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Original Research

SLEEP MEDICINE

Craniofacial Changes After 2 Years of Nasal Continuous Positive Airway Pressure Use in Patients With Obstructive Sleep Apnea

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Background: **Many patients with obstructive sleep apnea (OSA) use nasal continuous positive airway pressure (nCPAP) as a first-line therapy. Previous studies have reported midfacial hypoplasia in children using nCPAP. The aim of this study is to assess the craniofacial changes in adult subjects with OSA after nCPAP use.**

Methods: **Forty-six Japanese subjects who used nCPAP for a minimum of 2 years had both a baseline and a follow-up cephalometric radiograph taken. These two radiographs were analyzed, and changes in craniofacial structures were assessed. The cephalometric measurements evaluated were related to face height, interarch relationship, and tooth position.**

Results: **Most of the patients with OSA were men (89.1%), and the mean baseline values for age, BMI, and apnea-hypopnea index (AHI) were 56.3 ± 13.4 years, 26.8 ± 5.6 kg/m², and 42.0 ± 18.6/h. The average duration of nCPAP use was 35.0 ± 6.7 months. After nCPAP use, cephalometric variables demonstrated a significant retrusion of the anterior maxilla, a decrease in maxillary-mandibular discrepancy, a setback of the supramentale and chin positions, a retroclination of maxillary incisors, and a decrease of convexity. However, significant correlations between the craniofacial changes, demographic variables, or the duration of nCPAP use could not be identified. None of the patients self-reported any permanent change of occlusion or facial profile.**

Conclusion: **The use of an nCPAP machine for > 2 years may change craniofacial form by reducing maxillary and mandibular prominence and/or by altering the relationship between the dental arches.**

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Abbreviations: A = subspinale; AHI = apnea-hypopnea index; ANB = maxillary-mandibular discrepancy; ANS = anterior nasal spine; B = supramentale; Eb = base of epiglottis; Gn = gnathion; Go = gonion; H = hyoid point; L1 = mandibular incisor; Me = menton; MP = the line from menton to gonion; N = nasion; NA = line from nasion to subspinale; NB = line from nasion to supramentale; nCPAP = nasal continuous positive airway pressure; OA = oral appliance; OSA = obstructive sleep apnea; P = tip of soft palate; Pg = pogonion; PNS = posterior nasal spine; S = sella; SN = line from sella to nasion; SNA = anteroposterior position of maxilla; SNB = anteroposterior position of mandible; SNPg = chin position relative to cranium; U1 = maxillary incisor; U1-SN = maxillary incisor angle; VAL = vertical airway length

Most patients diagnosed with obstructive sleep apnea (OSA) use a nasal continuous positive airway pressure (nCPAP) machine as their first treatment option. Generally, nCPAP therapy is reported to have some side effects, such as air leakage, skin abrasions, mouth dryness, rhinitis, pressure intolerance, and aerophagia.[1]

A midfacial hypoplasia while using nCPAP in children has been documented in a case report,[2] and there are other reports describing these craniofacial

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side effects in children.[3,4] Although nCPAP patients are fitted with a mask on their face every night and receive positive air pressure from the machine, there are no previous reports of dental or skeletal changes with nCPAP therapy in an adult population.

It is hypothesized that most of the forces from the nCPAP machine, such as the pressure of the mask, could affect the anterior maxilla and/or anterior maxillary incisors as well as the position of the mandible. Should this occur in these patients, it could alter the profile, decrease tongue space, and perhaps affect OSA symptoms over time.

Cephalometry has been widely used for studies of patients with OSA, and characteristic skeletal and pharyngeal dimensions in people with OSA have also been described.[5,6] In addition, cephalometry is an appropriate method to demonstrate skeletal changes between time points, as it uses a standardized protocol.[7,8]

We hypothesize that long-term use of an nCPAP machine could directly affect the maxilla as well as anterior tooth position. The aim of this study was to determine the prevalence and characteristics of dental and skeletal changes in long-term nCPAP users and to estimate the factors that affect such changes.

