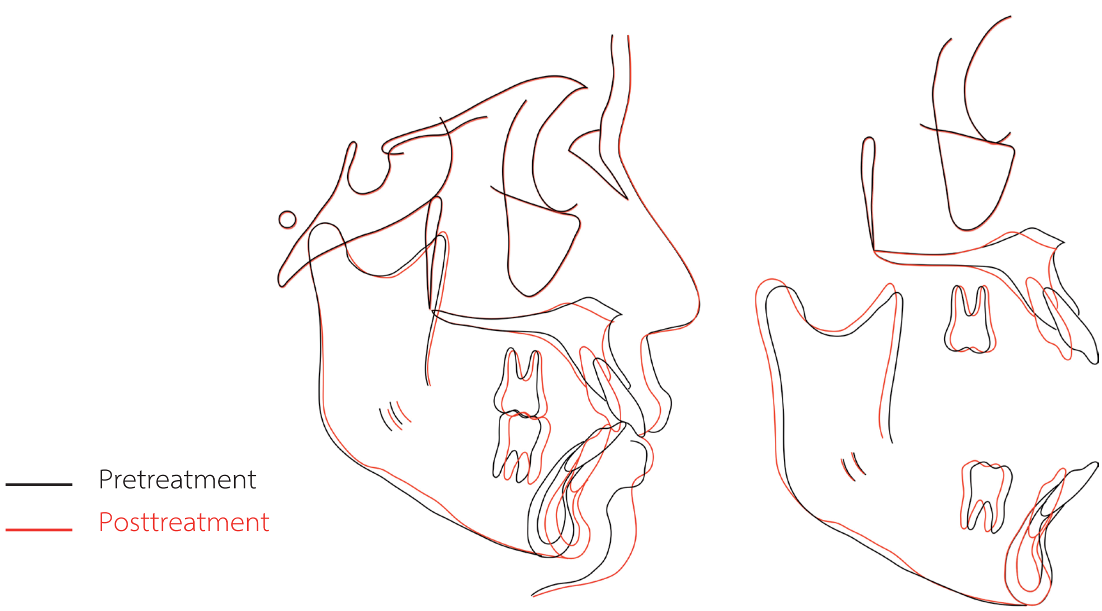

Figure 13 Cephalometric superimposition of pretreatment (black) and posttreatment (red) tracings.

Figure 14 Extraoral examination at 30 months after debonding

Figure 15 Intraoral examination at 30 months after debonding

lip had retruded, the lower lip had protruded, and the nasolabial angle had increased.

Wraparound retainers were used in both the maxillary and mandibular arches in the retention period. The maxillary arch included a passive anterior bite plane in the wraparound retainer to maintain the vertical dimension.[4,17] The vertical dimension in this case had to be maintained using a retainer with a passive anterior bite plane because initially before treatment the patient had a deep overbite. The patient was instructed to wear both the upper and lower retainers full time except during meals and tooth brushing. The follow-up times were at 1 week, 1 month, and 3 months after debonding, and every 6 months thereafter to evaluate the function, esthetics, and stability.

The patient was recalled at 30 months after completing the treatment. The results found an acceptable profile, occluded occlusion, and no interferences on lateral and protrusive excursion. The protocol of wearing the retainer full-time was followed as requested. She put a lot of emphasis on wearing the retainer to maintain good position of the teeth (Figures 14 and 15).[18]

Discussion

The patient's primary complaint when she arrived at the orthodontic clinic was protruding upper incisors and a gummy smile. On clinical examination, the frontal view showed a symmetrical dolichofacial type, and the lateral view showed a convex profile. The patient had incompetent lips at the rest position. A gummy smile was presented when the patient presented a full smile. In this case, the patient had a Class I molar relationship on both sides. On the other hand, the canine relationship on the right and left sides were Class II canine relationships. The maxillary and mandibular arches presented mild crowding, deep overbite (4 mm), and large overjet (5 mm). The diagnosis was skeletal Class II hyperdivergent pattern with orthognathic maxilla and retrognathic mandible and dental Class II malocclusion with mild crowding of the upper and lower anterior teeth.