Materials and Methods

This was a prospective study in which subjects were selected from Japanese patients at the Sleep Center, Kirigaoka Tsuda Hospital, who had a baseline polysomnogram and a lateral cephalometric radiograph taken before the commencement of nCPAP therapy as a routine clinical procedure. The aim of the study was fully explained to each subject, and informed consent for the treatment and radiographs were obtained from each patient. The study protocol was approved by the local Kirigaoka Tsuda Hospital review board. Inclusion criteria were as follows: (1) use of an nCPAP machine >2 years, (2) use of an nCPAP machine on a regular basis (>4 h/d and >5 d/wk), (3) use of a nasal mask. Exclusion criteria were as follows: (1) stop using nCPAP, (2) poor compliance (<4 h/d or <5 d/wk), (3) use of a nasal pillow or full-face type mask, (4) poor quality baseline radiograph for evaluation. Follow-up radiographs were taken for all subjects who met the inclusion criteria. Information on age, sex, BMI, baseline apnea-hypopnea index (AHI), compliance based on the recorded data from the nCPAP machine, mask type, nCPAP pressure, and duration of nCPAP use were collected from the patients' charts. Baseline and follow-up radiographs were analyzed and changes in craniofacial structures were assessed. Correlations between cephalometric changes and demographic variables, such as age, sex, BMI, baseline AHI, nCPAP pressure, duration of nCPAP use, and pretreatment cephalometric variables were evaluated.

Cephalometric Analyses

All lateral digital cephalometric radiographs were taken with the same cephalostat in the upright position with the Frankfort horizontal plane parallel to the floor in centric occlusion. After exporting the data to the computer, software (Dolphin Imaging, version 10.5 premium; Chatsworth, CA) was used to digitize and for analysis. The following variables as shown in Figure 1 were determined:

1. Upper face height (mm): the distance between N (nasion) and ANS (the tip of the anterior nasal spine)
2. Lower face height (mm): the distance between ANS and Me (menton)
3. Total face height (mm): the distance between N and Me
4. Hyoid position (MP-H, mm): the perpendicular distance from H (anterosuperior point of the hyoid) to MP (the line from Me to Go [gonion])
5. Soft palate length (mm): the distance between PNS (posterior nasal spine) and P (the tip of soft palate)
6. Mandibular plane angle (degree): the angle between the SN line (the line from S [sella] to N) and MP
7. Prominence of the hard tissue chin button (mm): the distance from the NB line and a line perpendicular to it to Pg (pogonion)
8. Anteroposterior position of maxilla (SNA) (degree): the angle between the SN line and the line from N to A (subspinale)
9. Anteroposterior position of mandible (SNB)(degree): the angle between SN line and the line from N to B (supramentale)
10. Maxillary-mandibular discrepancy (ANB)(degree): the angle between the line from A to N and the line from B to N
11. Chin position relative to cranium (SNPg)(degree): the angle between the SN line and the line from N to Pg
12. Length of the body of the mandible (mm): the distance between Go and gnathion (Gn)
13. Convexity (mm): the distance from the N-Pg line to A
14. Vertical airway length (VAL)(mm): the distance between PNS and Eb (base of epiglottis)
15. Interincisal angle (U1-L1)(degree): the angle between the maxillary incisor and the mandibular incisor
16. Maxillary incisor angle (U1-SN)(degree): the angle between the maxillary incisor and the SN line
17. Position of the maxillary dentition relative to the maxilla (U1-NA)(mm): the distance from the NA line and a line perpendicular to it to the tip of the maxillary incisor
18. Mandibular incisor angle (L1-MP)(degree): the angle between the mandibular incisor and MP
19. Position of the lower incisor relative to the mandible (L1-NB)(mm): the distance from the NB line and a line perpendicular to it to the tip of the mandibular incisor
20. Overjet (mm): the distance between the maxillary incisor edge and the mandibular incisor edge on the line from the midpoint between the maxillary and mandibular incisor edges to the midpoint between the maxillary and mandibular molar mesial cusps
21. Overbite (mm): the distance between the maxillary incisor edge and the mandibular incisor edge on a line perpendicular to the line from the midpoint between the maxillary and mandibular incisor edges to the midpoint between the maxillary and mandibular molar mesial cusps

The reference points and lines used in the cephalometric analysis are provided in Figure 1. Ten randomly selected radiographs were remeasured on a separate occasion and the error of method was evaluated. All measurements were performed blindly so that the investigator could not identify whether it was baseline or follow-up. The software that we used for this study can define each point on exact radiograph and export the defined point data. Tracings were done by a trained investigator.

Statistical analyses were performed with a statistical package (SPSS, Inc; Chicago, IL). Data are presented as mean and standard deviations. A P value <0.05 was considered significant. Paired t tests were used to compare baseline and follow-up data. Spearman rank correlations ($R<0.291$) were applied between demographic data and measured variables.