This patient had Class II skeletal characteristics with a hyperdivergent pattern and a convex facial profile with a retruded chin and protruded upper lip. The patient had a familial line with protruded upper incisors and a gummy smile. She reported no accidental trauma to the head or face area. Functional shift was not found in the clinical examination. The PA cephalometric analysis showed no chin deviation. The thin symphysis could limit orthodontic tooth movement in the lower incisors. Therefore, the treatment plan was to correct the upper incisor protrusions and gummy smile and improve the facial appearance and her smile. The plan included orthodontic treatment combined with orthognathic surgery. This treatment plan could correct her chief complaint and improve her skeletal structure. Moreover, this procedure had more stability than camouflage treatment by conventional orthodontic treatment.[19]

The gummy smile had a gingival show of 4-5 mm but no posterior gummy smile and no dual occlusal plane combined with an incisal show at rest of 3 mm. These observations indicated that a vertical problem did not cause the gummy smile. Therefore, the gummy smile would be corrected from the relationship between the alveolar bone and the anteroposterior protrusion of the upper incisors. The plan to correct the gummy smile and upper lip protrusion was performed by anterior maxillary osteotomy in the upper jaw combined with alar cinching to correct the wide nasal base. In the maxilla, a retroclined anterior segment was planned. In the mandible, the proclined and protruded lower incisors were corrected by subapical osteotomy setback and tilt back combined with the BSSRO mandibular advancement to achieve a normal position of the upper and lower lips.

Before starting the treatment, the treatment plan was discussed between the orthodontist and the maxillofacial surgeon. The patient was informed of all data, treatment objectives, treatment plan, expected outcome, and complications for a decision by the patient. The advantages of orthodontic treatment combined with orthognathic surgery[20] were 1) improved skeletal and dental conditions, 2) improved facial esthetics, 3) correcting the malocclusion, and 4) more stability than conventional orthodontic treatment. However, the disadvantages of this treatment plan were 1) risk of anesthesia, 2) surgical complications such as numbness, bleeding, or infection, 3) high cost, and 4) possible surgical relapse.[21]

In the presurgical orthodontic phase, the maxillary arch was well aligned in the normal alveolar bone; therefore 0.016 x 0.022-inch SS wire was used. The mild crowding of the mandibular arch was corrected, and the teeth were aligned and finally a 0.016 x 0.022-inch SS wire was used. From the maxillary and mandibular cephalometric superimposition of pre and posttreatment tracings, proclination of the upper and lower incisors was about 1 mm, but the upper and lower posterior teeth were in the same position. Extraction of the upper and lower first premolars, except for the lower right first premolar, was then planned.

A comparison of the clinical and lateral radiographic outcomes before and after treatment was performed. Skeletal position showed the anterior segment of the maxilla (2 mm retraction) and mandible (3 mm retraction) were retracted. The mandible was advanced 4 mm to reduce the Class II skeletal relationship. Dental position showed Class I molar relationship on both sides was achieved with good intercuspation. The canine relationship was Class II 1-2 mm but there was a good cusp to fossa relationship with no occlusal interference. Canine guidance was achieved during eccentric movement with normal overjet and overbite. The patient accepted all treatment outcomes. Soft tissue position showed the upper lip was retracted into a normal position. The nasolabial angle had increased. Retraction of the lower lip improved the esthetics and chin position. The gummy smile was corrected to a normal smile line. The lateral profile improved while the vertical proportion was maintained.[20,22]

The following factors contributed to the favorable prognosis.[23,24] Normal overjet and overbite was achieved after treatment with maximum intercuspation, and the patient had no abnormal oral habits. During treatment, the intercanine and intermolar width were maintained. Coordinating the upper and lower arch was performed to maintain the dental position to reduce transversal relapse.[24] The patient's compliance was high, and she had a positive attitude regarding her orthodontic therapy. The selected surgical procedure was stable, and no relapse after surgery occurred.

During the retention period, the upper and lower wraparound retainers were introduced to the patient because these appliances would not cause occlusal interference. The patient was instructed to reduce the duration and frequency of wearing the retainer as dental stability increased.[25] After treatment, follow-up should be conducted at 1 week, 1 and 3 months, and every 6 months thereafter until there is no relapse and every year thereafter.

Conclusion

In this case, good treatment outcomes were achieved by orthodontic treatment combined with two-jaw orthognathic surgery to correct the upper lip protrusion and gummy smile. The patient had a normal smile line and a better lateral profile. She was satisfied with the results of the treatment and smiled with more confidence. The treatment resulted in maintaining good occlusion, no dental interference when performing eccentric movement, normal overjet and overbite, and normal interincisal angle.

Author contributions

TS: Original draft preparation, Manuscript review and editing; SP: Original draft preparation, Manuscript review and editing; and CK: Resources.

Ethical statement

The patiant's consent was obtained before publication.

Disclosure statement

Authors have no the conflict of interest.

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Review Article

Orthodontist and Obstructive Sleep Apnea Screening Tools

Tuangporn Jessadapornchai* Bancha Samruajbenjakun**

Abstract

Obstructive sleep apnea (OSA) is a sleep disorder that contributes to disrupted sleep due to a cessation of breathing or a decrease in airflow. OSA is diagnosed by polysomnography (PSG), which is considered to be the gold standard. However, conducting a PSG has limitations that include, time consumption, inconvenience, and cost. Also, all institutions may not have the equipment, technicians, or expert sleep physicians for a definitive diagnosis of OSA. Patients who have subclinical symptoms may go undiagnosed because of its non-specificity and patient unawareness. OSA should be examined in a timely manner. If the disease goes undiagnosed for an extended time, many short- and long-term unsatisfactory outcomes may occur that affect a person's lifestyle leading to dramatic consequences. Recent literature encourages orthodontists to know how to investigate OSA and the upper airway using questionnaires and radiography as screening tools before undergoing polysomnography.

Keywords: Cone beam computed tomography, Obstructive sleep apnea, Questionnaire, Screening, Upper airway

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Introduction

Obstructive sleep apnea (OSA) is a disorder that causes difficulty sleeping. On a spectrum of increasing severity sleep disorders, OSA is at the top. Its characteristics are either partial or total constriction of the upper airway. The two main reasons that cause OSA are anatomical and non-anatomical. When the upper airway does not allow normal respiratory flow, the availability of oxygen is reduced and the level of carbon dioxide increases,[1,2] which activates the brain and sympathetic nervous system. The upper airway dilating muscle then contracts sufficiently to widen the respiratory tract for normal air flow. A recuring cycle of this situation leads to sleep deprivation,[3] which causes a person to feel sleepy all day that may result in work-related and vehicle accidents in addition to memory impairment and inappropriate behavior. Snoring is one of the distinctive symptoms of the disease that disturbs a person who sleeps nearby. This recurrent sympathetic nervous system overactivation can lead to adverse health outcomes such as hypertension, cardiovascular disease, and metabolic disease.[2]

According to a population-based prevalence study among middle-aged people, OSA occurs in 24 % and 9 % of males and females, respectively.[4] Surprisingly, one-third of formerly undiagnosed OSA patients who attended a primary health care system were found to have moderate to severe OSA.[5] From an exploratory prevalence research study in a southern Thailand population, 85.60 % of subjects had experienced OSA.[6] In central Thailand, a study revealed OSA in 11.40 % of the population.[7] Other population groups susceptible to obstructive sleep apnea include children and patients with cleft lip and palate.[8] For a definitive diagnosis using the polysomnography sleep test, information from patients includes clinical symptoms related to sleep, sleep performance, history of OSA, predisposing conditions, and a physical examination of the respiratory, cardiovascular, and nervous systems.[1] Due to the unavailability of the