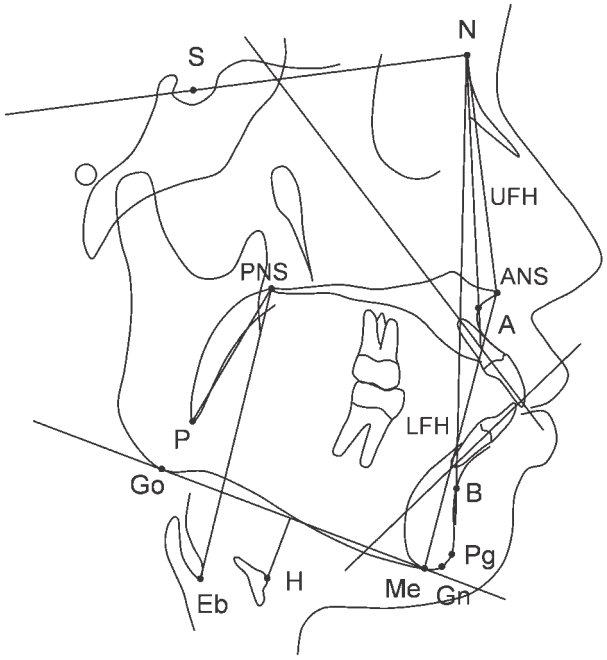

FIGURE 1. Diagram representation of landmarks and variables. A = subspinale; ANS = anterior nasal spine; B = supramentale; Eb = base of epiglottis; Gn = gnathion; Go = gonion; H = hyoid point; LFH = lower face height; Me = menton; N = nasion; P = tip of soft palate; Pg = pogonion; PNS = posterior nasal spine; S = sella; UFH = upper face height.

RESULTS

The subjects were recruited from 134 patients who were prescribed an nCPAP machine at Kirigaoka Tsuda Hospital from 2005 to 2006. Data collection was completed in a total of 46 subjects. These subjects had monthly follow-ups, which checked the condition of the nCPAP machine, the mask, and the patient's health. Because the patient has an obligation to have monthly follow-up checks according to the requirement from the Japanese health insurance system, all subjects consistently visited this hospital once a month. All cephalometric radiographs were taken before nCPAP use, and it was the first nCPAP machine for the subjects. Thirteen subjects were excluded from this study (n = 2 for poor compliance; n = 9 for different type of mask [nasal pillow]; n = 2 for poor quality of radiograph). Demographic data are provided in Table 1. Nasal mask types included Mirage Activa (n = 21) (ResMed; Sydney, NSW, Australia), ComfortGel (n = 21), ComfortSelect (n = 1), and ComfortFusion (n = 3) (Respironics; Andover, MA). All of the subjects used auto nCPAP and the average nCPAP pressure was used for analysis.

The errors of method were calculated and were found to be 0.69 ± 0.35 mm for linear measurements and 0.64° ± 0.22° for angular measurements. For a difference between measurements to be considered statistically significant, the change of each specific variable had to be > 2 SDs of the same specific variable measurements error.

After nCPAP use, mean changes in the cephalometric variables of SNA, ANB, SNB, SNPg, U1-SN, and convexity decreased significantly (Table 2). A superimposition with typical craniofacial changes is provided in Figure 2. Note the retropositioning of A and B points, as well as the retroclination of the maxillary incisors and the downward rotation of the mandible. No significant correlations between demographic variables, craniofacial changes, duration of nCPAP use, or pretreatment cephalometric variables, such as overjet or overbite, were identified. None of the patients self-reported permanent changes of occlusion or facial profile.

DISCUSSION

This is the first report, to our knowledge, to show the side effects of nCPAP use on craniofacial morphology in adult subjects by comparing baseline and follow-up time points. Although our subjects are adult nongrowers, significant dental changes were observed. However, the amount of change is not considered to be sufficient to stop using nCPAP at this time point. These changes may affect the profile, tongue space, and OSA symptoms.

Major changes occurred in the maxillary area. Considering the area to which the nasal mask applies pressure, the whole front area of the maxilla was pushed back and the maxillary incisor became retroclined. Although the mask does not touch the mandible, mandibular position also rotated downward and backward because of the maxillary molar distalization and extrusion, as shown in Figure 2. This is considered to be a dental compensatory response to the change in the maxillary dental arch position. Because radiographic data are limited to two-dimensional information, it is impossible to know the lateral direction changes. To fully estimate and understand these changes caused by nCPAP, a detailed dental arch evaluation and comprehensive three-dimensional analysis would be required.