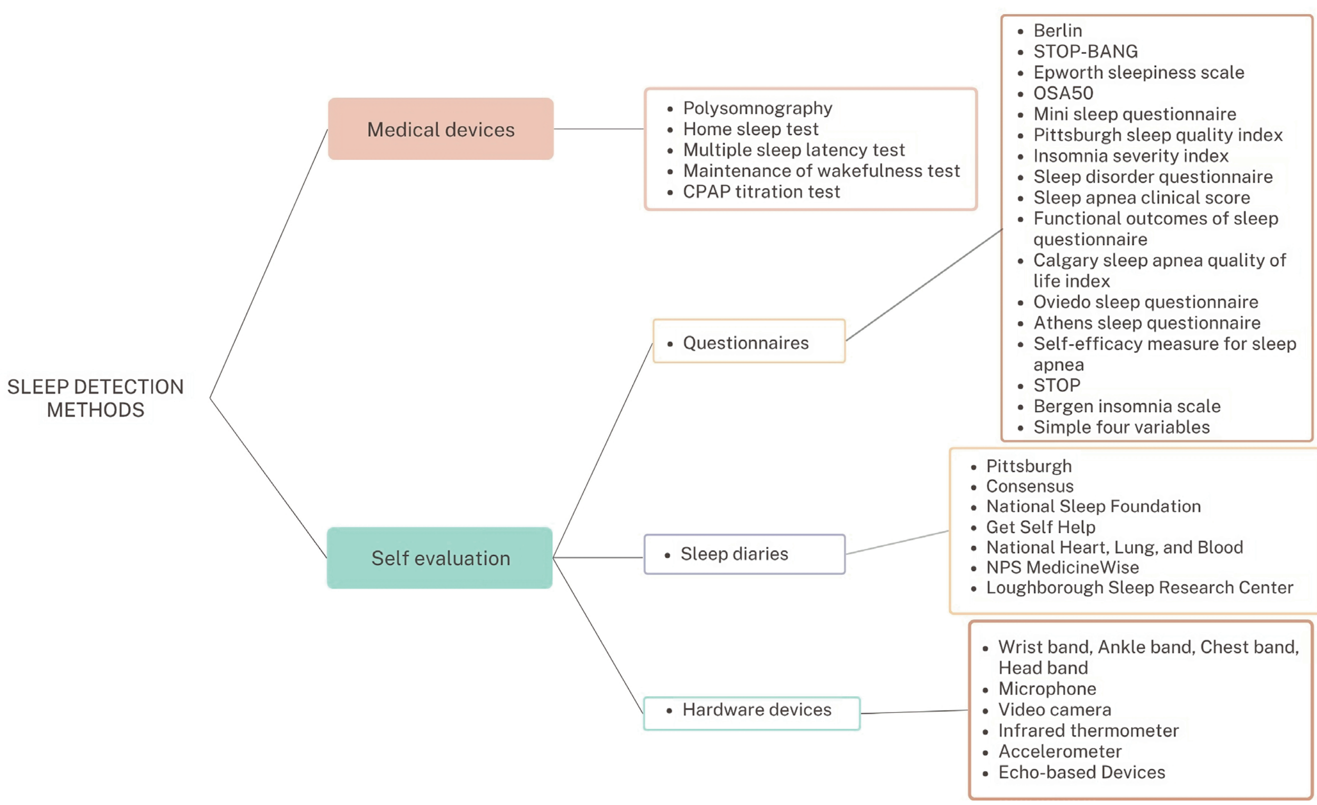

Figure 1 Sleep detection methods[10]

proper equipment and expert technicians and doctors, researchers have attempted to create tools for an initial diagnosis.

An orthodontist is part of a multidisciplinary team in OSA clinical care because of the opportunities to see many patients who may have symptoms of OSA but lack knowledge for treatment. Many adult patients who need orthodontic treatment may simultaneously have symptoms of OSA that can be evaluated by diagnostic tools. Furthermore, the orthodontist can educate patients concerning the disease. If any serious concerns arise from the objective tools, patients can be referred to a sleep specialist for a definitive diagnosis.[9] The objective of this current literature review is to collect evaluation methods that focus on questionnaires and radiographic methods for a tentative diagnosis of OSA in orthodontic practice.

Literature review

Questionnaire methods

Figure 1 Showed the questionnaires as one of the methods used to evaluate day and night clinical symptoms.[10]

Self-evaluation by questionnaires is a preliminary assessment tool used in primary care because it is inexpensive and fast. However, the drawback is perception bias of the respondents that yields low accuracy. In fact, this type of tool has the lowest accuracy among other sleep detection methods. Currently, there is no agreement on which questionnaire should be the primary questionnaire. Selection of a questionnaire should be dependent on the purpose of the questionnaire with academic evidence on the sensitivity and specificity, and convenience in its utilization. Questionnaires that contain too many questions, complex score evaluations, and computer calculations will lead to disuse of such questionnaires.[11]

STOP-BANG questionnaire (SBQ)[10]

The SBQ was developed by a Canadian anesthesiologist to assess patients before surgery. It is one of the popular questionnaires used for a preliminary diagnosis because it is simple. The patient can complete the questionnaire within 5 minutes. The questionnaire contains yes-no questions on eight topics: snoring, fatigue, sleep apnea, hypertension, body mass index over 35 kg/m^2, age > 50 years, neck circumference > 40 cm, and male gender. A score of 3 out of 8 identifies OSA patients from patients without OSA. Therefore, this questionnaire is considered to have the best sensitivity. However, the specificity was found to be < 50 % since it yields false positive results in patients with OSA in the moderate to severe level. Hence, Banhiran et al.[11] suggested adding one more parameter, the waist-to-height ratio since it is a good indicator for the moderate to severe level of OSA.

Berlin questionnaire (BQ)[12]

The BQ was the first questionnaire available to general practitioners in Berlin, Germany in 1996 by U.S. and German pulmonary and primary care physicians. It consists of 11 questions with three categories of questions: witnessed apneas, daytime sleepiness or fatigue, and hypertension and obesity. This questionnaire divides patients into two categories: patients with high and low risk of OSA. There was reported the internal validity of the first two categories that category 1 = 0.92 and category 2 = 0.63.[13] Moreover, it was found that this questionnaire has 76 % sensitivity and 45 % specificity with apnea-hypopnea index (AHI) cut off ≥ 15.[1]

Aged over 50 (OSA50)[12]

The OSA50 questionnaire was created by a group of physicians who were sleep specialists in Australia, and their aim was to create a short and concise questionnaire for primary care providers. The questionnaire consists of only 4 topics that predict the severity level of OSA derived from logistic regression analysis: obesity measured by waist circumference, snoring, witnessed apneas, and age > 50 years. If the score ≥ 5, it is identified moderate to severe OSA with 100 % sensitivity and 29 % specificity. From ROC curve analysis, the OSA50 questionnaire was significantly predictive of moderate to severe OSA. However, this questionnaire alone is not enough accuracy for with and without OSA differentiation.[14] The OSA50 questionnaire is illustrated in Table 1.

Epworth Sleepiness Scale (ESS)[12]

The ESS questionnaire aims to determine daytime sleepiness through eight scenarios by rating the level of sleepiness from 0 to 3 in each scenario. The total score is 24. A higher score indicates a higher level of daytime sleepiness. If the score is ≥ 8, it indicates a low level of daytime sleepiness. The ESS score is not correlated with the AHI. The patient with daytime sleepiness may not be detected by this questionnaire. Furthermore, daytime sleepiness is not necessarily caused by OSA. It may be caused by other types of sleep disorders or depression as well. Therefore, this questionnaire should be used together with another questionnaire to identify clinical symptoms with high risks of illness and to gain benefit from the treatment. Moreover, it was found that patients with OSA usually score < 8 in the ESS.

Assessment by radiography

Since the abnormality of craniofacial and respiratory structures is one of the causes of OSA, plenty of previous studies focused on the relationship between them and OSA using various radiographic tools.

Lateral cephalometry

Anatomical abnormality in craniofacial regions and upper airway is a possible risk factor of OSA.[2,15] Combination of skeletal and soft tissue anatomy and

Table 1 OSA50 screening questionnaire

Factor	Question	If yes, score
Obesity	Waist circumference measured at the umbilicus level (> 102 cm for males or > 88 cm for females)	3
Snoring	Has your snoring ever bothered other people?	3
Apneas	Has anyone noticed that you stop breathing during your sleep?	2
Age	Are you over 50 years of age?	2
	Total score	10 points

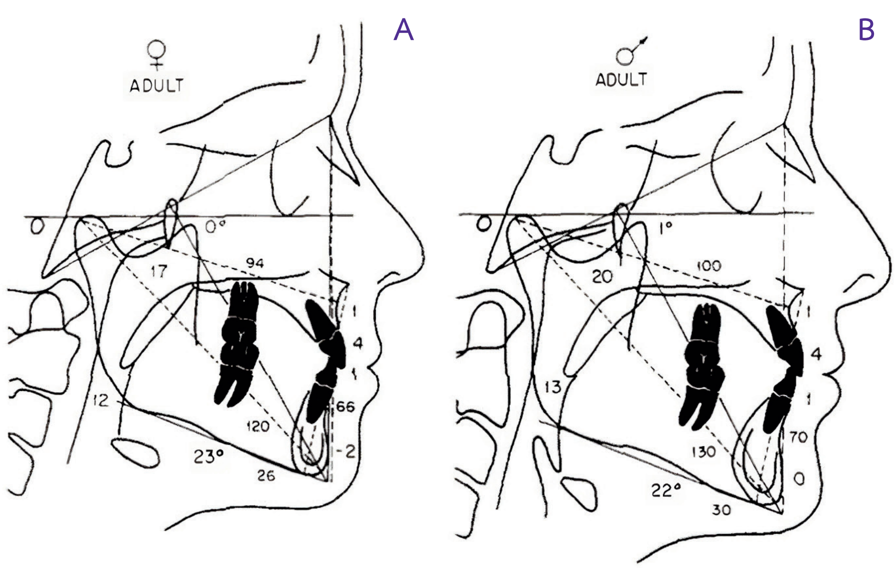

Figure 2 Lateral cephalometric upper airway analysis by McNamara: (A) ideal female; (B) ideal male[16]

function determines upper airway patency. Lateral cephalometry is the routine radiograph in orthodontic practice to analyze craniofacial region and broadly used in oropharyngeal airway area.[15]

In 1984, McNamara conducted a study that analyzed the probability of an abnormal airway. The tongue is believed to be the organ that causes obstruction in the upper airway, which can be observed in a lateral cephalogram. Measurement of lateral cephalograms was conducted to obtain normal values. Measurement from the posterior part of the soft palate to the closest posterior pharyngeal wall was 5 mm or less while the average sagittal dimension of the upper airway of the samples was 17.40 mm and increased with age. At the lower airway, the average measurement from the intersection between the posterior tongue and the posterior border position to the closest posterior pharyngeal wall was 10-12 mm, which did not increase with age.[16] Lateral cephalometric upper airway analysis by McNamara is displayed in Figure 2.