Table 1—*Demographic Data*

No.	46
Sex, M (F)	41 (5)
Age, y	56.3 ± 13.4 (28-84)
BMI, kg/m²	26.8 ± 5.6 (20.8-51.1)
AHI, events/h	42.0 ± 18.6 (6.7-85.8)
nCPAP pressure, average	7.2 ± 1.7 (4.3-10.5)
Duration of nCPAP use, mo	35.0 ± 6.7 (25.0-46.0)
Compliance, h/d	6.0 ± 0.9 (4.0-8.0)
Compliance, d/wk	6.5 ± 0.8 (5.0-7.0)

Data are presented as mean ± SD (range). AHI = apnea-hypopnea index; nCPAP = nasal continuous positive airway pressure.

Table 2—*Cephalometric Variables*

	Pre-nCPAP	Follow-up	Amount of Change	*P* Value
Facial height				
Upper face height (N-ANS), mm	62.4 ± 4.7	63.8 ± 4.7	1.4 ± 3.8	NS
Lower face height (ANS-Me), mm	84.9 ± 7.4	85.4 ± 7.5	0.5 ± 3.3	NS
Total face height (N-Me), mm	145.7 ± 9.8	147.1 ± 8.7	1.4 ± 5.6	NS
MP-H: hyoid position, mm	24.8 ± 7.5	25.2 ± 8.2	0.4 ± 3.1	NS
PNS-P, mm	44.4 ± 5.5	45.5 ± 6.4	1.1 ± 5.1	NS
MP-SN, °	37.5 ± 7.3	38.1 ± 7.3	0.6 ± 1.8	NS
Pg-NB, mm	0.5 ± 1.9	0.3 ± 2.1	−0.3 ± 0.8	NS
Interarch relationship				
SNA, °	**84.3 ± 3.6**	**83.2 ± 3.9**	**−1.1 ± 1.6**	**<.01**
SNB, °	**77.8 ± 3.9**	**77.5 ± 4.0**	**−0.4 ± 0.9**	**<.05**
ANB, °	**6.3 ± 2.2**	**5.7 ± 2.5**	**−0.6 ± 1.1**	**<.01**
SNPg, °	**78.1 ± 4.0**	**77.6 ± 4.1**	**−0.5 ± 0.9**	**<.05**
Go-Gn, mm	87.9 ± 6.9	88.9 ± 7.4	1.1 ± 6.7	NS
Convexity (A-NPg), mm	**7.7 ± 3.1**	**6.9 ± 3.7**	**−0.7 ± 1.7**	**<.05**
VAL (PNS-Eb), mm	85.9 ± 8.6	87.3 ± 7.6	1.4 ± 4.4	NS
Tooth position				
Interincisal angle (U1-L1), °	122.8 ± 12.4	123.8 ± 13.5	1.0 ± 4.4	
U1-SN, °	**103.3 ± 9.1**	**102.1 ± 9.8**	**−1.2 ± 3.2**	**<.05**
U1-NA, mm	3.6 ± 3.6	4.1 ± 4.0	0.5 ± 1.7	NS
L1-MP, °	95.6 ± 7.1	95.3 ± 8.6	−0.3 ± 4.1	NS
L1-NB, mm	9.7 ± 3.3	9.7 ± 3.1	0.0 ± 1.1	NS
Overjet, mm	5.0 ± 2.0	4.6 ± 2.4	−0.4 ± 1.3	NS
Overbite, mm	1.8 ± 2.2	2.1 ± 1.8	0.2 ± 1.6	NS

Data are presented as mean ± SD. Changes are expressed as follow-up minus baseline values. Significant variables are shown in boldface. A = subspinale; ANB = maxillary-mandibular discrepancy; ANS = anterior nasal spine; Eb = base of epiglottis; Gn = gnathion; Go = gonion; H = hyoid point; L1 = mandibular incisor; Me = menton; MP = the line from menton to gonion; N = nasion; NA = line from nasion to subspinale; NB = line from nasion to supramentale; nCPAP = nasal continuous positive airway pressure; NS = not significant ($P > .05$); P = tip of soft palate; Pg = pogonion; PNS = posterior nasal spine; SN = line from sella to nasion; SNA = anteroposterior position of maxilla; SNB = anteroposterior position of mandible; SNPg = chin position relative to cranium; U1 = maxillary incisor; VAL = vertical airway length.

It has been reported that children who used nCPAP had midface hypoplasia with a concave midface and a class 3 malocclusion.[2-4] Although there was no cephalometric analysis in these reports, the characteristic changes that occurred in the adults appear similar to the changes observed in children. In growing children, a tight-fitting mask has resulted in facial growth impairment and the symptom of midface hypoplasia could occur more severely than in adults. Although adult subjects are not growing, because bone structure keeps remodeling, these change could occur because of the constant pressure from the nCPAP mask.