Studies were conducted by otolaryngologists and radiologists on the structures of the cranial bones, face, jaw, and upper airway based on lateral cephalograms of 105 samples who were of Thai ethnicity with no

Table 2 Normal values of lateral cephalometric data of the upper airway in Thai non-OSA population.

Parameters (Mean ± SD)	Males	Females	*P* value
HP/SP (degree)	124.80 ± 7.00	126.10 ± 7.60	0.42
N-ANS (mm)	58.60 ± 3.80	55.70 ± 3.60	0.02*
ANS-GN (mm)	73.50 ± 4.60	71.30 ± 6.0	0.60
GN-GO (mm)	84.80 ± 4.70	80.40 ± 4.30	< 0.01*
PNS-PP (mm)	26.60 ± 3.50	26.90 ± 3.20	0.68
H-PP (mm)	35.60 ± 4.40	29.00 ± 2.90	< 0.01
H-GN (mm)	50.90 ± 6.50	50.00 ± 7.20	0.59
MPH (mm)	16.10 ± 5.30	10.80 ± 4.90	< 0.01*
PAS (mm)	14.20 ± 3.40	11.10 ± 3.30	< 0.01*
PNS-P (mm)	34.80 ± 6.10	32.30 ± 3.10	0.05
TL (mm)	81.00 ± 5.40	76.70 ± 4.70	< 0.01*

The significant difference between genders at $P < 0.05$.

HP/SP = angle between hard palate and soft palate; N-ANS distance between nasion and anterior nasal spine; ANS-GN = distance between anterior nasal spine and gnathion; GN-GO = distance between gnathion and gonion, PNS-PP = the shortest distance between posterior nasal spine and posterior pharyngeal wall; H-PP = the shortest distance from hyoid bone to posterior pharyngeal wall; H-GN distance from hyoid bone to gnathion; MPH = distance from mandibular plane to hyoid bone; PAS = the shortest distance between base of tongue and posterior pharyngeal wall; PNS-P = length of soft palate, distance between posterior nasal spine and tip of soft palate; TL = distance between tip of tongue and valleculae, the intersection of epiglottis and base of tongue symptoms of OSA confirmed by ESS score ≤ 8. Table 2 showed the lateral cephalometric data of the normal values of the upper airway in Thai non-OSA population.[17]

From the study by Sforza et al.,[18] the relationship between pharyngeal collapsibility and cephalometric parameters was found in PNS-P, H-PP, and MPH. From the logistic regression analysis, patients with MP-H ≥ 18 mm, NSBa ≤ 130 degree, and PAS ≤ 10 mm tend to increase risk of AHI ≥ 15 (moderate to severe OSA).[19] Moreover, there is strength of the correlation between some of the adult craniofacial morphology and upper airway found by meta-analysis. OSA patients have a significant decrease in cranial base angle (S-N-Ba) and length (S-N). Decreasing cranial base angle made posterior pharyngeal wall more anterior position. Decreasing cranial base length made maxilla more retrusion and upper airway space was consequently reduced. Longer facial height (SN-GoMe, ANS-Me, N-Me, SN-MP), normal maxillary position (SNA) but reduced maxillary length (ANS-PNS), smaller and retruded mandible (SNB, Go-Me, Go-Gn, mandibular length), coexistence of acute cranial base angle with bimaxillary retrusion leads to less airway space. Increased area and length of tongue and soft palate, also increased with aging will be more posterior position of tongue that invade upper airway space. Upper airway length (UAL), posterior airway space (PAS), and PNS-Pharyngeal wall are decreased in OSA patients from intrusion of surrounding skeletal and soft tissue structures. The inferior position of hyoid bone (GoMe-H, MPH) made the upper airway longer leading upper airway tended to collapse.[15] To sum up, according to these studies, cephalometric parameters which indicate OSA could focus on SNB, NSBA, Gn-Go, PNS-PP, MPH, PAS, and PNS-P.

The data from studies on cephalometric radiographs against a preliminary diagnosis of adenoid hypertrophy revealed that the sensitivity and specificity were 61-75 % and 41-55 %, respectively.[20,21] The researcher suggested that the studies and analysis should be done by a 3D device in the future because that would likely yield more accurate results.[15] Lateral cephalometric radiograph may not provide complete information on respiratory structures from an axial plane or transverse dimension and cannot assess complications of the airway.[22] Moreover, a 2D-radiographic device may also cause misinterpretation[23] due to magnification and overlapping of the structures. However, the advantage of this type of radiographic device is that it emits low radiation, and it is less expensive.

Three-dimensional radiography

Conventional computed tomography (CT) versus cone beam computed tomography (CBCT)

In the past, conventional CT was used to study the structures of the upper airway in relation to OSA. However, since the introduction of cone beam computed tomography (CBCT) in the late 1990s, CBCT has been used for measurements of the upper airway. The advantage of CBCT is that it uses less radiation,[24] Furthermore, it takes less time, which results in a lower amount of radiation exposure to the patients.[25] The device moves only in one cycle to collect all data in a total of 8-40 seconds,[26] which results in approximately 10 times less radiation than a conventional CT. Even though it offers low resolution of soft tissue,[27] it does not cause problems on measurements for accuracy and re-measuring[28] because there is a high contrast between the bone, space, and soft tissue, which is considered good information. Therefore, it is commonly used in oral and maxillofacial surgery. Moreover, the radiographic procedure is simple and compatible with Digital Imaging and Communications in Medicine files[29] that can be easily accessed by dentists[30] with a low cost.[25]

Assessment of the upper airway by CBCT

In addition to using CBCT to compare patients with OSA and without OSA, it is also used to compare changes in the airway after certain types of treatment, such as maxillary expansion or jaw surgery.[31]

Focus on the anatomy, no statistically significant differences were reported between craniofacial structures farther from the airway among those with and without OSA.[32,33] Therefore, the studies usually done in the area of upper airway.

The pharynx of the upper airway can be categorized into four different sections from the upper part to the lower part: nasopharynx, velopharynx, oropharynx and hypopharynx.[26] Presently, the literature does not offer clear definitions of the referenced positions to determine the extent of the airway structure to analyze the upper airway. Therefore, measurements of the upper airway in each study can vary. In general, however, analyses are conducted at the position lower than the second cervical vertebra since a small window can be used which results in the reduction of radiation exposure to patients. It is also common to make assessments around the oropharynx because OSA is often found in this area.[23]

Airway assessments normally start from the nasopharynx down to the oropharynx. It is common to measure the following parameters: the minimum cross-sectional area, anteroposterior and lateral dimensions, shape, volume, and length,[3] which can be accurately measured and can be re-measured, using computer technology to create a 3D-image.[32,33] At the nasopharynx level, a deviation of nasal septum could be a radiographic marker in OSA screening.[34] Seeing that major septal deviation can contribute to severe nasal congestion, OSA could subsequently occur.[35] Meanwhile, in the study of Jafari-Pozve et al., not found significant difference in the anteroposterior and transverse dimension of nasopharynx, oropharynx, and hypopharynx.[36]

At the oropharynx level, Momany et al. discovered the airway narrowest cross-sectional area (CSA) showed a significant negative correlation with AHI and was a significant variable in OSA prediction by multiple regression analysis.[37] One study that presented a correlation between the cross-sectional area dimension and the level of risk of OSA concluded that if the minimum cross-sectional retropalatal area is < 52 mm^2, the risk of OSA would be high. If the minimum cross-sectional retropalatal area is <110 mm^2, the risk of OSA would be low.[38]

The studies on the upper airway structure found that the minimum cross-sectional area is a statistically significant[3,22] parameter that involves the pathophysiology of OSA explained by Poiseuille's Law. This law states that the resistance to airflow is proportional to the fourth power of the airway radius but inversely proportional to airway length, which means a small airway radius results in increased resistance to air flow.[39]

According to Poiseuille's Law, the parameter of total airway volume may not provide sufficient data on the upper airway in line with OSA as much as the cross-sectional area of the airway.[40] However, according to previous studies, it was found that the average airway volume and the total airway volume in patients with OSA was statistically significantly[24] lower than subjects without OSA. Consequently, the assessment of airway volume is also important.