However, it has already been shown that oral appliance (OA) use for the treatment of OSA can cause dental changes in adults with night use only. Therefore, despite mean 6 h/d use of nCPAP, it may be possible to cause some dental changes. Based on cephalometric analyses, it has been reported that long-term OA use could result in dental changes.[7,8] Compared with the side effects of OA therapy (ANB: −0.5° ± 1.2°; SNPg: −0.4° ± 1.4°; U1-SN: −3.1° ± 4.8°),[7] the amount of change with long-term nCPAP use is similar. Our subjects used an nCPAP machine for approximately 3 years, whereas the OA users in the previous report used it for some 7.3 years.

No significant change occurred in the characteristic variables of patients with OSA, such as hyoid position, soft palate, and VAL, with long-term nCPAP therapy. Our two-dimensional data suggest that these anatomic

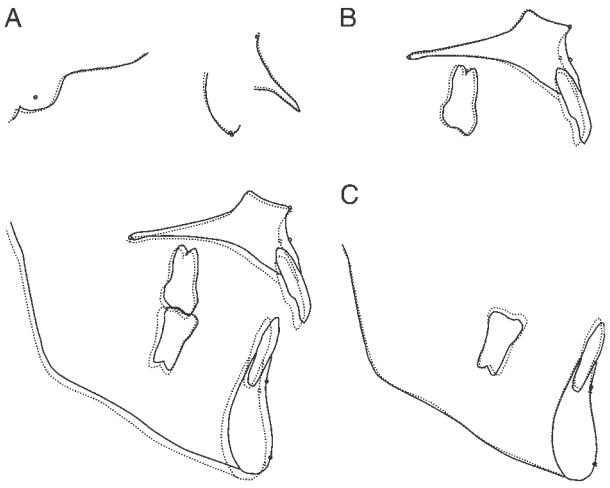

FIGURE 2. Superimpositions on the line from sella to nasion (*A*), ANS-posterior nasal spine line (*B*), and mandibular plane (*C*) of one typical subject with obstructive sleep apnea (OSA) at baseline and follow-up radiographs. The solid line shows baseline data and the broken line indicates follow-up data. See Figure 1 legend for expansion of other abbreviation.

structures are not altered, even if the OSA symptoms are controlled by nCPAP therapy.

Although it was speculated that the long-term nCPAP with high-pressure patients would have more dental changes, no correlation could be identified. Because we selected subjects who used nCPAP >4 h/d and >5 d/wk, it could be considered that the factor of compliance did not affect the result. However, this study did not estimate band pressure from the mask directly on the face, and the nCPAP pressure data were measured from the average pressure of auto-nCPAP.

A limitation of this study is the absence of control data. One of the confounding factors may be dental and skeletal changes associated with aging. Previous reports suggest that no significant change occurred during 10 years of observation,[9,10] or an opposite direction change occurred in >25 years of observation on SNA, SNB, ANB, and U1-SN.[11,12] Considering the almost 3-year time period of this study, age may not be the affecting factor.

Despite multiple comparisons, we have shown a significance value of 0.05. We believe this is important, because this is the first report to our knowledge on this issue. Further studies with a longer term of CPAP use and a larger sample size are needed to confirm those findings. To approximate the possible pressure from the mask only, subjects who used the nasal pillow mask were excluded in this study. As the amount or direction of the force to the patient's face might be different between mask types, the pressure from the mask could affect the resultant changes. In addition, dental conditions, such as skeletal type, baseline tooth position, or periodontal status, may be possible contribution factors. We could not identify any significant difference between groups when divided by skeletal type in the present study.

The side effects of dental changes obviously have a small impact compared with the beneficial effects of nCPAP, such as reducing the AHI and daytime sleepiness.[1] However, because the effects of these dental and skeletal changes have not been fully investigated, further study is required to uncover the factors affecting these changes. Considering that patients must use nCPAP therapy for a lifelong span, similar to OA therapy, patients are not always aware of the changes that may continue over time.[7]

In conclusion, the use of an nCPAP machine for >2 years could be associated with change in the craniofacial form by reducing maxillary and mandibular prominence, the interrelationship of the two dental arches, and the prominence of the upper incisors. Considering that nCPAP is often used for long time periods, the side effects of nCPAP use warrant further detailed studies over longer time periods to quantify absolute craniofacial changes.

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Dr H. Tsuda: contributed to conceiving the study, carrying out the data analysis, performing statistical analysis, drafting the manuscript, and reading and approving the final manuscript.
Dr Almeida: contributed to interpreting the results and reading and approving the final manuscript.
Dr T. Tsuda: contributed to coordinating the study, interpreting the results, and reading and approving the final manuscript.
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