Studies on the shape of the cross-sectional area of the upper airway found that subjects with OSA had a concave cross-sectional area. However, in normal individuals, the cross-sectional area of the airway appeared in various shapes, such as concave, circular, or square.[22]

Enciso et al, developed prediction model to determine OSA risk factors from CBCT with Berlin questionnaire. They found age > 57 years, male, high risk Berlin questionnaire, narrow lateral dimension of the upper airway (< 17 mm) were risk factors to present OSA.[41]

Limitations of CBCT

CBCT is a static analysis that captures the image by recording when the patient is in the sitting position and awake and does not involve the sleeping process. Moreover, CBCT does not offer the best soft tissue contrast. It is difficult to clearly differentiate soft tissues such as the tonsils, lymph nodes, muscles, tendons, blood vessels, salivary glands, and connective tissues from hard tissues. However, CBCT offers high spatial resolution enough that can be used for preliminary examination. Additionally, some errors in interpretation of CBCT images may be caused by the breathing phases and position of the head and tongue. Other errors may be due to craniocervical inclination, which affects the cross-sectional dimension of the airway despite attempts to set the same criteria for everyone.[3]

CBCT accuracy for upper airway measurement is high.[42] There was an erroneous of MCA and volume measurement by CBCT 11-20 % and less than 4 % respectively.[29] Result from another study showed 59 % of subjects in nasopharynx measurement found 0-10 % difference between twice CBCT scanning results. In oropharynx, 10-20 % difference in 44 cases, and hypopharynx, 0-10 % from 50 cases was found.[32] In terms of CBCT file exportation to Dolphin software for measurement, in oropharynx, there was overestimation 12 % and underestimation 23 %.[33] In addition, concerning reliability, CBCT also contributed to high.[29]

Discussion

Although PSG is the gold standard of OSA diagnosis and clinical characteristics alone could not be replaced, PSG still have several disadvantages in case of population-level on the ground of high cost, long waiting lists, and lacking experts.[37] Furthermore, sleep difficulty or "first-night effect" leads to less reliability results.[17]

The clinical symptoms of OSA can be investigated through questionnaires. Their advantages of short and concise form make them appropriate for primary care level. In addition, assessing posttreatment symptoms is often the purpose for application. From a previous study, even though several types of questionnaires have high sensitivity, the specificity varies from average to low contributing to false positive results. Thus, questionnaires are just methods in the initial diagnosis. They should be used in combination with radiograph and clinical examination for more accuracy.[43]

The Berlin questionnaire is not generally used due to the complex scoring system contributing to time consuming[12]and large number of false negative results (209 per 1000 patients).[1] In terms of STOP-BANG, the lower the cut point, the lower specificity leading to less true positive result. Moreover, some items in the questionnaire might inappropriately be used for everyone, for example, snoring and witness apnea, if the patients sleep alone, they cannot apparently know that they encounter with these symptoms. ESS emphasizes daytime sleepiness issue which does not relate to AHI. In addition, this symptom is not specific to only OSA but can be inferred to other sleep disorders.[12] Recommendation of American academy of sleep medicine (AASM) experts is clinical tools, questionnaires, and prediction algorithms not used to diagnose adult OSA without the conjunction with polysomnography or home sleep apnea testing because of low level of accuracy. They accentuated that the harms outweigh benefits on account of undiagnosed false negative and unimportant further investigation and treatment because of false positive.[1]

Prediction algorithm set by clinical and radiographic of risk factors may be helpful to differentiate high risk OSA from non-OSA patients in non-sleep clinic setting even if, they are less precision for OSA diagnosis.[1] Nonetheless, there are some issues that make utilization of this equipment confronted the difficulty. To use the CBCT data in conjunction with questionnaire, there is still controversy in the diagnosis. The study of Chaudry et al. found minimum cross-sectional area in retropalatal region is less than 110 mm^2, 90 % of subjects in STOP-Bang scores ≥ 3 subgroup considered to be OSA.[44] which differed from the study of Lowe et al, that indicated minimum cross-sectional area in retropalatal region less than 110 mm^2, would be low risk of OSA.[38] Differences in upper airway measurement boundaries in each study, until now, there is no consensus on which upper airway anatomical landmarks are related to OSA pathophysiology.[3] Due to dynamic changes of upper airway anatomical structures, researchers should be aware of different breathing stages, tongue positions, swallowing phases, occlusion indicating mandibular position, and the sleep-awake cycle[32] when lateral cephalogram and CBCT taken. These issues could make difficulty in daily practice.

Conclusion

Questionnaires and radiographic assessment for preliminary OSA diagnosis have several benefits in particular unavailable sleep specialist areas, unreadiness of equipment setting, general practitioner, and orthodontic practice. However, the limitations of these tools raise questions as to whether a questionnaire or radiography is better. Still, lateral cephalometric film is one of the advantages over questionnaires since it is a routine procedure for all patients before orthodontic treatment. According to the AASM recommendation, they should be used in conjunction with at least home sleep apnea testing regarding accuracy improvement.

Author contributions

TJ: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, Supervision, and Project administration; BS: Conceptualization, Validation, Formal analysis, Writing - Review & Editing, and Supervision.

Disclosure statement

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